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- as to the identity of the inventor (Rule 4.17(i))
- as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))

[Continued on next page]

(54) Title: ROBOTICALLY-CONTROLLED SURGICAL INSTRUMENT WITH FORCE-FEEDBACK CAPABILITIES

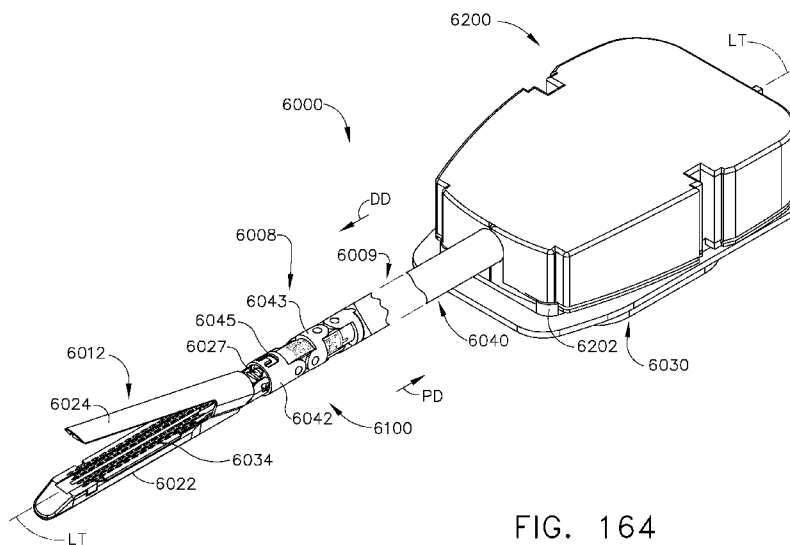


FIG. 164

(57) Abstract: A surgical instrument. Various embodiments of the surgical instrument include an end effector that has a moveable cutting implement. A main drive shaft assembly operably interfaces with the end effector for transmitting an actuation motion to the moveable cutting implement therein. A gear drive train is connected to the main drive shaft assembly. The gear drive train is actuated by a motor that is configured to receive control signals from a robotic system. Various embodiments include a sensor arrangement that operably interfaces the end effector to communicate forces experienced by the end effector to the robotic system.

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TITLE**ROBOTICALLY-CONTROLLED SURGICAL INSTRUMENT
WITH FORCE-FEEDBACK CAPABILITIES****CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] The present application is a continuation-in-part patent application and claims the benefit of U.S. Patent Application Serial No. 12/949,099, filed on November 18, 2010, entitled "Surgical Instrument Having Recording Capabilities" to Frederick E. Shelton, IV, John N. Ouwerkerk, and Eugene L. Timperman, which is a continuation of and claims the benefit of U.S. Patent Application Serial No. 11/343,803, filed on January 31, 2006, entitled "Surgical Instrument Having Recording Capabilities" to Frederick E. Shelton, IV, John N. Ouwerkerk, and Eugene L. Timperman, now U.S. Patent No. 7,845,537, which issued on December 7, 2010, which is incorporated herein by reference in its entirety.

[0002] The present application is related to the following U.S. patent applications, which are incorporated herein by reference:

U.S. Patent Application Serial No. 11/343,498, filed January 31, 2006, now U.S. Patent No. 7,766,210, entitled MOTOR-DRIVEN SURGICAL CUTTING AND FASTENING INSTRUMENT WITH USER FEEDBACK SYSTEM; Inventors: Frederick E. Shelton, IV, John Ouwerkerk and Jerome R. Morgan

U.S. Patent Application Serial No. 11/343,573, filed January 31, 2006, now U.S. Patent No. 7,416,101, entitled MOTOR-DRIVEN SURGICAL CUTTING AND FASTENING INSTRUMENT WITH LOADING FORCE FEEDBACK; Inventors: Frederick E. Shelton, IV, John N. Ouwerkerk, Jerome R. Morgan, and Jeffrey S. Swayze

U.S. Patent Application Serial No. 11/344,035, filed January 31, 2006, now U.S. Patent No. 7,422,139, entitled MOTOR-DRIVEN SURGICAL CUTTING AND FASTENING INSTRUMENT WITH TACTILE POSITION FEEDBACK; Inventors: Frederick E. Shelton, IV, John N. Ouwerkerk, Jerome R. Morgan, and Jeffrey S. Swayze

U.S. Patent Application Serial No. 11/343,447, filed January 31, 2006, now U.S. Patent No. 7,770,775, entitled MOTOR-DRIVEN SURGICAL CUTTING AND FASTENING INSTRUMENT WITH ADAPTIVE USER FEEDBACK; Inventors: Frederick E. Shelton, IV, John N. Ouwerkerk, and Jerome R. Morgan

U.S. Patent Application Serial No. 11/343,562, filed January 31, 2006, now U.S. Patent No. 7,568,603, entitled MOTOR-DRIVEN SURGICAL CUTTING AND FASTENING INSTRUMENT WITH ARTICULATABLE END EFFECTOR; Inventors: Frederick E. Shelton, IV and Christoph L. Gillum

U.S. Patent Application Serial No. 11/344,024, filed January 31, 2006, now U.S. Patent Publication No. 2007/0175955, entitled MOTOR-DRIVEN SURGICAL CUTTING AND FASTENING INSTRUMENT WITH MECHANICAL CLOSURE SYSTEM; Inventors: Frederick E. Shelton, IV and Christoph L. Gillum

U.S. Patent Application Serial No. 11/343,321, filed January 31, 2006, now U.S. Patent Publication No. 2007/0175955, entitled SURGICAL CUTTING AND FASTENING INSTRUMENT WITH CLOSURE TRIGGER LOCKING MECHANISM; Inventors: Frederick E. Shelton, IV and Kevin R. Doll

U.S. Patent Application Serial No. 11/343,563, filed January 31, 2006, now U.S. Patent Publication No. 2007/0175951, entitled GEARING SELECTOR FOR A POWERED SURGICAL CUTTING AND FASTENING STAPLING INSTRUMENT; Inventors: Frederick E. Shelton, IV, Jeffrey S. Swayze, Eugene L. Timperman

U.S. Patent Application Serial No. 11/344,020, filed January 31, 2006, now U.S. Patent No. 7,464,846, entitled SURGICAL INSTRUMENT HAVING A REMOVABLE BATTERY; Inventors: Frederick E. Shelton, IV, Kevin R. Doll, Jeffrey S. Swayze and Eugene Timperman

U.S. Patent Application Serial No. 11/343,439, filed January 31, 2006, now U.S. Patent No. 7,644,848, entitled ELECTRONIC LOCKOUTS AND SURGICAL INSTRUMENT INCLUDING SAME; Inventors: Jeffrey S. Swayze, Frederick E. Shelton, IV, Kevin R. Doll

U.S. Patent Application Serial No. 11/343,547, filed January 31, 2006, now U.S. Patent No. 7,753,904, entitled ENDOSCOPIC SURGICAL INSTRUMENT WITH A HANDLE THAT CAN ARTICULATE WITH RESPECT TO THE SHAFT; Inventors: Frederick E. Shelton, IV, Jeffrey S. Swayze, Mark S. Ortiz, and Leslie M. Fugikawa

U.S. Patent Application Serial No. 11/344,021, filed January 31, 2006, now U.S. Patent No. 7,464,849, entitled ELECTRO-MECHANICAL SURGICAL CUTTING AND FASTENING INSTRUMENT HAVING A ROTARY FIRING AND CLOSURE SYSTEM WITH PARALLEL CLOSURE AND ANVIL ALIGNMENT COMPONENTS; Inventors: Frederick E. Shelton, IV, Stephen J. Balek and Eugene L. Timperman

U.S. Patent Application Serial No. 11/343,546, filed January 31, 2006, now U.S. Patent Publication No. 2007/0175950, entitled DISPOSABLE STAPLE CARTRIDGE HAVING AN ANVIL WITH TISSUE LOCATOR FOR USE WITH A SURGICAL CUTTING AND FASTENING INSTRUMENT AND MODULAR END EFFECTOR SYSTEM THEREFOR; Inventors: Frederick E. Shelton, IV, Michael S. Cropper, Joshua M. Broehl, Ryan S. Crisp, Jamison J. Float, Eugene L. Timperman

U.S. Patent Application Serial No. 11/343,545, filed January 31, 2006, now U.S. Patent Publication No. 2007/0175949, entitled SURGICAL INSTRUMENT HAVING A FEEDBACK SYSTEM; Inventors: Frederick E. Shelton, IV, Jerome R. Morgan, Kevin R. Doll, Jeffrey S. Swayze and Eugene Timperman

U.S. Patent Application Serial No. 13/021,105, filed February 4, 2011, entitled SURGICAL INSTRUMENT HAVING RECORDING CAPABILITIES; Inventors: Frederick E. Shelton,

IV, John N. Ouwerkerk, Eugene L. Timperman (Attorney Docket No. END5773USCNT2/050698CON2)

BACKGROUND

[0003] The present invention relates in general to surgical instruments, and more particularly to minimally invasive surgical instruments capable of recording various conditions of the instrument.

[0004] Endoscopic surgical instruments are often preferred over traditional open surgical devices because a smaller incision tends to reduce the post-operative recovery time and complications. Consequently, significant development has gone into a range of endoscopic surgical instruments that are suitable for precise placement of a distal end effector at a desired surgical site through a cannula of a trocar. These distal end effectors engage the tissue in a number of ways to achieve a diagnostic or therapeutic effect (e.g., endocutter, grasper, cutter, staplers, clip applicator, access device, drug/gene therapy delivery device, and energy device using ultrasound, RF, laser, etc.).

[0005] Known surgical staplers include an end effector that simultaneously makes a longitudinal incision in tissue and applies lines of staples on opposing sides of the incision. The end effector includes a pair of cooperating jaw members that, if the instrument is intended for endoscopic or laparoscopic applications, are capable of passing through a cannula passageway. One of the jaw members receives a staple cartridge having at least two laterally spaced rows of staples. The other jaw member defines an anvil having staple-forming pockets aligned with the rows of staples in the cartridge. The instrument includes a plurality of reciprocating wedges which, when driven distally, pass through openings in the staple cartridge and engage drivers supporting the staples to effect the firing of the staples toward the anvil.

[0006] An example of a surgical stapler suitable for endoscopic applications is described in U.S. Pat. No. 5,465,895, entitled "SURGICAL STAPLER INSTRUMENT" to Knodel et al., which discloses an endocutter with distinct closing and firing actions. A clinician using this device is able to close the jaw members upon tissue to position the tissue prior to firing. Once the clinician has determined that the jaw members are properly gripping tissue, the clinician can then fire the surgical stapler with a single firing stroke, or multiple firing strokes, depending on the device. Firing the surgical stapler causes severing and stapling of the tissue. The simultaneous severing and stapling avoids complications that may arise when

performing such actions sequentially with different surgical tools that respectively only sever and staple.

[0007] One specific advantage of being able to close upon tissue before firing is that the clinician is able to verify via an endoscope that the desired location for the cut has been achieved, including a sufficient amount of tissue has been captured between opposing jaws. Otherwise, opposing jaws may be drawn too close together, especially pinching at their distal ends, and thus not effectively forming closed staples in the severed tissue. At the other extreme, an excessive amount of clamped tissue may cause binding and an incomplete firing.

[0008] When endoscopic surgical instruments fail, they are often returned to the manufacturer, or other entity, for analysis of the failure. If the failure resulted in a critical class of defect in the instrument, it is necessary for the manufacturer to determine the cause of the failure and determine whether a design change is required. In that case, the manufacturer may spend many hundreds of man-hours analyzing a failed instrument and attempting to reconstruct the conditions under which it failed based only on the damage to the instrument. It can be expensive and very challenging to analyze instrument failures in this way. Also, many of these analyses simply conclude that the failure was due to improper use of the instrument.

SUMMARY

[0009] In one general aspect, the present invention is directed to a surgical instrument. The surgical instrument has an end effector and a trigger in communication with the end effector. The surgical instrument also has a first sensor and an externally accessible memory device in communication with the first sensor. The first sensor has an output that represents a first condition of either the trigger or the end effector. The memory device is configured to record the output of the first sensor. In various embodiments, memory device may include an output port and/or a removable storage medium.

[0010] Also, in various embodiments, the output of the first sensor represents a condition of the end effector and the instrument further comprises a second sensor with an output representing a condition of the trigger. The memory device is configured to record the output of the first sensor and the second sensor.

[0011] In another general aspect, the present invention is directed to a method of recording the state of a surgical instrument. The method comprises the step of monitoring outputs of a plurality of sensors. The outputs represent conditions of the surgical instrument. The method also comprises the step of recording the outputs to a memory device when at least one of the

conditions of the surgical instrument changes. In various embodiments, the method may also comprise the step of providing the recorded outputs of the plurality of sensors to an outside device.

[0012] In accordance with other general aspects with embodiments of the present invention, there is provided a surgical cutting and fastening instrument that includes an end effector that has a moveable cutting implement operably supported therein. A main drive shaft assembly operably interfaces with the end effector for transmitting an actuation motion to the moveable cutting implement therein. A gear drive train is connected to the main drive shaft assembly. A motor for actuating the gear drive train is configured to receive control signals from a robotic system. A sensor arrangement operably interfaces with the end effector and the robotic system to communicate forces experienced by the end effector to said robotic system.

[0013] In accordance with other general aspects of various embodiments of the present invention there is provided a surgical instrument that includes an end effector. In various embodiments, the end effector comprises an elongated channel that is configured to operably support a staple cartridge therein. An anvil is movably supported relative to the elongated channel and is movable to an open position relative to a staple cartridge within the elongated channel upon application of an opening motion thereto. The anvil is movable to a closed position relative to the staple cartridge upon application of a closing motion to the anvil. A tissue cutting implement is operably supported for reciprocable movement within the elongated channel upon application of actuation and retraction motions thereto. In certain embodiments, the surgical instrument further comprises a shaft assembly that is connected to the end effector and includes a drive shaft that operably interfaces with the tissue cutting implement for transmitting the actuation and retraction motions thereto. A gear drive train operably interfaces with the drive shaft. A motor actuates the gear drive train and is configured to receive control signals from a robotic system. The instrument further comprises means for communicating forces experienced by the end effector to the robotic system.

DRAWINGS

[0014] Various embodiments of the present invention are described herein by way of example in conjunction with the following figures, wherein

[0015] FIGS. 1 and 2 are perspective views of a surgical cutting and fastening instrument according to various embodiments of the present invention;

[0016] FIGS. 3-5 are exploded views of an end effector and shaft of the instrument according to various embodiments of the present invention;

- [0017] FIG. 6 is a side view of the end effector according to various embodiments of the present invention;
- [0018] FIG. 7 is an exploded view of the handle of the instrument according to various embodiments of the present invention;
- [0019] FIGS. 8 and 9 are partial perspective views of the handle according to various embodiments of the present invention;
- [0020] FIG. 10 is a side view of the handle according to various embodiments of the present invention;
- [0021] FIGS. 10A and 10B illustrate a proportional sensor that may be used according to various embodiments of the present invention;
- [0022] Figure 11 is a schematic diagram of a circuit used in the instrument according to various embodiments of the present invention;
- [0023] FIGS. 12-13 are side views of the handle according to other embodiments of the present invention;
- [0024] FIGS. 14-22 illustrate different mechanisms for locking the closure trigger according to various embodiments of the present invention;
- [0025] FIGS. 23A-B show a universal joint (“u-joint”) that may be employed at the articulation point of the instrument according to various embodiments of the present invention;
- [0026] FIGS. 24A-B shows a torsion cable that may be employed at the articulation point of the instrument according to various embodiments of the present invention;
- [0027] FIGS. 25-31 illustrate a surgical cutting and fastening instrument with power assist according to another embodiment of the present invention;
- [0028] FIGS. 32-36 illustrate a surgical cutting and fastening instrument with power assist according to yet another embodiment of the present invention;
- [0029] FIGS. 37-40 illustrate a surgical cutting and fastening instrument with tactile feedback to embodiments of the present invention;
- [0030] FIG. 41 illustrates an exploded view of an end effector and shaft of the instrument according to various embodiments of the present invention;
- [0031] FIG. 42 illustrates a side view of the handle of a mechanically instrument according to various embodiments of the present invention;
- [0032] FIG. 43 illustrates an exploded view of the handle of the mechanically actuated instrument of FIG. 42;

- [0033] FIG. 44 illustrates a block diagram of a recording system for recording various conditions of the instrument according to various embodiments of the present invention;
- [0034] FIGS. 45-46 illustrate cut away side views of a handle of the instrument showing various sensors according to various embodiments of the present invention;
- [0035] FIG. 47 illustrates the end effector of the instrument showing various sensors according to various embodiments of the present invention;
- [0036] FIG. 48 illustrates a firing bar of the instrument including a sensor according to various embodiments of the present invention;
- [0037] FIG. 49 illustrates a side view of the handle, end effector, and firing bar of the instrument showing a sensor according to various embodiments of the present invention;
- [0038] Figure 50 illustrates an exploded view of the staple channel and portions of a staple cartridge of the instrument showing various sensors according to various embodiments of the present invention;
- [0039] FIG. 51 illustrates a top down view of the staple channel of the instrument showing various sensors according to various embodiments of the present invention;
- [0040] FIGS. 52A and 52B illustrate a flow chart showing a method for operating the instrument according to various embodiments;
- [0041] FIG. 53 illustrates a memory chart showing exemplary recorded conditions of the instrument according to various embodiments of the present invention;
- [0042] FIG. 54 is a perspective view of one robotic controller embodiment;
- [0043] FIG. 55 is a perspective view of one robotic surgical arm cart/manipulator of a robotic system operably supporting a plurality of surgical tool embodiments of the present invention;
- [0044] FIG. 56 is a side view of the robotic surgical arm cart/manipulator depicted in FIG. 55;
- [0045] FIG. 57 is a perspective view of an exemplary cart structure with positioning linkages for operably supporting robotic manipulators that may be used with various surgical tool embodiments of the present invention;
- [0046] FIG. 58 is a perspective view of a surgical tool embodiment of the present invention;
- [0047] FIG. 59 is an exploded assembly view of an adapter and tool holder arrangement for attaching various surgical tool embodiments to a robotic system;

- [0048] FIG. 60 is a side view of the adapter shown in FIG. 59;
- [0049] FIG. 61 is a bottom view of the adapter shown in FIG. 59;
- [0050] FIG. 62 is a top view of the adapter of FIGS. 59 and 60;
- [0051] FIG. 63 is a partial bottom perspective view of the surgical tool embodiment of FIG. 58;
- [0052] FIG. 64 is a partial exploded view of a portion of an articulatable surgical end effector embodiment of the present invention;
- [0053] FIG. 65 is a perspective view of the surgical tool embodiment of FIG. 63 with the tool mounting housing removed;
- [0054] FIG. 66 is a rear perspective view of the surgical tool embodiment of FIG. 63 with the tool mounting housing removed;
- [0055] FIG. 67 is a front perspective view of the surgical tool embodiment of FIG. 63 with the tool mounting housing removed;
- [0056] FIG. 68 is a partial exploded perspective view of the surgical tool embodiment of FIG. 67;
- [0057] FIG. 69 is a partial cross-sectional side view of the surgical tool embodiment of FIG. 63;
- [0058] FIG. 70 is an enlarged cross-sectional view of a portion of the surgical tool depicted in FIG. 69;
- [0059] FIG. 71 is an exploded perspective view of a portion of the tool mounting portion of the surgical tool embodiment depicted in FIG. 63;
- [0060] FIG. 72 is an enlarged exploded perspective view of a portion of the tool mounting portion of FIG. 71;
- [0061] FIG. 73 is a partial cross-sectional view of a portion of the elongated shaft assembly of the surgical tool of FIG. 63;
- [0062] FIG. 74 is a side view of a half portion of a closure nut embodiment of a surgical tool embodiment of the present invention;
- [0063] FIG. 75 is a perspective view of another surgical tool embodiment of the present invention;

[0064] FIG. 76 is a cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. 75 with the anvil in the open position and the closure clutch assembly in a neutral position;

[0065] FIG. 77 is another cross-sectional side view of the surgical end effector and elongated shaft assembly shown in FIG. 76 with the clutch assembly engaged in a closure position;

[0066] FIG. 78 is another cross-sectional side view of the surgical end effector and elongated shaft assembly shown in FIG. 76 with the clutch assembly engaged in a firing position;

[0067] FIG. 79 is a top view of a portion of a tool mounting portion embodiment of the present invention;

[0068] FIG. 80 is a perspective view of another surgical tool embodiment of the present invention;

[0069] FIG. 81 is a cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. 80 with the anvil in the open position;

[0070] FIG. 82 is another cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. 80 with the anvil in the closed position;

[0071] FIG. 83 is a perspective view of a closure drive nut and portion of a knife bar embodiment of the present invention;

[0072] FIG. 84 is a top view of another tool mounting portion embodiment of the present invention;

[0073] FIG. 85 is a perspective view of another surgical tool embodiment of the present invention;

[0074] FIG. 86 is a cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. 85 with the anvil in the open position;

[0075] FIG. 87 is another cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. 86 with the anvil in the closed position;

[0076] FIG. 88 is a cross-sectional view of a mounting collar embodiment of a surgical tool embodiment of the present invention showing the knife bar and distal end portion of the closure drive shaft;

[0077] FIG. 89 is a cross-sectional view of the mounting collar embodiment of FIG. 88;

[0078] FIG. 90 is a top view of another tool mounting portion embodiment of another surgical tool embodiment of the present invention;

[0079] FIG. 90A is an exploded perspective view of a portion of a gear arrangement of another surgical tool embodiment of the present invention;

[0080] FIG. 90B is a cross-sectional perspective view of the gear arrangement shown in FIG. 90A;

[0081] FIG. 91 is a cross-sectional side view of a portion of a surgical end effector and elongated shaft assembly of another surgical tool embodiment of the present invention employing a pressure sensor arrangement with the anvil in the open position;

[0082] FIG. 92 is another cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. 91 with the anvil in the closed position;

[0083] FIG. 93 is a side view of a portion of another surgical tool embodiment of the present invention in relation to a tool holder portion of a robotic system with some of the components thereof shown in cross-section;

[0084] FIG. 94 is a side view of a portion of another surgical tool embodiment of the present invention in relation to a tool holder portion of a robotic system with some of the components thereof shown in cross-section;

[0085] FIG. 95 is a side view of a portion of another surgical tool embodiment of the present invention with some of the components thereof shown in cross-section;

[0086] FIG. 96 is a side view of a portion of another surgical end effector embodiment of a portion of a surgical tool embodiment of the present invention with some components thereof shown in cross-section;

[0087] FIG. 97 is a side view of a portion of another surgical end effector embodiment of a portion of a surgical tool embodiment of the present invention with some components thereof shown in cross-section;

[0088] FIG. 98 is a side view of a portion of another surgical end effector embodiment of a portion of a surgical tool embodiment of the present invention with some components thereof shown in cross-section;

[0089] FIG. 99 is an enlarged cross-sectional view of a portion of the end effector of FIG. 98;

[0090] FIG. 100 is another cross-sectional view of a portion of the end effector of FIGS. 98 and 99;

[0091] FIG. 101 is a cross-sectional side view of a portion of a surgical end effector and elongated shaft assembly of another surgical tool embodiment of the present invention with the anvil in the open position;

[0092] FIG. 102 is an enlarged cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIG. 101;

[0093] FIG. 103 is another cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of FIGS. 101 and 102 with the anvil thereof in the closed position;

[0094] FIG. 104 is an enlarged cross-sectional side view of a portion of the surgical end effector and elongated shaft assembly of the surgical tool embodiment of FIGS. 101-103;

[0095] FIG. 105 is a top view of a tool mounting portion embodiment of a surgical tool embodiment of the present invention;

[0096] FIG. 106 is a perspective assembly view of another surgical tool embodiment of the present invention;

[0097] FIG. 107 is a front perspective view of a disposable loading unit arrangement that may be employed with various surgical tool embodiments of the present invention;

[0098] FIG. 108 is a rear perspective view of the disposable loading unit of FIG. 107;

[0099] FIG. 109 is a bottom perspective view of the disposable loading unit of FIGS. 107 and 108;

- [0100] FIG. 110 is a bottom perspective view of another disposable loading unit embodiment that may be employed with various surgical tool embodiments of the present invention;
- [0101] FIG. 111 is an exploded perspective view of a mounting portion of a disposable loading unit depicted in FIGS. 107-109;
- [0102] FIG. 112 is a perspective view of a portion of a disposable loading unit and an elongated shaft assembly embodiment of a surgical tool embodiment of the present invention with the disposable loading unit in a first position;
- [0103] FIG. 113 is another perspective view of a portion of the disposable loading unit and elongated shaft assembly of FIG. 112 with the disposable loading unit in a second position;
- [0104] FIG. 114 is a cross-sectional view of a portion of the disposable loading unit and elongated shaft assembly embodiment depicted in FIGS. 112 and 113;
- [0105] FIG. 115 is another cross-sectional view of the disposable loading unit and elongated shaft assembly embodiment depicted in FIGS. 112-114;
- [0106] FIG. 116 is a partial exploded perspective view of a portion of another disposable loading unit embodiment and an elongated shaft assembly embodiment of a surgical tool embodiment of the present invention;
- [0107] FIG. 117 is a partial exploded perspective view of a portion of another disposable loading unit embodiment and an elongated shaft assembly embodiment of a surgical tool embodiment of the present invention;
- [0108] FIG. 118 is another partial exploded perspective view of the disposable loading unit embodiment and an elongated shaft assembly embodiment of FIG. 117;
- [0109] FIG. 119 is a top view of another tool mounting portion embodiment of a surgical tool embodiment of the present invention;
- [0110] FIG. 120 is a side view of another surgical tool embodiment of the present invention with some of the components thereof shown in cross-section and in relation to a robotic tool holder of a robotic system;
- [0111] FIG. 121 is an exploded assembly view of a surgical end effector embodiment that may be used in connection with various surgical tool embodiments of the present invention;

[0112] FIG. 122 is a side view of a portion of a cable-driven system for driving a cutting instrument employed in various surgical end effector embodiments of the present invention;

[0113] FIG. 123 is a top view of the cable-driven system and cutting instrument of FIG. 122;

[0114] FIG. 124 is a top view of a cable drive transmission embodiment of the present invention in a closure position;

[0115] FIG. 125 is another top view of the cable drive transmission embodiment of FIG. 124 in a neutral position;

[0116] FIG. 126 is another top view of the cable drive transmission embodiment of FIGS. 124 and 125 in a firing position;

[0117] FIG. 127 is a perspective view of the cable drive transmission embodiment in the position depicted in FIG. 124;

[0118] FIG. 128 is a perspective view of the cable drive transmission embodiment in the position depicted in FIG. 125;

[0119] FIG. 129 is a perspective view of the cable drive transmission embodiment in the position depicted in FIG. 126;

[0120] FIG. 130 is a perspective view of another surgical tool embodiment of the present invention;

[0121] FIG. 131 is a side view of a portion of another cable-driven system embodiment for driving a cutting instrument employed in various surgical end effector embodiments of the present invention;

[0122] FIG. 132 is a top view of the cable-driven system embodiment of FIG. 131;

[0123] FIG. 133 is a top view of a tool mounting portion embodiment of another surgical tool embodiment of the present invention;

[0124] FIG. 134 is a top cross-sectional view of another surgical tool embodiment of the present invention;

[0125] FIG. 135 is a cross-sectional view of a portion of a surgical end effector embodiment of a surgical tool embodiment of the present invention;

[0126] FIG. 136 is a cross-sectional end view of the surgical end effector of FIG. 103 taken along line 136-136 in FIG. 135;

[0127] FIG. 137 is a perspective view of the surgical end effector of FIGS. 135 and 136 with portions thereof shown in cross-section;

[0128] FIG. 138 is a side view of a portion of the surgical end effector of FIGS. 135-137;

[0129] FIG. 139 is a perspective view of a sled assembly embodiment of various surgical tool embodiments of the present invention;

[0130] FIG. 140 is a cross-sectional view of the sled assembly embodiment of FIG. 139 and a portion of the elongated channel of FIG. 138;

[0131] FIGS. 141-146 diagrammatically depict the sequential firing of staples in a surgical tool embodiment of the present invention;

[0132] FIG. 147 is a partial perspective view of a portion of a surgical end effector embodiment of the present invention;

[0133] FIG. 148 is a partial cross-sectional perspective view of a portion of a surgical end effector embodiment of a surgical tool embodiment of the present invention;

[0134] FIG. 149 is another partial cross-sectional perspective view of the surgical end effector embodiment of FIG. 148 with a sled assembly axially advancing therethrough;

[0135] FIG. 150 is a perspective view of another sled assembly embodiment of another surgical tool embodiment of the present invention;

[0136] FIG. 151 is a partial top view of a portion of the surgical end effector embodiment depicted in FIGS. 148 and 149 with the sled assembly axially advancing therethrough;

[0137] FIG. 152 is another partial top view of the surgical end effector embodiment of FIG. 151 with the top surface of the surgical staple cartridge omitted for clarity;

[0138] FIG. 153 is a partial cross-sectional side view of a rotary driver embodiment and staple pusher embodiment of the surgical end effector depicted in FIGS. 148 and 149;

[0139] FIG. 154 is a perspective view of an automated reloading system embodiment of the present invention with a surgical end effector in extractive engagement with the extraction system thereof;

- [0140] FIG. 155 is another perspective view of the automated reloading system embodiment depicted in FIG. 154;
- [0141] FIG. 156 is a cross-sectional elevational view of the automated reloading system embodiment depicted in FIGS. 154 and 155;
- [0142] FIG. 157 is another cross-sectional elevational view of the automated reloading system embodiment depicted in FIGS. 154-156 with the extraction system thereof removing a spent surgical staple cartridge from the surgical end effector;
- [0143] FIG. 158 is another cross-sectional elevational view of the automated reloading system embodiment depicted in FIGS. 154-157 illustrating the loading of a new surgical staple cartridge into a surgical end effector;
- [0144] FIG. 159 is a perspective view of another automated reloading system embodiment of the present invention with some components shown in cross-section;
- [0145] FIG. 160 is an exploded perspective view of a portion of the automated reloading system embodiment of FIG. 159;
- [0146] FIG. 161 is another exploded perspective view of the portion of the automated reloading system embodiment depicted in FIG. 160;
- [0147] FIG. 162 is a cross-sectional elevational view of the automated reloading system embodiment of FIGS. 159-161;
- [0148] FIG. 163 is a cross-sectional view of an orientation tube embodiment supporting a disposable loading unit therein;
- [0149] FIG. 164 is a perspective view of another surgical tool embodiment of the present invention;
- [0150] FIG. 165 is a partial perspective view of an articulation joint embodiment of a surgical tool embodiment of the present invention;
- [0151] FIG. 166 is a perspective view of a closure tube embodiment of a surgical tool embodiment of the present invention;
- [0152] FIG. 167 is a perspective view of the closure tube embodiment of FIG. 166 assembled on the articulation joint embodiment of FIG. 165;
- [0153] FIG. 168 is a top view of a portion of a tool mounting portion embodiment of a surgical tool embodiment of the present invention;

[0154] FIG. 169 is a perspective view of an articulation drive assembly embodiment employed in the tool mounting portion embodiment of FIG. 168;

[0155] FIG. 170 is a perspective view of another surgical tool embodiment of the present invention; and

[0156] FIG. 171 is a perspective view of another surgical tool embodiment of the present invention.

DETAILED DESCRIPTION

[0157] Applicant of the present application also owns the following patent applications that have been filed on even date herewith and which are each herein incorporated by reference in their respective entireties:

- U.S. Patent Application Serial No. _____, entitled “Surgical Instrument With Wireless Communication Between a Control Unit of a Robotic System and Remote Sensor”, Attorney Docket No. END5924USCIP2/060339CIP2;
- U.S. Patent Application Serial No. _____, entitled “Robotically-Controlled Disposable Motor Driven Loading Unit”, Attorney Docket No. END6213USCIP1/070330CIP1;
- U.S. Patent Application Serial No. _____, entitled “Robotically-Controlled Endoscopic Accessory Channel”, Attorney Docket No. END5568USCIP2/100809CIP2;
- U. S. Patent Application Serial No. _____, entitled “Robotically-Controlled Motorized Surgical Instrument”, Attorney Docket No. END6416USCIP1/080205CIP1;
- U.S. Patent Application Serial No. _____, entitled “Robotically-Controlled Surgical Stapling Devices That Produce Formed Staples Having Different Lengths”, Attorney Docket No. END5675USCIP6/050504CIP6;
- U.S. Patent Application Serial No. _____, entitled “Robotically-Controlled Motorized Cutting and Fastening Instrument”, Attorney Docket No. END6269USCIP1/070391CIP1;
- U.S. Patent Application Serial No. _____, entitled “Robotically-Controlled Shaft Based Rotary Drive Systems For Surgical Instruments”, Attorney Docket No. END6089USCIP1/070059CIP1;
- U.S. Patent Application Serial No. _____, entitled “Robotically-Controlled Surgical Instrument Having Recording Capabilities”, Attorney Docket No. END5773USCIP4/050698CIP4;

- U.S. Patent Application Serial No. _____, entitled “Robotically-Driven Surgical Instrument With E-Beam Driver”, Attorney Docket No. END0908USCIP2/100810CIP2;
- U.S. Patent Application Serial No. _____, entitled “Surgical Stapling Instruments With Rotatable Staple Deployment Arrangements”, Attorney Docket No. END7002USNP/110262.

[0158] Certain exemplary embodiments will now be described to provide an overall understanding of the principles of the structure, function, manufacture, and use of the devices and methods disclosed herein. One or more examples of these embodiments are illustrated in the accompanying drawings. Those of ordinary skill in the art will understand that the devices and methods specifically described herein and illustrated in the accompanying drawings are non-limiting exemplary embodiments and that the scope of the various embodiments of the present invention is defined solely by the claims. The features illustrated or described in connection with one exemplary embodiment may be combined with the features of other embodiments. Such modifications and variations are intended to be included within the scope of the present invention.

[0159] Uses of the phrases “in various embodiments,” “in some embodiments,” “in one embodiment”, or “in an embodiment”, or the like, throughout the specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics of one or more embodiments may be combined in any suitable manner in one or more other embodiments. Such modifications and variations are intended to be included within the scope of the present invention.

[0160] Figures 1 and 2 depict a surgical cutting and fastening instrument 10 according to various embodiments of the present invention. The illustrated embodiment is an endoscopic surgical instrument 10 and in general, the embodiments of the instrument 10 described herein are endoscopic surgical cutting and fastening instruments. It should be noted, however, that according to other embodiments of the present invention, the instrument 10 may be a non-endoscopic surgical cutting instrument, such as a laproscopic instrument.

[0161] The surgical instrument 10 depicted in Figures 1 and 2 comprises a handle 6, a shaft 8, and an articulating end effector 12 pivotally connected to the shaft 8 at an articulation pivot 14. An articulation control 16 may be provided adjacent to the handle 6 to effect rotation of the end effector 12 about the articulation pivot 14. It will be appreciated that various embodiments may include a non-pivoting end effector, and therefore may not have an articulation pivot 14 or articulation control 16. Also, in the illustrated embodiment, the end effector 12 is configured to act as an endocutter for clamping, severing and stapling tissue,

although, in other embodiments, different types of end effectors may be used, such as end effectors for other types of surgical devices, such as graspers, cutters, staplers, clip applicators, access devices, drug/gene therapy devices, ultrasound, RF or laser devices, etc.

[0162] The handle 6 of the instrument 10 may include a closure trigger 18 and a firing trigger 20 for actuating the end effector 12. It will be appreciated that instruments having end effectors directed to different surgical tasks may have different numbers or types of triggers or other suitable controls for operating the end effector 12. The end effector 12 is shown separated from the handle 6 by a preferably elongate shaft 8. In one embodiment, a clinician or operator of the instrument 10 may articulate the end effector 12 relative to the shaft 8 by utilizing the articulation control 16, as described in more detail in pending United States Patent Application Serial No. 11/329,020, filed January 10, 2006, entitled "Surgical Instrument Having An Articulating End Effector," by Geoffrey C. Hueil et al., which is incorporated herein by reference.

[0163] The end effector 12 includes in this example, among other things, a staple channel 22 and a pivotally translatable clamping member, such as an anvil 24, which are maintained at a spacing that assures effective stapling and severing of tissue clamped in the end effector 12. The handle 6 includes a pistol grip 26 toward which a closure trigger 18 is pivotally drawn by the clinician to cause clamping or closing of the anvil 24 towards the staple channel 22 of the end effector 12 to thereby clamp tissue positioned between the anvil 24 and channel 22. The firing trigger 20 is farther outboard of the closure trigger 18. Once the closure trigger 18 is locked in the closure position as further described below, the firing trigger 20 may rotate slightly toward the pistol grip 26 so that it can be reached by the operator using one hand. Then the operator may pivotally draw the firing trigger 20 toward the pistol grip 26 to cause the stapling and severing of clamped tissue in the end effector 12. In other embodiments, different types of clamping members besides the anvil 24 could be used, such as, for example, an opposing jaw, etc.

[0164] It will be appreciated that the terms "proximal" and "distal" are used herein with reference to a clinician gripping the handle 6 of an instrument 10. Thus, the end effector 12 is distal with respect to the more proximal handle 6. It will be further appreciated that, for convenience and clarity, spatial terms such as "vertical" and "horizontal" are used herein with respect to the drawings. However, surgical instruments are used in many orientations and positions, and these terms are not intended to be limiting and absolute.

[0165] The closure trigger 18 may be actuated first. Once the clinician is satisfied with the positioning of the end effector 12, the clinician may draw back the closure trigger 18 to its

fully closed, locked position proximate to the pistol grip 26. The firing trigger 20 may then be actuated. The firing trigger 20 returns to the open position (shown in Figures 1 and 2) when the clinician removes pressure, as described more fully below. A release button on the handle 6, when depressed may release the locked closure trigger 18. The release button may be implemented in various forms such as, for example, release button 30 shown in Figures 42-43, slide release button 160 shown in Figure 14, and/or button 172 shown in Figure 16.

[0166] Figures 3-6 show embodiments of a rotary-driven end effector 12 and shaft 8 according to various embodiments. Figure 3 is an exploded view of the end effector 12 according to various embodiments. As shown in the illustrated embodiment, the end effector 12 may include, in addition to the previously-mentioned channel 22 and anvil 24, a cutting instrument 32, a sled 33, a staple cartridge 34 that is removably seated in the channel 22, and a helical screw shaft 36. The cutting instrument 32 may be, for example, a knife. The anvil 24 may be pivotably opened and closed at pivot pins 25 connected to the proximate end of the channel 22. The anvil 24 may also include a tab 27 at its proximate end that is inserted into a component of the mechanical closure system (described further below) to open and close the anvil 24. When the closure trigger 18 is actuated, that is, drawn in by a user of the instrument 10, the anvil 24 may pivot about the pivot pins 25 into the clamped or closed position. If clamping of the end effector 12 is satisfactory, the operator may actuate the firing trigger 20, which, as explained in more detail below, causes the knife 32 and sled 33 to travel longitudinally along the channel 22, thereby cutting tissue clamped within the end effector 12. The movement of the sled 33 along the channel 22 causes the staples (not shown) of the staple cartridge 34 to be driven through the severed tissue and against the closed anvil 24, which turns the staples to fasten the severed tissue. In various embodiments, the sled 33 may be an integral component of the cartridge 34. United States Pat. No. 6,978,921, entitled "SURGICAL STAPLING INSTRUMENT INCORPORATING AN E-BEAM FIRING MECHANISM" to Shelton, IV et al., which is incorporated herein by reference, provides more details about such two-stroke cutting and fastening instruments. The sled 33 may be part of the cartridge 34, such that when the knife 32 retracts following the cutting operation, the sled 33 does not retract.

[0167] It should be noted that although the embodiments of the instrument 10 described herein employ an end effector 12 that staples the severed tissue, in other embodiments different techniques for fastening or sealing the severed tissue may be used. For example, end effectors that use RF energy or adhesives to fasten the severed tissue may also be used. U.S. Pat. No. 5,709,680 entitled "ELECTROSURGICAL HEMOSTATIC DEVICE" to Yates

et al., and U.S. Pat. No. 5,688,270 entitled "ELECTOSURGICAL HEMOSTATIC DEVICE WITH RECESSED AND/OR OFFSET ELECTRODES" to Yates et al. which are incorporated herein by reference, disclose an endoscopic cutting instrument that uses RF energy to seal the severed tissue. U.S. Patent Application Serial No. 11/267,811 to Jerome R. Morgan, *et. al.*, and U.S. Patent Application Serial No. 11/267,383 to Frederick E. Shelton, IV, *et. al.*, which are also incorporated herein by reference, disclose cutting instruments that uses adhesives to fasten the severed tissue. Accordingly, although the description herein refers to cutting/stapling operations and the like below, it should be recognized that this is an exemplary embodiment and is not meant to be limiting. Other tissue fastening techniques may also be used.

[0168] Figures 4 and 5 are exploded views and Figure 6 is a side view of the end effector 12 and shaft 8 according to various embodiments. As shown in the illustrated embodiment, the shaft 8 may include a proximate closure tube 40 and a distal closure tube 42 pivotably linked by a pivot link 44. The distal closure tube 42 includes an opening 45 into which the tab 27 on the anvil 24 is inserted in order to open and close the anvil 24, as further described below. Disposed inside the closure tubes 40, 42 may be a proximate spine tube 46. Disposed inside the proximate spine tube 46 may be a main rotational (or proximate) drive shaft 48 that communicates with a secondary (or distal) drive shaft 50 via a bevel gear assembly 52. The secondary drive shaft 50 is connected to a drive gear 54 that engages a proximate drive gear 56 of the helical screw shaft 36. The vertical bevel gear 52b may sit and pivot in an opening 57 in the distal end of the proximate spine tube 46. A distal spine tube 58 may be used to enclose the secondary drive shaft 50 and the drive gears 54, 56. Collectively, the main drive shaft 48, the secondary drive shaft 50, and the articulation assembly (*e.g.*, the bevel gear assembly 52a-c) are sometimes referred to herein as the "main drive shaft assembly."

[0169] A bearing 38, positioned at a distal end of the staple channel 22, receives the helical drive screw 36, allowing the helical drive screw 36 to freely rotate with respect to the channel 22. The helical screw shaft 36 may interface a threaded opening (not shown) of the knife 32 such that rotation of the shaft 36 causes the knife 32 to translate distally or proximally (depending on the direction of the rotation) through the staple channel 22. Accordingly, when the main drive shaft 48 is caused to rotate by actuation of the firing trigger 20 (as explained in more detail below), the bevel gear assembly 52a-c causes the secondary drive shaft 50 to rotate, which in turn, because of the engagement of the drive gears 54, 56, causes the helical screw shaft 36 to rotate, which causes the knife driving member 32 to travel longitudinally along the channel 22 to cut any tissue clamped within the end effector 12. The

sled 33 may be made of, for example, plastic, and may have a sloped distal surface. As the sled 33 traverses the channel 22, the sloped forward surface may push up or drive the staples in the staple cartridge through the clamped tissue and against the anvil 24. The anvil 24 turns the staples, thereby stapling the severed tissue. When the knife 32 is retracted, the knife 32 and sled 33 may become disengaged, thereby leaving the sled 33 at the distal end of the channel 22.

[0170] As described above, because of the lack of user feedback for the cutting/stapling operation, there is a general lack of acceptance among physicians of motor-driven endocutters where the cutting/stapling operation is actuated by merely pressing a button. In contrast, embodiments of the present invention provide a motor-driven endocutter with user-feedback of the deployment, force and/or position of the cutting instrument 32 in end effector 12.

[0171] Figures 7-10 illustrate an exemplary embodiment of a motor-driven endocutter, and in particular the handle thereof, that provides user-feedback regarding the deployment and loading force of the cutting instrument 32 in the end effector 12. In addition, the embodiment may use power provided by the user in retracting the firing trigger 20 to power the device (a so-called “power assist” mode). The embodiment may be used with the rotary driven end effector 12 and shaft 8 embodiments described above. As shown in the illustrated embodiment, the handle 6 includes exterior lower side pieces 59, 60 and exterior upper side pieces 61, 62 that fit together to form, in general, the exterior of the handle 6. A battery 64, such as a Li ion battery, may be provided in the pistol grip portion 26 of the handle 6. The battery 64 powers a motor 65 disposed in an upper portion of the pistol grip portion 26 of the handle 6. According to various embodiments, the motor 65 may be a DC brushed driving motor having a maximum rotation of, approximately, 5000 RPM. The motor 65 may drive a 90° bevel gear assembly 66 comprising a first bevel gear 68 and a second bevel gear 70. The bevel gear assembly 66 may drive a planetary gear assembly 72. The planetary gear assembly 72 may include a pinion gear 74 connected to a drive shaft 76. The pinion gear 74 may drive a mating ring gear 78 that drives a helical gear drum 80 via a drive shaft 82. A ring 84 may be threaded on the helical gear drum 80. Thus, when the motor 65 rotates, the ring 84 is caused to travel along the helical gear drum 80 by means of the interposed bevel gear assembly 66, planetary gear assembly 72 and ring gear 78.

[0172] The handle 6 may also include a run motor sensor 110 (see Figure 10) in communication with the firing trigger 20 to detect when the firing trigger 20 has been drawn in (or “closed”) toward the pistol grip portion 26 of the handle 6 by the operator to thereby

actuate the cutting/stapling operation by the end effector 12. The sensor 110 may be a proportional sensor such as, for example, a rheostat or variable resistor. When the firing trigger 20 is drawn in, the sensor 110 detects the movement, and sends an electrical signal indicative of the voltage (or power) to be supplied to the motor 65. When the sensor 110 is a variable resistor or the like, the rotation of the motor 65 may be generally proportional to the amount of movement of the firing trigger 20. That is, if the operator only draws or closes the firing trigger 20 in a little bit, the rotation of the motor 65 is relatively low. When the firing trigger 20 is fully drawn in (or in the fully closed position), the rotation of the motor 65 is at its maximum. In other words, the harder the user pulls on the firing trigger 20, the more voltage is applied to the motor 65, causing greater rates of rotation.

[0173] The handle 6 may include a middle handle piece 104 adjacent to the upper portion of the firing trigger 20. The handle 6 also may comprise a bias spring 112 connected between posts on the middle handle piece 104 and the firing trigger 20. The bias spring 112 may bias the firing trigger 20 to its fully open position. In that way, when the operator releases the firing trigger 20, the bias spring 112 will pull the firing trigger 20 to its open position, thereby removing actuation of the sensor 110, thereby stopping rotation of the motor 65. Moreover, by virtue of the bias spring 112, any time a user closes the firing trigger 20, the user will experience resistance to the closing operation, thereby providing the user with feedback as to the amount of rotation exerted by the motor 65. Further, the operator could stop retracting the firing trigger 20 to thereby remove force from the sensor 100, to thereby stop the motor 65. As such, the user may stop the deployment of the end effector 12, thereby providing a measure of control of the cutting/fastening operation to the operator.

[0174] The distal end of the helical gear drum 80 includes a distal drive shaft 120 that drives a ring gear 122, which mates with a pinion gear 124. The pinion gear 124 is connected to the main drive shaft 48 of the main drive shaft assembly. In that way, rotation of the motor 65 causes the main drive shaft assembly to rotate, which causes actuation of the end effector 12, as described above.

[0175] The ring 84 threaded on the helical gear drum 80 may include a post 86 that is disposed within a slot 88 of a slotted arm 90. The slotted arm 90 has an opening 92 its opposite end 94 that receives a pivot pin 96 that is connected between the handle exterior side pieces 59, 60. The pivot pin 96 is also disposed through an opening 100 in the firing trigger 20 and an opening 102 in the middle handle piece 104.

[0176] In addition, the handle 6 may include a reverse motor sensor (or end-of-stroke sensor) 130 and a stop motor (or beginning-of-stroke) sensor 142. In various embodiments,

the reverse motor sensor 130 may be a limit switch located at the distal end of the helical gear drum 80 such that the ring 84 threaded on the helical gear drum 80 contacts and trips the reverse motor sensor 130 when the ring 84 reaches the distal end of the helical gear drum 80. The reverse motor sensor 130, when activated, sends a signal to the motor 65 to reverse its rotation direction, thereby withdrawing the knife 32 of the end effector 12 following the cutting operation.

[0177] The stop motor sensor 142 may be, for example, a normally-closed limit switch. In various embodiments, it may be located at the proximate end of the helical gear drum 80 so that the ring 84 trips the switch 142 when the ring 84 reaches the proximate end of the helical gear drum 80.

[0178] In operation, when an operator of the instrument 10 pulls back the firing trigger 20, the sensor 110 detects the deployment of the firing trigger 20 and sends a signal to the motor 65 to cause forward rotation of the motor 65, for example, at a rate proportional to how hard the operator pulls back the firing trigger 20. The forward rotation of the motor 65 in turn causes the ring gear 78 at the distal end of the planetary gear assembly 72 to rotate, thereby causing the helical gear drum 80 to rotate, causing the ring 84 threaded on the helical gear drum 80 to travel distally along the helical gear drum 80. The rotation of the helical gear drum 80 also drives the main drive shaft assembly as described above, which in turn causes deployment of the knife 32 in the end effector 12. That is, the knife 32 and sled 33 are caused to traverse the channel 22 longitudinally, thereby cutting tissue clamped in the end effector 12. Also, the stapling operation of the end effector 12 is caused to happen in embodiments where a stapling-type end effector 12 is used.

[0179] By the time the cutting/stapling operation of the end effector 12 is complete, the ring 84 on the helical gear drum 80 will have reached the distal end of the helical gear drum 80, thereby causing the reverse motor sensor 130 to be tripped, which sends a signal to the motor 65 to cause the motor 65 to reverse its rotation. This in turn causes the knife 32 to retract, and also causes the ring 84 on the helical gear drum 80 to move back to the proximate end of the helical gear drum 80.

[0180] The middle handle piece 104 includes a backside shoulder 106 that engages the slotted arm 90 as best shown in Figures 8 and 9. The middle handle piece 104 also has a forward motion stop 107 that engages the firing trigger 20. The movement of the slotted arm 90 is controlled, as explained above, by rotation of the motor 65. When the slotted arm 90 rotates counter clockwise as the ring 84 travels from the proximate end of the helical gear drum 80 to the distal end, the middle handle piece 104 will be free to rotate counter

clockwise. Thus, as the user draws in the firing trigger 20, the firing trigger 20 will engage the forward motion stop 107 of the middle handle piece 104, causing the middle handle piece 104 to rotate counter clockwise. Due to the backside shoulder 106 engaging the slotted arm 90, however, the middle handle piece 104 will only be able to rotate counter clockwise as far as the slotted arm 90 permits. In that way, if the motor 65 should stop rotating for some reason, the slotted arm 90 will stop rotating, and the user will not be able to further draw in the firing trigger 20 because the middle handle piece 104 will not be free to rotate counter clockwise due to the slotted arm 90.

[0181] Figures 10A and 10B illustrate two states of a variable sensor that may be used as the run motor sensor 110 according to various embodiments of the present invention. The sensor 110 may include a face portion 280, a first electrode (A) 282, a second electrode (B) 284, and a compressible dielectric material 286 between the electrodes 282, 284, such as, for example, an electroactive polymer (EAP). The sensor 110 may be positioned such that the face portion 280 contacts the firing trigger 20 when retracted. Accordingly, when the firing trigger 20 is retracted, the dielectric material 286 is compressed, as shown in Figure 10B, such that the electrodes 282, 284 are closer together. Since the distance “b” between the electrodes 282, 284 is directly related to the impedance between the electrodes 282, 284, the greater the distance the more impedance, and the closer the distance the less impedance. In that way, the amount that the dielectric 286 is compressed due to retraction of the firing trigger 20 (denoted as force “F” in Figure 42) is proportional to the impedance between the electrodes 282, 284, which can be used to proportionally control the motor 65.

[0182] Components of an exemplary closure system for closing (or clamping) the anvil 24 of the end effector 12 by retracting the closure trigger 18 are also shown in Figures 7-10. In the illustrated embodiment, the closure system includes a yoke 250 connected to the closure trigger 18 by a pivot pin 251 inserted through aligned openings in both the closure trigger 18 and the yoke 250. A pivot pin 252, about which the closure trigger 18 pivots, is inserted through another opening in the closure trigger 18 which is offset from where the pin 251 is inserted through the closure trigger 18. Thus, retraction of the closure trigger 18 causes the upper part of the closure trigger 18, to which the yoke 250 is attached via the pin 251, to rotate counterclockwise. The distal end of the yoke 250 is connected, via a pin 254, to a first closure bracket 256. The first closure bracket 256 connects to a second closure bracket 258. Collectively, the closure brackets 256, 258 define an opening in which the proximate end of the proximate closure tube 40 (see Figure 4) is seated and held such that longitudinal movement of the closure brackets 256, 258 causes longitudinal motion by the proximate

closure tube 40. The instrument 10 also includes a closure rod 260 disposed inside the proximate closure tube 40. The closure rod 260 may include a window 261 into which a post 263 on one of the handle exterior pieces, such as exterior lower side piece 59 in the illustrated embodiment, is disposed to fixedly connect the closure rod 260 to the handle 6. In that way, the proximate closure tube 40 is capable of moving longitudinally relative to the closure rod 260. The closure rod 260 may also include a distal collar 267 that fits into a cavity 269 in proximate spine tube 46 and is retained therein by a cap 271 (see Figure 4).

[0183] In operation, when the yoke 250 rotates due to retraction of the closure trigger 18, the closure brackets 256, 258 cause the proximate closure tube 40 to move distally (i.e., away from the handle end of the instrument 10), which causes the distal closure tube 42 to move distally, which causes the anvil 24 to rotate about the pivot pins 25 into the clamped or closed position. When the closure trigger 18 is unlocked from the locked position, the proximate closure tube 40 is caused to slide proximally, which causes the distal closure tube 42 to slide proximally, which, by virtue of the tab 27 being inserted in the window 45 of the distal closure tube 42, causes the anvil 24 to pivot about the pivot pins 25 into the open or unclamped position. In that way, by retracting and locking the closure trigger 18, an operator may clamp tissue between the anvil 24 and channel 22, and may unclamp the tissue following the cutting/stapling operation by unlocking the closure trigger 20 from the locked position.

[0184] Figure 11 is a schematic diagram of an electrical circuit of the instrument 10 according to various embodiments of the present invention. When an operator initially pulls in the firing trigger 20 after locking the closure trigger 18, the sensor 110 is activated, allowing current to flow there through. If the normally-open reverse motor sensor switch 130 is open (meaning the end of the end effector stroke has not been reached), current will flow to a single pole, double throw relay 132. Since the reverse motor sensor switch 130 is not closed, the inductor 134 of the relay 132 will not be energized, so the relay 132 will be in its non-energized state. The circuit also includes a cartridge lockout sensor 136. If the end effector 12 includes a staple cartridge 34, the sensor 136 will be in the closed state, allowing current to flow. Otherwise, if the end effector 12 does not include a staple cartridge 34, the sensor 136 will be open, thereby preventing the battery 64 from powering the motor 65.

[0185] When the staple cartridge 34 is present, the sensor 136 is closed, which energizes a single pole, single throw relay 138. When the relay 138 is energized, current flows through the relay 136, through the variable resistor sensor 110, and to the motor 65 via a double pole, double throw relay 140, thereby powering the motor 65 and allowing it to rotate in the forward direction.

[0186] When the end effector 12 reaches the end of its stroke, the reverse motor sensor 130 will be activated, thereby closing the switch 130 and energizing the relay 134. This causes the relay 134 to assume its energized state (not shown in Figure 13), which causes current to bypass the cartridge lockout sensor 136 and variable resistor 110, and instead causes current to flow to both the normally-closed double pole, double throw relay 142 and back to the motor 65, but in a manner, via the relay 140, that causes the motor 65 to reverse its rotational direction.

[0187] Because the stop motor sensor switch 142 is normally-closed, current will flow back to the relay 134 to keep it closed until the switch 142 opens. When the knife 32 is fully retracted, the stop motor sensor switch 142 is activated, causing the switch 142 to open, thereby removing power from the motor 65.

[0188] In other embodiments, rather than a proportional-type sensor 110, an on-off type sensor could be used. In such embodiments, the rate of rotation of the motor 65 would not be proportional to the force applied by the operator. Rather, the motor 65 would generally rotate at a constant rate. But the operator would still experience force feedback because the firing trigger 20 is geared into the gear drive train.

[0189] Figure 12 is a side-view of the handle 6 of a power-assist motorized endocutter according to another embodiment. The embodiment of Figure 12 is similar to that of Figures 7-10 except that in the embodiment of Figure 12, there is no slotted arm connected to the ring 84 threaded on the helical gear drum 80. Instead, in the embodiment of Figure 12, the ring 84 includes a sensor portion 114 that moves with the ring 84 as the ring 84 advances down (and back) on the helical gear drum 80. The sensor portion 114 includes a notch 116. The reverse motor sensor 130 may be located at the distal end of the notch 116 and the stop motor sensor 142 may be located at the proximate end of the notch 116. As the ring 84 moves down the helical gear drum 80 (and back), the sensor portion 114 moves with it. Further, as shown in Figure 12, the middle piece 104 may have an arm 118 that extends into the notch 12.

[0190] In operation, as an operator of the instrument 10 retracts in the firing trigger 20 toward the pistol grip 26, the run motor sensor 110 detects the motion and sends a signal to power the motor 65, which causes, among other things, the helical gear drum 80 to rotate. As the helical gear drum 80 rotates, the ring 84 threaded on the helical gear drum 80 advances (or retracts, depending on the rotation). Also, due to the pulling in of the firing trigger 20, the middle piece 104 is caused to rotate counter clockwise with the firing trigger 20 due to the forward motion stop 107 that engages the firing trigger 20. The counter clockwise rotation of the middle piece 104 cause the arm 118 to rotate counter clockwise with the sensor portion

114 of the ring 84 such that the arm 118 stays disposed in the notch 116. When the ring 84 reaches the distal end of the helical gear drum 80, the arm 118 will contact and thereby trip the reverse motor sensor 130. Similarly, when the ring 84 reaches the proximate end of the helical gear drum 80, the arm will contact and thereby trip the stop motor sensor 142. Such actions may reverse and stop the motor 65, respectively as described above.

[0191] Figure 13 is a side-view of the handle 6 of a power-assist motorized endocutter according to another embodiment. The embodiment of Figure 13 is similar to that of Figures 7-10 except that in the embodiment of Figure 13, there is no slot in the arm 90. Instead, the ring 84 threaded on the helical gear drum 80 includes a vertical channel 126. Instead of a slot, the arm 90 includes a post 128 that is disposed in the channel 126. As the helical gear drum 80 rotates, the ring 84 threaded on the helical gear drum 80 advances (or retracts, depending on the rotation). The arm 90 rotates counter clockwise as the ring 84 advances due to the post 128 being disposed in the channel 126, as shown in Figure 13.

[0192] As mentioned above, in using a two-stroke motorized instrument, the operator first pulls back and locks the closure trigger 18. Figures 14 and 15 show one embodiment of a way to lock the closure trigger 18 to the pistol grip portion 26 of the handle 6. In the illustrated embodiment, the pistol grip portion 26 includes a hook 150 that is biased to rotate counter clockwise about a pivot point 151 by a torsion spring 152. Also, the closure trigger 18 includes a closure bar 154. As the operator draws in the closure trigger 18, the closure bar 154 engages a sloped portion 156 of the hook 150, thereby rotating the hook 150 upward (or clockwise in Figures 14-15) until the closure bar 154 completely passes the sloped portion 156 passes into a recessed notch 158 of the hook 150, which locks the closure trigger 18 in place. The operator may release the closure trigger 18 by pushing down on a slide button release 160 on the back or opposite side of the pistol grip portion 26. Pushing down the slide button release 160 rotates the hook 150 clockwise such that the closure bar 154 is released from the recessed notch 158.

[0193] Figure 16 shows another closure trigger locking mechanism according to various embodiments. In the embodiment of Figure 16, the closure trigger 18 includes a wedge 160 having an arrow-head portion 161. The arrow-head portion 161 is biased downward (or clockwise) by a leaf spring 162. The wedge 160 and leaf spring 162 may be made from, for example, molded plastic. When the closure trigger 18 is retracted, the arrow-head portion 161 is inserted through an opening 164 in the pistol grip portion 26 of the handle 6. A lower chamfered surface 166 of the arrow-head portion 161 engages a lower sidewall 168 of the opening 164, forcing the arrow-head portion 161 to rotate counter clockwise. Eventually the

lower chamfered surface 166 fully passes the lower sidewall 168, removing the counter clockwise force on the arrow-head portion 161, causing the lower sidewall 168 to slip into a locked position in a notch 170 behind the arrow-head portion 161.

[0194] To unlock the closure trigger 18, a user presses down on a button 172 on the opposite side of the closure trigger 18, causing the arrow-head portion 161 to rotate counter clockwise and allowing the arrow-head portion 161 to slide out of the opening 164.

[0195] Figures 17-22 show a closure trigger locking mechanism according to another embodiment. As shown in this embodiment, the closure trigger 18 includes a flexible longitudinal arm 176 that includes a lateral pin 178 extending therefrom. The arm 176 and pin 178 may be made from molded plastic, for example. The pistol grip portion 26 of the handle 6 includes an opening 180 with a laterally extending wedge 182 disposed therein. When the closure trigger 18 is retracted, the pin 178 engages the wedge 182, and the pin 178 is forced downward (i.e., the arm 176 is rotated clockwise) by the lower surface 184 of the wedge 182, as shown in Figures 17 and 18. When the pin 178 fully passes the lower surface 184, the clockwise force on the arm 176 is removed, and the pin 178 is rotated counter clockwise such that the pin 178 comes to rest in a notch 186 behind the wedge 182, as shown in Figure 19, thereby locking the closure trigger 18. The pin 178 is further held in place in the locked position by a flexible stop 188 extending from the wedge 184.

[0196] To unlock the closure trigger 18, the operator may further squeeze the closure trigger 18, causing the pin 178 to engage a sloped backwall 190 of the opening 180, forcing the pin 178 upward past the flexible stop 188, as shown in Figures 20 and 21. The pin 178 is then free to travel out an upper channel 192 in the opening 180 such that the closure trigger 18 is no longer locked to the pistol grip portion 26, as shown in Figure 22.

[0197] Figures 23A-B show a universal joint (“u-joint”) 195. The second piece 195-2 of the u-joint 195 rotates in a horizontal plane in which the first piece 195-1 lies. Figure 23A shows the u-joint 195 in a linear (180°) orientation and Figure 23B shows the u-joint 195 at approximately a 150° orientation. The u-joint 195 may be used instead of the bevel gears 52a-c (see Figure 4, for example) at the articulation point 14 of the main drive shaft assembly to articulate the end effector 12. Figures 24A-B show a torsion cable 197 that may be used in lieu of both the bevel gears 52a-c and the u-joint 195 to realize articulation of the end effector 12.

[0198] Figures 25-31 illustrate another embodiment of a motorized, two-stroke surgical cutting and fastening instrument 10 with power assist according to another embodiment of the present invention. The embodiment of Figures 25-31 is similar to that of Figures 6-10

except that instead of the helical gear drum 80, the embodiment of Figures 23-28 includes an alternative gear drive assembly. The embodiment of Figures 25-31 includes a gear box assembly 200 including a number of gears disposed in a frame 201, wherein the gears are connected between the planetary gear 72 and the pinion gear 124 at the proximate end of the drive shaft 48. As explained further below, the gear box assembly 200 provides feedback to the user via the firing trigger 20 regarding the deployment and loading force of the end effector 12. Also, the user may provide power to the system via the gear box assembly 200 to assist the deployment of the end effector 12. In that sense, like the embodiments described above, the embodiment of Figures 23-32 is another power assist motorized instrument 10 that provides feedback to the user regarding the loading force experienced by the instrument.

[0199] In the illustrated embodiment, the firing trigger 20 includes two pieces: a main body portion 202 and a stiffening portion 204. The main body portion 202 may be made of plastic, for example, and the stiffening portion 204 may be made out of a more rigid material, such as metal. In the illustrated embodiment, the stiffening portion 204 is adjacent to the main body portion 202, but according to other embodiments, the stiffening portion 204 could be disposed inside the main body portion 202. A pivot pin 207 may be inserted through openings in the firing trigger pieces 202, 204 and may be the point about which the firing trigger 20 rotates. In addition, a spring 222 may bias the firing trigger 20 to rotate in a counter clockwise direction. The spring 222 may have a distal end connected to a pin 224 that is connected to the pieces 202, 204 of the firing trigger 20. The proximate end of the spring 222 may be connected to one of the handle exterior lower side pieces 59, 60.

[0200] In the illustrated embodiment, both the main body portion 202 and the stiffening portion 204 includes gear portions 206, 208 (respectively) at their upper end portions. The gear portions 206, 208 engage a gear in the gear box assembly 200, as explained below, to drive the main drive shaft assembly and to provide feedback to the user regarding the deployment of the end effector 12.

[0201] The gear box assembly 200 may include as shown, in the illustrated embodiment, six (6) gears. A first gear 210 of the gear box assembly 200 engages the gear portions 206, 208 of the firing trigger 20. In addition, the first gear 210 engages a smaller second gear 212, the smaller second gear 212 being coaxial with a large third gear 214. The third gear 214 engages a smaller fourth gear 216, the smaller fourth gear being coaxial with a fifth gear 218. The fifth gear 218 is a 90° bevel gear that engages a mating 90° bevel gear 220 (best shown in Figure 31) that is connected to the pinion gear 124 that drives the main drive shaft 48.

[0202] In operation, when the user retracts the firing trigger 20, a run motor sensor (not shown) is activated, which may provide a signal to the motor 65 to rotate at a rate proportional to the extent or force with which the operator is retracting the firing trigger 20. This causes the motor 65 to rotate at a speed proportional to the signal from the sensor. The sensor is not shown for this embodiment, but it could be similar to the run motor sensor 110 described above. The sensor could be located in the handle 6 such that it is depressed when the firing trigger 20 is retracted. Also, instead of a proportional-type sensor, an on/off type sensor may be used.

[0203] Rotation of the motor 65 causes the bevel gears 68, 70 to rotate, which causes the planetary gear 72 to rotate, which causes, via the drive shaft 76, the ring gear 122 to rotate. The ring gear 122 meshes with the pinion gear 124, which is connected to the main drive shaft 48. Thus, rotation of the pinion gear 124 drives the main drive shaft 48, which causes actuation of the cutting/stapling operation of the end effector 12.

[0204] Forward rotation of the pinion gear 124 in turn causes the bevel gear 220 to rotate, which causes, by way of the rest of the gears of the gear box assembly 200, the first gear 210 to rotate. The first gear 210 engages the gear portions 206, 208 of the firing trigger 20, thereby causing the firing trigger 20 to rotate counter clockwise when the motor 65 provides forward drive for the end effector 12 (and to rotate counter clockwise when the motor 65 rotates in reverse to retract the end effector 12). In that way, the user experiences feedback regarding loading force and deployment of the end effector 12 by way of the user's grip on the firing trigger 20. Thus, when the user retracts the firing trigger 20, the operator will experience a resistance related to the load force experienced by the end effector 12.

Similarly, when the operator releases the firing trigger 20 after the cutting/stapling operation so that it can return to its original position, the user will experience a clockwise rotation force from the firing trigger 20 that is generally proportional to the reverse speed of the motor 65.

[0205] It should also be noted that in this embodiment the user can apply force (either in lieu of or in addition to the force from the motor 65) to actuate the main drive shaft assembly (and hence the cutting/stapling operation of the end effector 12) through retracting the firing trigger 20. That is, retracting the firing trigger 20 causes the gear portions 206, 208 to rotate counter clockwise, which causes the gears of the gear box assembly 200 to rotate, thereby causing the pinion gear 124 to rotate, which causes the main drive shaft 48 to rotate.

[0206] Although not shown in Figures 25-31, the instrument 10 may further include reverse motor and stop motor sensors. As described above, the reverse motor and stop motor sensors may detect, respectively, the end of the cutting stroke (full deployment of the knife 32) and

the end of retraction operation (full retraction of the knife 32). A similar circuit to that described above in connection with Figure 11 may be used to appropriately power the motor 65.

[0207] Figures 32-36 illustrate a two-stroke, motorized surgical cutting and fastening instrument 10 with power assist according to another embodiment. The embodiment of Figures 32-36 is similar to that of Figures 25-31 except that in the embodiment of Figures 32-36, the firing trigger 20 includes a lower portion 228 and an upper portion 230. Both portions 228, 230 are connected to and pivot about a pivot pin 207 that is disposed through each portion 228, 230. The upper portion 230 includes a gear portion 232 that engages the first gear 210 of the gear box assembly 200. The spring 222 is connected to the upper portion 230 such that the upper portion is biased to rotate in the clockwise direction. The upper portion 230 may also include a lower arm 234 that contacts an upper surface of the lower portion 228 of the firing trigger 20 such that when the upper portion 230 is caused to rotate clockwise the lower portion 228 also rotates clockwise, and when the lower portion 228 rotates counter clockwise the upper portion 230 also rotates counter clockwise. Similarly, the lower portion 228 includes a rotational stop 238 that engages a shoulder of the upper portion 230. In that way, when the upper portion 230 is caused to rotate counter clockwise the lower portion 228 also rotates counter clockwise, and when the lower portion 228 rotates clockwise the upper portion 230 also rotates clockwise.

[0208] The illustrated embodiment also includes the run motor sensor 110 that communicates a signal to the motor 65 that, in various embodiments, may cause the motor 65 to rotate at a speed proportional to the force applied by the operator when retracting the firing trigger 20. The sensor 110 may be, for example, a rheostat or some other variable resistance sensor, as explained herein. In addition, the instrument 10 may include reverse motor sensor 130 that is tripped or switched when contacted by a front face 242 of the upper portion 230 of the firing trigger 20. When activated, the reverse motor sensor 130 sends a signal to the motor 65 to reverse direction. Also, the instrument 10 may include a stop motor sensor 142 that is tripped or actuated when contacted by the lower portion 228 of the firing trigger 20. When activated, the stop motor sensor 142 sends a signal to stop the reverse rotation of the motor 65.

[0209] In operation, when an operator retracts the closure trigger 18 into the locked position, the firing trigger 20 is retracted slightly (through mechanisms known in the art, including United States Patent No. 6,978,921 to Frederick Shelton, IV *et. al* and United States Patent No. 6,905,057 to Jeffery S. Swayze *et. al*, which are incorporated herein by

reference) so that the user can grasp the firing trigger 20 to initiate the cutting/stapling operation, as shown in Figures 32 and 33. At that point, as shown in Figure 33, the gear portion 232 of the upper portion 230 of the firing trigger 20 moves into engagement with the first gear 210 of the gear box assembly 200. When the operator retracts the firing trigger 20, according to various embodiments, the firing trigger 20 may rotate a small amount, such as five degrees, before tripping the run motor sensor 110, as shown in Figure 34. Activation of the sensor 110 causes the motor 65 to forward rotate at a rate proportional to the retraction force applied by the operator. The forward rotation of the motor 65 causes, as described above, the main drive shaft 48 to rotate, which causes the knife 32 in the end effector 12 to be deployed (i.e., begin traversing the channel 22). Rotation of the pinion gear 124, which is connected to the main drive shaft 48, causes the gears 210-220 in the gear box assembly 200 to rotate. Since the first gear 210 is in engagement with the gear portion 232 of the upper portion 230 of the firing trigger 20, the upper portion 232 is caused to rotate counter clockwise, which causes the lower portion 228 to also rotate counter clockwise.

[0210] When the knife 32 is fully deployed (i.e., at the end of the cutting stroke), the front face 242 of the upper portion 230 trips the reverse motor sensor 130, which sends a signal to the motor 65 to reverse rotational direction. This causes the main drive shaft assembly to reverse rotational direction to retract the knife 32. Reverse rotation of the main drive shaft assembly also causes the gears 210-220 in the gear box assembly to reverse direction, which causes the upper portion 230 of the firing trigger 20 to rotate clockwise, which causes the lower portion 228 of the firing trigger 20 to rotate clockwise until the lower portion 228 trips or actuates the stop motor sensor 142 when the knife 32 is fully retracted, which causes the motor 65 to stop. In that way, the user experiences feedback regarding deployment of the end effector 12 by way of the user's grip on the firing trigger 20. Thus, when the user retracts the firing trigger 20, the operator will experience a resistance related to the deployment of the end effector 12 and, in particular, to the loading force experienced by the knife 32. Similarly, when the operator releases the firing trigger 20 after the cutting/stapling operation so that it can return to its original position, the user will experience a clockwise rotation force from the firing trigger 20 that is generally proportional to the reverse speed of the motor 65.

[0211] It should also be noted that in this embodiment the user can apply force (either in lieu of or in addition to the force from the motor 65) to actuate the main drive shaft assembly (and hence the cutting/stapling operation of the end effector 12) through retracting the firing trigger 20. That is, retracting the firing trigger 20 causes the gear portion 232 of the upper portion 230 to rotate counter clockwise, which causes the gears of the gear box assembly 200

to rotate, thereby causing the pinion gear 124 to rotate, which causes the main drive shaft assembly to rotate.

[0212] The above-described embodiments employed power-assist user feedback systems, with or without adaptive control (e.g., using a sensor 110, 130, and 142 outside of the closed loop system of the motor 65, gear drive train, and end effector 12) for a two-stroke, motorized surgical cutting and fastening instrument. That is, force applied by the user in retracting the firing trigger 20 may be added to the force applied by the motor 65 by virtue of the firing trigger 20 being geared into (either directly or indirectly) the gear drive train between the motor 65 and the main drive shaft 48. In other embodiments of the present invention, the user may be provided with tactile feedback regarding the position of the knife 32 in the end effector, but without having the firing trigger 20 geared into the gear drive train. Figures 37-40 illustrate a motorized surgical cutting and fastening instrument with such a tactile position feedback system.

[0213] In the illustrated embodiment of Figures 37-40, the firing trigger 20 may have a lower portion 228 and an upper portion 230, similar to the instrument 10 shown in Figures 32-36. Unlike the embodiment of Figure 32-36, however, the upper portion 230 does not have a gear portion that mates with part of the gear drive train. Instead, the instrument includes a second motor 265 with a threaded rod 266 threaded therein. The threaded rod 266 reciprocates longitudinally in and out of the motor 265 as the motor 265 rotates, depending on the direction of rotation. The instrument 10 also includes an encoder 268 that is responsive to the rotations of the main drive shaft 48 for translating the incremental angular motion of the main drive shaft 48 (or other component of the main drive assembly) into a corresponding series of digital signals, for example. In the illustrated embodiment, the pinion gear 124 includes a proximate drive shaft 270 that connects to the encoder 268.

[0214] The instrument 10 also includes a control circuit (not shown), which may be implemented using a microcontroller or some other type of integrated circuit, that receives the digital signals from the encoder 268. Based on the signals from the encoder 268, the control circuit may calculate the stage of deployment of the knife 32 in the end effector 12. That is, the control circuit can calculate if the knife 32 is fully deployed, fully retracted, or at an intermittent stage. Based on the calculation of the stage of deployment of the end effector 12, the control circuit may send a signal to the second motor 265 to control its rotation to thereby control the reciprocating movement of the threaded rod 266.

[0215] In operation, as shown in Figure 37, when the closure trigger 18 is not locked into the clamped position, the firing trigger 20 rotated away from the pistol grip portion 26 of the

handle 6 such that the front face 242 of the upper portion 230 of the firing trigger 20 is not in contact with the proximate end of the threaded rod 266. When the operator retracts the closure trigger 18 and locks it in the clamped position, the firing trigger 20 rotates slightly towards the closure trigger 20 so that the operator can grasp the firing trigger 20, as shown in Figure 38. In this position, the front face 242 of the upper portion 230 contacts the proximate end of the threaded rod 266.

[0216] As the user then retracts the firing trigger 20, after an initial rotational amount (e.g. 5 degrees of rotation) the run motor sensor 110 may be activated such that, as explained above, the sensor 110 sends a signal to the motor 65 to cause it to rotate at a forward speed proportional to the amount of retraction force applied by the operator to the firing trigger 20. Forward rotation of the motor 65 causes the main drive shaft 48 to rotate via the gear drive train, which causes the knife 32 and sled 33 to travel down the channel 22 and sever tissue clamped in the end effector 12. The control circuit receives the output signals from the encoder 268 regarding the incremental rotations of the main drive shaft assembly and sends a signal to the second motor 265 to cause the second motor 265 to rotate, which causes the threaded rod 266 to retract into the motor 265. This allows the upper portion 230 of the firing trigger 20 to rotate counter clockwise, which allows the lower portion 228 of the firing trigger to also rotate counter clockwise. In that way, because the reciprocating movement of the threaded rod 266 is related to the rotations of the main drive shaft assembly, the operator of the instrument 10, by way of his/her grip on the firing trigger 20, experiences tactile feedback as to the position of the end effector 12. The retraction force applied by the operator, however, does not directly affect the drive of the main drive shaft assembly because the firing trigger 20 is not geared into the gear drive train in this embodiment.

[0217] By virtue of tracking the incremental rotations of the main drive shaft assembly via the output signals from the encoder 268, the control circuit can calculate when the knife 32 is fully deployed (i.e., fully extended). At this point, the control circuit may send a signal to the motor 65 to reverse direction to cause retraction of the knife 32. The reverse direction of the motor 65 causes the rotation of the main drive shaft assembly to reverse direction, which is also detected by the encoder 268. Based on the reverse rotation detected by the encoder 268, the control circuit sends a signal to the second motor 265 to cause it to reverse rotational direction such that the threaded rod 266 starts to extend longitudinally from the motor 265. This motion forces the upper portion 230 of the firing trigger 20 to rotate clockwise, which causes the lower portion 228 to rotate clockwise. In that way, the operator may experience a clockwise force from the firing trigger 20, which provides feedback to the operator as to the

retraction position of the knife 32 in the end effector 12. The control circuit can determine when the knife 32 is fully retracted. At this point, the control circuit may send a signal to the motor 65 to stop rotation.

[0218] According to other embodiments, rather than having the control circuit determine the position of the knife 32, reverse motor and stop motor sensors may be used, as described above. In addition, rather than using a proportional sensor 110 to control the rotation of the motor 65, an on/off switch or sensor can be used. In such an embodiment, the operator would not be able to control the rate of rotation of the motor 65. Rather, it would rotate at a preprogrammed rate.

[0219] Figures 41-43 illustrate an exemplary embodiment of a mechanically actuated endocutter, and in particular the handle 6, shaft 8 and end effector 12 thereof. Further details of a mechanically actuated endocutter may be found in U.S. Patent Application Serial No. 11/052,632 entitled, "Surgical Stapling Instrument Incorporating A Multi-Stroke Firing Mechanism With Automatic End Of Firing Travel Retraction," which is incorporated herein by reference. With reference to Figure 41, the end effector 12 responds to the closure motion from the handle 6 (not depicted in Figure 41) first by including an anvil face 1002 connecting to an anvil proximal end 1004 that includes laterally projecting anvil pivot pins 25 that are proximal to a vertically projecting anvil tab 27. The anvil pivot pins 25 translate within kidney shaped openings 1006 in the staple channel 22 to open and close anvil 24 relative to channel 22. The tab 27 engages a bent tab 1007 extending inwardly in tab opening 45 on a distal end 1008 of the closure tube 1005, the latter distally terminating in a distal edge 1008 that pushes against the anvil face 1002. Thus, when the closure tube 1005 moves proximally from its open position, the bent tab 1007 of the closure tube 1005 draws the anvil tab 27 proximally, and the anvil pivot pins 25 follow the kidney shaped openings 1006 of the staple channel 22 causing the anvil 24 to simultaneously translate proximally and rotate upward to the open position. When the closure tube 1005 moves distally, the bent tab 1007 in the tab opening 45 releases from the anvil tab 27 and the distal edge 1008 pushes on the anvil face 1002, closing the anvil 24.

[0220] With continued reference to Figure 41, the shaft 8 and end effector 12 also include components that respond to a firing motion of a firing rod 1010. In particular, the firing rod 1010 rotatably engages a firing trough member 1012 having a longitudinal recess 1014. Firing trough member 1012 moves longitudinally within frame 1016 in direct response to longitudinal motion of firing rod 1010. A longitudinal slot 1018 in the closure tube 1005 operably couples with the right and left exterior side handle pieces 61, 62 of the handle 6 (not

shown in Figure 41). The length of the longitudinal slot 1018 in the closure tube 1005 is sufficiently long to allow relative longitudinal motion with the handle pieces 61, 62 to accomplish firing and closure motions respectively with the coupling of the handle pieces 61, 62 passing on through a longitudinal slot 1020 in the frame 1016 to slidingly engage the longitudinal recess 1014 in the frame trough member 1012.

[0221] The distal end of the frame trough member 1012 is attached to a proximal end of a firing bar 1022 that moves within the frame 1016, specifically within a guide 1024 therein, to distally project the knife 32 into the end effector 12. The end effector 12 includes a staple cartridge 34 that is actuated by the knife 32. The staple cartridge 34 has a tray 1028 that holds a staple cartridge body 1030, a wedge sled driver 33, staple drivers 1034 and staples 1036. It will be appreciated that the wedge sled driver 33 longitudinally moves within a firing recess (not shown) located between the cartridge tray 1028 and the cartridge body 1030. The wedge sled driver 33 presents camming surfaces that contact and lift the staple drivers 1034 upward, driving the staples 1036. The staple cartridge body 1030 further includes a proximally open, vertical slot 1031 for passage of the knife 32. Specifically, a cutting surface 1027 is provided along a distal end of knife 32 to cut tissue after it is stapled.

[0222] It should be appreciated that the shaft 8 is shown in Figure 4 as a non-articulating shaft. Nonetheless, applications of the present invention may include instruments capable of articulation, for example, as such shown above with reference to Figures 1-4 and described in the following U.S. patents and patent applications, the disclosure of each being hereby incorporated by reference in their entirety: (1) "SURGICAL INSTRUMENT INCORPORATING AN ARTICULATION MECHANISM HAVING ROTATION ABOUT THE LONGITUDINAL AXIS", U.S. Patent Application Publication No. 2005/0006434, by Frederick E. Shelton IV, Brian J. Hemmelgarn, Jeffrey S. Swayze, Kenneth S. Wales, filed 9 Jul. 2003; (2) "SURGICAL STAPLING INSTRUMENT INCORPORATING AN ARTICULATION JOINT FOR A FIRING BAR TRACK", U.S. Patent No. 6,786,382, to Brian J. Hemmelgarn; (3) "A SURGICAL INSTRUMENT WITH A LATERAL-MOVING ARTICULATION CONTROL", U.S. Patent No. 6,981,628, to Jeffrey S. Swayze; (4) "SURGICAL STAPLING INSTRUMENT INCORPORATING A TAPERED FIRING BAR FOR INCREASED FLEXIBILITY AROUND THE ARTICULATION JOINT", U.S. Patent No. 6,964,363, to Frederick E. Shelton IV, Michael Setser, Bruce Weisenburgh II; and (5) "SURGICAL STAPLING INSTRUMENT HAVING ARTICULATION JOINT SUPPORT PLATES FOR SUPPORTING A FIRING BAR", U.S. Patent Application Publication No. 2005/0006431, by Jeffrey S. Swayze, Joseph Charles Hueil, filed 9 Jul. 2003.

[0223] Figures 42-43 show an embodiment of the handle 6 that is configured for use in a mechanically actuated endocutter along with the embodiment of the shaft 8 and end effector 12 as shown above in Figure 41. It will be appreciated that any suitable handle design may be used to mechanically close and fire the end effector 12. In Figures 42-43, the handle 6 of the surgical stapling and severing instrument 10 includes a linked transmission firing mechanism 1060 that provides features such as increased strength, reduced handle size, minimized binding, etc.

[0224] Closure of the end effector 12 (not shown in Figures 42-43) is caused by depressing the closure trigger 18 toward the pistol grip 26 of handle 6. The closure trigger 18 pivots about a closure pivot pin 252 that is coupled to right and left exterior lower side pieces 59, 60 the handle 6, causing an upper portion 1094 of the closure trigger 18 to move forward. The closure tube 1005 receives this closure movement via the closure yoke 250 that is pinned to a closure link 1042 and to the upper portion 1094 of the closure trigger 18 respectively by a closure yoke pin 1044 and a closure link pin 1046.

[0225] In the fully open position of Figure 42, the upper portion 1094 of the closure trigger 18 contacts and holds a locking arm 1048 of the pivoting closure release button 30 in the position shown. When the closure trigger 18 reaches its fully depressed position, the closure trigger 18 releases the locking arm 1048 and an abutting surface 1050 rotates into engagement with a distal rightward notch 1052 of the pivoting locking arm 1048, holding the closure trigger 18 in this clamped or closed position. A proximal end of the locking arm 1048 pivots about a lateral pivotal connection 1054 with the pieces 59, 60 to expose the closure release button 30. An intermediate, distal side 1056 of the closure release button 30 is urged proximally by a compression spring 1058, which is compressed between a housing structure 1040 and closure release button 30. The result is that the closure release button 30 urges the locking arm 1048 counterclockwise (when viewed from the left) into locking contact with the abutting surface 1050 of closure trigger 18, which prevents unclamping of closure trigger 18 when the linked transmission firing system 1040 is in an un-retracted condition.

[0226] With the closure trigger 18 retracted and fully depressed, the firing trigger 20 is unlocked and may be depressed toward the pistol grip 26, multiple times in this embodiment, to effect firing of the end effector 12. As depicted, the linked transmission firing mechanism 1060 is initially retracted, urged to remain in this position by a combination tension/compression spring 1062 that is constrained within the pistol grip 26 of the handle 6, with its nonmoving end 1063 connected to the pieces 59, 60 and a moving end 1064 connected to a downwardly flexed and proximal, retracted end 1067 of a steel band 1066.

[0227] A distally-disposed end 1068 of the steel band 1066 is attached to a link coupling 1070 for structural loading, which in turn is attached to a front link 1072a of a plurality of links 1072a-1072d that form a linked rack 1074. Linked rack 1074 is flexible yet has distal links that form a straight rigid rack assembly that may transfer a significant firing force through the firing rod 1010 in the shaft 6, yet readily retract into the pistol grip 26 to minimize the longitudinal length of the handle 6. It should be appreciated that the combination tension/compression spring 1062 increases the amount of firing travel available while essentially reducing the minimum length by half over a single spring.

[0228] The firing trigger 20 pivots about a firing trigger pin 96 that is connected to the handle pieces 59, 60. An upper portion 228 of the firing trigger 20 moves distally about the firing trigger pin 96 as the firing trigger 20 is depressed towards pistol grip 26, stretching a proximally placed firing trigger tension spring 222 proximally connected between the upper portion 228 of the firing trigger 20 and the pieces 59, 60. The upper portion 228 of the firing trigger 20 engages the linked rack 1074 during each firing trigger depression by a traction biasing mechanism 1078 that also disengages when the firing trigger 20 is released. Firing trigger tension spring 222 urges the firing trigger 20 distally when released and disengages the traction biasing mechanism 1078.

[0229] As the linked transmission firing mechanism 1040 actuates, an idler gear 1080 is rotated clockwise (as viewed from the left side) by engagement with a toothed upper surface 1082 of the linked rack 1074. This rotation is coupled to an indicator gear 1084, which thus rotates counterclockwise in response to the idler gear 1080. Both the idler gear 1080 and indicator gear 1084 are rotatably connected to the pieces 59, 60 of the handle 6. The gear relationship between the linked rack 1074, idler gear 1080 and indicator gear 1084 may be advantageously selected so that the toothed upper surface 1082 has tooth dimensions that are suitably strong and that the indicator gear 1084 makes no more than one revolution during the full firing travel of the linked transmission firing mechanism 1060.

[0230] As described in greater detail below, the indicator gear 1084 performs at least four functions. First, when the linked rack 1074 is fully retracted and both triggers 18, 20 are open as shown in Figure 42, an opening 1086 in a circular ridge 1088 on the left side of the indicator gear 1084 is presented to an upper surface 1090 of the locking arm 1048. Locking arm 1048 is biased into the opening 1086 by contact with the closure trigger 18, which in turn is urged to the open position by a closure tension spring 1092. Closure trigger tension spring 1092 is connected proximally to the upper portion 1094 of the closure trigger 18 and the

handle pieces 59, 60, and thus has energy stored during closing of the closure trigger 18 that urges the closure trigger 18 distally to its unclosed position.

[0231] A second function of the indicator gear 1084 is that it is connected to the indicating retraction knob 1096 externally disposed on the handle 6. Thus, the indicator gear 1084 communicates the relative position of the firing mechanism 1060 to the indicating retraction knob 1096 so that the surgeon has a visual indication of how many strokes of the firing trigger 20 are required to complete firing.

[0232] A third function of the indicator gear 1084 is to longitudinally and angularly move an anti-backup release lever 1098 of an anti-backup mechanism (one-way clutch mechanism) 1097 as the surgical stapling and severing instrument 10 is operated. During the firing strokes, proximal movement of anti-backup release lever 1098 by indicator gear 1084 activates the anti-backup mechanism 1097 that allows distal movement of firing bar 1010 and prevents proximal motion of firing bar 1010. This movement also extends the anti-backup release button 1100 from the proximal end of the handle pieces 59, 60 for the operator to actuate should the need arise for the linked transmission firing mechanism 1060 to be retracted during the firing strokes. After completion of the firing strokes, the indicator gear 1084 reverses direction of rotation as the firing mechanism 1060 retracts. The reversed rotation deactivates the anti-backup mechanism 1097, withdraws the anti-backup release button 1100 into the handle 6, and rotates the anti-backup release lever 1098 laterally to the right to allow continued reverse rotation of the indicator gear 1084.

[0233] A fourth function of the indicator gear 1084 is to receive a manual rotation from the indicating retraction knob 1096 (clockwise in the depiction of Figure 42) to retract the firing mechanism 1060 with anti-backup mechanism 1097 unlocked, thereby overcoming any binding in the firing mechanism 1060 that is not readily overcome by the combination tension/compression spring 1062. This manual retraction assistance may be employed after a partial firing of the firing mechanism 1060 that would otherwise be prevented by the anti-backup mechanism 1097 that withdraws the anti-backup release button 1100 so that the latter may not laterally move the anti-backup release lever 1098.

[0234] Continuing with Figures 42-43, anti-backup mechanism 1097 consists of the operator accessible anti-backup release lever 1098 operably coupled at the proximal end to the anti-backup release button 1100 and at the distal end to an anti-backup yoke 1102. In particular, a distal end 1099 of the anti-backup release lever 1098 is engaged to the anti-backup yoke 1102 by an anti-backup yoke pin 1104. The anti-backup yoke 1102 moves longitudinally to impart a rotation to an anti-backup cam slot tube 1106 that is longitudinally

constrained by the handle pieces 59, 90 and that encompasses the firing rod 1010 distally to the connection of the firing rod 1010 to the link coupling 1070 of the linked rack 1074. The anti-backup yoke 1102 communicates the longitudinal movement from the anti-backup release lever 1098 via a cam slot tube pin 1108 to the anti-backup cam slot tube 1106. That is, longitudinal movement of cam slot tube pin 1108 in an angled slot in the anti-backup cam slot tube 1106 rotates the anti-backup cam slot tube 1106.

[0235] Trapped between a proximal end of the frame 1016 and the anti-backup cam slot tube 1106 respectively are an anti-backup compression spring 1110, an anti-backup plate 1112, and an anti-backup cam tube 1114. As depicted, proximal movement of the firing rod 1010 causes the anti-backup plate 1112 to pivot top to the rear, presenting an increased frictional contact to the firing rod 1010 that resists further proximal movement of the firing rod 1010.

[0236] This anti-backup plate 1112 pivots in a manner similar to that of a screen door lock that holds open a screen door when the anti-backup cam slot tube 1106 is closely spaced to the anti-backup cam tube 1114. Specifically, the anti-backup compression spring 1110 is able to act upon a top surface of the plate 1112 to tip the anti-backup plate 1112 to its locked position. Rotation of the anti-backup cam slot tube 1106 causes a distal camming movement of the anti-backup cam tube 1114 thereby forcing the top of the anti-backup plate 1112 distally, overcoming the force from the anti-backup compression spring 1110, thus positioning the anti-backup plate 1112 in an untipped (perpendicular), unlocked position that allows proximal retraction of the firing rod 1010.

[0237] With particular reference to Figure 43, the traction biasing mechanism 1078 is depicted as being composed of a pawl 1116 that has a distally projecting narrow tip 1118 and a rightwardly projecting lateral pin 1120 at its proximal end that is rotatably inserted through a hole 1076 in the upper portion 230 of the firing trigger 20. On the right side of the firing trigger 20 the lateral pin 1120 receives a biasing member, depicted as biasing wheel 1122. As the firing trigger 20 translates fore and aft, the biasing wheel 1122 traverses an arc proximate to the right half piece 59 of the handle 6, overrunning at its distal portion of travel a biasing ramp 1124 integrally formed in the right half piece 59. The biasing wheel 1122 may advantageously be formed from a resilient, frictional material that induces a counterclockwise rotation (when viewed from the left) into the lateral pin 1120 of the pawl 1116, thus traction biasing the distally projecting narrow tip 1118 downward into a ramped central track 1075 of the nearest link 1072a-d to engage the linked rack 1074.

[0238] As the firing trigger 20 is released, the biasing wheel 1122 thus tractionally biases the pawl 1116 in the opposite direction, raising the narrow tip 1118 from the ramped central track 1075 of the linked rack 1074. To ensure disengagement of the tip 1118 under high load conditions and at nearly full distal travel of the pawl 1116, the right side of the pawl 1116 ramps up onto a proximally and upwardly facing beveled surface 1126 on the rightside of the closure yoke 250 to disengage the narrow tip 1118 from the ramped central track 1075. If the firing trigger 20 is released at any point other than full travel, the biasing wheel 1122 is used to lift the narrow tip 1118 from the ramped central track 1075. Whereas a biasing wheel 1122 is depicted, it should be appreciated that the shape of the biasing member or wheel 1122 is illustrative and may be varied to accommodate a variety of shapes that use friction or traction to engage or disengage the firing of the end effector 12.

[0239] Various embodiments of the surgical instrument 10 have the capability to record instrument conditions at one or more times during use. Figure 44 shows a block diagram of a system 2000 for recording conditions of the instrument 10. It will be appreciated that the system 2000 may be implemented in embodiments of the instrument 10 having motorized or motor-assisted firing, for example, as described above with reference to Figures 1-40, as well as embodiments of the instrument 10 having mechanically actuated firing, for example, as described above with reference to figures 41-43.

[0240] The system 2000 may include various sensors 2002, 2004, 2006, 2008, 2010, 2012 for sensing instrument conditions. The sensors may be positioned, for example, on or within the instrument 10. In various embodiments, the sensors may be dedicated sensors that provide output only for the system 2000, or may be dual-use sensors that perform other functions with in the instrument 10. For example, sensors 110, 130, 142 described above may be configured to also provide output to the system 2000.

[0241] Directly or indirectly, each sensor provides a signal to the memory device 2001, which records the signals as described in more detail below. The memory device 2001 may be any kind of device capable of storing or recording sensor signals. For example, the memory device 2001 may include a microprocessor, an Electrically Erasable Programmable Read Only Memory (EEPROM), or any other suitable storage device. The memory device 2001 may record the signals provided by the sensors in any suitable way. For example, in one embodiment, the memory device 2001 may record the signal from a particular sensor when that signal changes states. In another embodiment, the memory device 2001 may record a state of the system 2000, *e.g.*, the signals from all of the sensors included in the system 2000, when the signal from any sensor changes states. This may provide a snap-shot

of the state of the instrument 10. In various embodiments, the memory device 2001 and/or sensors may be implemented to include 1-WIRE bus products available from DALLAS SEMICONDUCTOR such as, for example, a 1-WIRE EEPROM.

[0242] In various embodiments, the memory device 2001 is externally accessible, allowing an outside device, such as a computer, to access the instrument conditions recorded by the memory device 2001. For example, the memory device 2001 may include a data port 2020. The data port 2020 may provide the stored instrument conditions according to any wired or wireless communication protocol in, for example, serial or parallel format. The memory device 2001 may also include a removable medium 2021 in addition to or instead of the output port 2020. The removable medium 2021 may be any kind of suitable data storage device that can be removed from the instrument 10. For example, the removable medium 2021 may include any suitable kind of flash memory, such as a Personal Computer Memory Card International Association (PCMCIA) card, a COMPACTFLASH card, a MULTIMEDIA card, a FLASHMEDIA card, *etc.* The removable medium 2021 may also include any suitable kind of disk-based storage including, for example, a portable hard drive, a compact disk (CD), a digital video disk (DVD), *etc.*

[0243] The closure trigger sensor 2002 senses a condition of the closure trigger 18. Figures 45 and 46 show an exemplary embodiment of the closure trigger sensor 2002. In Figures 45 and 46, the closure trigger sensor 2002 is positioned between the closure trigger 18 and closure pivot pin 252. It will be appreciated that pulling the closure trigger 18 toward the pistol grip 26 causes the closure trigger 18 to exert a force on the closure pivot pin 252. The sensor 2002 may be sensitive to this force, and generate a signal in response thereto, for example, as described above with respect to sensor 110 and Figures 10A and 10B. In various embodiments, the closure trigger sensor 2002 may be a digital sensor that indicates only whether the closure trigger 18 is actuated or not actuated. In other various embodiments, the closure trigger sensor 2002 may be an analog sensor that indicates the force exerted on the closure trigger 18 and/or the position of the closure trigger 18. If the closure trigger sensor 2002 is an analog sensor, an analog-to-digital converter may be logically positioned between the sensor 2002 and the memory device 2001. Also, it will be appreciated that the closure trigger sensor 2002 may take any suitable form and be placed at any suitable location that allows sensing of the condition of the closure trigger.

[0244] The anvil closure sensor 2004 may sense whether the anvil 24 is closed. Figure 47 shows an exemplary anvil closure sensor 2004. The sensor 2004 is positioned next to, or within the kidney shaped openings 1006 of the staple channel 22 as shown. As the anvil 24 is

closed, anvil pivot pins 25 slides through the kidney shaped openings 1006 and into contact with the sensor 2004, causing the sensor 2004 to generate a signal indicating that the anvil 24 is closed. The sensor 2004 may be any suitable kind of digital or analog sensor including a proximity sensor, *etc.* It will be appreciated that when the anvil closure sensor 2004 is an analog sensor, an analog-to-digital converter may be included logically between the sensor 2004 and the memory device 2001.

[0245] Anvil closure load sensor 2006 is shown placed on an inside bottom surface of the staple channel 22. In use, the sensor 2006 may be in contact with a bottom side of the staple cartridge 34 (not shown in Figure 46). As the anvil 24 is closed, it exerts a force on the staple cartridge 34 which is transferred to the sensor 2006. In response, the sensor 2006 generates a signal. The signal may be an analog signal proportional to the force exerted on the sensor 2006 by the staple cartridge 34 and due to the closing of the anvil 24. Referring the Figure 44, the analog signal may be provided to an analog-to-digital converter 2014, which converts the analog signal to a digital signal before providing it to the memory device 2001. It will be appreciated that embodiments where the sensor 2006 is a digital or binary sensor may not include analog-to-digital converter 2014.

[0246] The firing trigger sensor 110 senses the position and/or state of the firing trigger 20. In motorized or motor-assisted embodiments of the instrument, the firing trigger sensor may double as the run motor sensor 110 described above. In addition, the firing trigger sensor 110 may take any of the forms described above, and may be analog or digital. Figures 45 and 46 show an additional embodiment of the firing trigger sensor 110. In Figures 45 and 46, the firing trigger sensor is mounted between firing trigger 20 and firing trigger pivot pin 96. When firing trigger 20 is pulled, it will exert a force on firing trigger pivot pin 96 that is sensed by the sensor 110. Referring to Figure 44, in embodiments where the output of the firing trigger sensor 110 is analog, analog-to-digital converter 2016 is included logically between the firing trigger sensor 110 and the memory device 2001.

[0247] The knife position sensor 2008 senses the position of the knife 32 or cutting surface 1027 within the staple channel 22. Figures 47 and 48 show embodiments of a knife position sensor 2008 that are suitable for use with the mechanically actuated shaft 8 and end effector 12 shown in Figure 41. The sensor 2008 includes a magnet 2009 coupled to the firing bar 1022 of the instrument 10. A coil 2011 is positioned around the firing bar 1022, and may be installed; for example, along the longitudinal recess 1014 of the firing trough member 1012 (see Figure 41). As the knife 32 and cutting surface 1027 are reciprocated through the staple channel 22, the firing bar 1022 and magnet 2009 may move back and forth through the coil

2011. This motion relative to the coil induces a voltage in the coil proportional to the position of the firing rod within the coil and the cutting edge 1027 within the staple channel 22. This voltage may be provided to the memory device 2001, for example, via analog-to-digital converter 2018.

[0248] In various embodiments, the knife position sensor 2008 may instead be implemented as a series of digital sensors (not shown) placed at various positions on or within the shaft 8. The digital sensors may sense a feature of the firing bar 1022 such as, for example, magnet 2009, as the feature reciprocates through the shaft 8. The position of the firing bar 1022 within the shaft 8, and by extension, the position of the knife 32 within the staple channel 22, may be approximated as the position of the last digital sensor tripped.

[0249] It will be appreciated that the knife position may also be sensed in embodiments of the instrument 10 having a rotary driven end effector 12 and shaft 8, for example, as described above, with reference to Figures 3-6. An encoder, such as encoder 268, may be configured to generate a signal proportional to the rotation of the helical screw shaft 36, or any other drive shaft or gear. Because the rotation of the shaft 36 and other drive shafts and gears is proportional to the movement of the knife 32 through the channel 22, the signal generated by the encoder 268 is also proportional to the movement of the knife 32. Thus, the output of the encoder 268 may be provided to the memory device 2001.

[0250] The cartridge present sensor 2010 may sense the presence of the staple cartridge 34 within the staple channel 22. In motorized or motor-assisted instruments, the cartridge present sensor 2010 may double as the cartridge lock-out sensor 136 described above with reference to Figure 11. Figures 50 and 51 show an embodiment of the cartridge present sensor 2010. In the embodiment shown, the cartridge present sensor 2010 includes two contacts, 2011 and 2013. When no cartridge 34 is present, the contacts 2011, 2013 form an open circuit. When a cartridge 34 is present, the cartridge tray 1028 of the staple cartridge 34 contacts the contacts 2011, 2013, a closed circuit is formed. When the circuit is open, the sensor 2010 may output a logic zero. When the circuit is closed, the sensor 2010 may output a logic one. The output of the sensor 2010 is provided to memory device 2001, as shown in Figure 44.

[0251] The cartridge condition sensor 2012 may indicate whether a cartridge 34 installed within the staple channel 22 has been fired or spent. As the knife 32 is translated through the end effector 12, it pushes the sled 33, which fires the staple cartridge. Then the knife 32 is translated back to its original position, leaving the sled 33 at the distal end of the cartridge. Without the sled 33 to guide it, the knife 32 may fall into lock-out pocket 2022. Sensor 2012

may sense whether the knife 32 is present in the lock-out pocket 2022, which indirectly indicates whether the cartridge 34 has been spent. It will be appreciated that in various embodiments, sensor 2012 may directly sense the presence of the sled at the proximate end of the cartridge 34, thus eliminating the need for the knife 32 to fall into the lock-out pocket 2022.

[0252] Figures 52A and 52B depict a process flow 2200 for operating embodiments of the surgical instrument 10 configured as an endocutter and having the capability to record instrument conditions according to various embodiments. At box 2202, the anvil 24 of the instrument 10 may be closed. This causes the closure trigger sensor 2002 and/or the anvil closure sensor 2006 to change state. In response, the memory device 2001 may record the state of all of the sensors in the system 2000 at box 2203. At box 2204, the instrument 10 may be inserted into a patient. When the instrument is inserted, the anvil 24 may be opened and closed at box 2206, for example, to manipulate tissue at the surgical site. Each opening and closing of the anvil 24 causes the closure trigger sensor 2002 and/or the anvil closure sensor 2004 to change state. In response, the memory device 2001 records the state of the system 2000 at box 2205.

[0253] At box 2208, tissue is clamped for cutting and stapling. If the anvil 24 is not closed at decision block 2210, continued clamping is required. If the anvil 24 is closed, then the sensors 2002, 2004 and/or 2006 may change state, prompting the memory device 2001 to record the state of the system at box 2213. This recording may include a closure pressure received from sensor 2006. At box 2212, cutting and stapling may occur. Firing trigger sensor 110 may change state as the firing trigger 20 is pulled toward the pistol grip 26. Also, as the knife 32 moves through the staple channel 22, knife position sensor 2008 will change state. In response, the memory device 2001 may record the state of the system 2000 at box 2013.

[0254] When the cutting and stapling operations are complete, the knife 32 may return to a pre-firing position. Because the cartridge 34 has now been fired, the knife 32 may fall into lock-out pocket 2022, changing the state of cartridge condition sensor 2012 and triggering the memory device 2001 to record the state of the system 2000 at box 2015. The anvil 24 may then be opened to clear the tissue. This may cause one or more of the closure trigger sensor 2002, anvil closure sensor 2004 and anvil closure load sensor 2006 to change state, resulting in a recordation of the state of the system 2000 at box 2017. After the tissue is cleared, the anvil 24 may be again closed at box 2220. This causes another state change for at least sensors 2002 and 2004, which in turn causes the memory device 2001 to record the state of

the system at box 2019. Then the instrument 10 may be removed from the patient at box 2222.

[0255] If the instrument 10 is to be used again during the same procedure, the anvil may be opened at box 2224, triggering another recordation of the system state at box 2223. The spent cartridge 34 may be removed from the end effector 12 at box 2226. This causes cartridge present sensor 2010 to change state and cause a recordation of the system state at box 2225. Another cartridge 34 may be inserted at box 2228. This causes a state change in the cartridge present sensor 2010 and a recordation of the system state at box 2227. If the other cartridge 34 is a new cartridge, indicated at decision block 2230, its insertion may also cause a state change to cartridge condition sensor 2012. In that case, the system state may be recorded at box 2231.

[0256] Figure 53 shows an exemplary memory map 2300 from the memory device 2001 according to various embodiments. The memory map 2300 includes a series of columns 2302, 2304, 2306, 2308, 2310, 2312, 2314, 2316 and rows (not labeled). Column 2302 shows an event number for each of the rows. The other columns represent the output of one sensor of the system 2000. All of the sensor readings recorded at a given time may be recorded in the same row under the same event number. Hence, each row represents an instance where one or more of the signals from the sensors of the system 2000 are recorded.

[0257] Column 2304 lists the closure load recorded at each event. This may reflect the output of anvil closure load sensor 2006. Column 2306 lists the firing stroke position. This may be derived from the knife position sensor 2008. For example, the total travel of the knife 32 may be divided into partitions. The number listed in column 2306 may represent the partition where the knife 32 is currently present. The firing load is listed in column 2308. This may be derived from the firing trigger sensor 110. The knife position is listed at column 2310. The knife position may be derived from the knife position sensor 2008 similar to the firing stroke. Whether the anvil 24 is open or closed may be listed at column 2312. This value may be derived from the output of the anvil closure sensor 2004 and/or the anvil closure load sensor 2006. Whether the sled 33 is present, or whether the cartridge 34 is spent, may be indicated at column 2314. This value may be derived from the cartridge condition sensor 2012. Finally, whether the cartridge 34 is present may be indicated a column 2316. This value may be derived from cartridge present sensor 2010. It will be appreciated that various other values may be stored at memory device 2001 including, for example, the end and beginning of firing strokes, for example, as measured by sensors 130, 142.

[0258] While the present invention has been illustrated by description of several embodiments and while the illustrative embodiments have been described in considerable detail, it is not the intention of the applicant to restrict or in any way limit the scope of the appended claims to such detail. Additional advantages and modifications may readily appear to those skilled in the art.

[0259] For example, although the embodiments described above have advantages for an endoscopically employed surgical severing and stapling instrument 100, a similar embodiments may be used in other clinical procedures. It is generally accepted that endoscopic procedures are more common than laparoscopic procedures. Accordingly, the present invention has been discussed in terms of endoscopic procedures and apparatus. However, use herein of terms such as "endoscopic", should not be construed to limit the present invention to a surgical instrument for use only in conjunction with an endoscopic tube (i.e., trocar). On the contrary, it is believed that the present invention may find use in any procedure where access is limited to a small incision, including but not limited to laparoscopic procedures, as well as open procedures.

[0260] Any patent, publication, or information, in whole or in part, that is said to be incorporated by reference herein is incorporated herein only to the extent that the incorporated material does not conflict with existing definitions, statements, or other disclosure material set forth in this document. As such the disclosure as explicitly set forth herein supersedes any conflicting material incorporated herein by reference.

[0261] Over the years a variety of minimally invasive robotic (or "telesurgical") systems have been developed to increase surgical dexterity as well as to permit a surgeon to operate on a patient in an intuitive manner. Many of such systems are disclosed in the following U.S. Patents which are each herein incorporated by reference in their respective entirety: U.S. Pat. No. 5,792,135, entitled "Articulated Surgical Instrument For Performing Minimally Invasive Surgery With Enhanced Dexterity and Sensitivity", U.S. Patent No. 6,231,565, entitled "Robotic Arm DLUS For Performing Surgical Tasks", U.S. Patent No. 6,783,524, entitled "Robotic Surgical Tool With Ultrasound Cauterizing and Cutting Instrument", U.S. Patent No. 6,364,888, entitled "Alignment of Master and Slave In a Minimally Invasive Surgical Apparatus", U.S. Patent No. 7,524,320, entitled "Mechanical Actuator Interface System For Robotic Surgical Tools", U.S. Patent No. 7,691,098, entitled Platform Link Wrist Mechanism", U.S. Patent No. 7,806,891, entitled "Repositioning and Reorientation of Master/Slave Relationship in Minimally Invasive Telesurgery", and U.S. Patent No.

7,824,401, entitled “Surgical Tool With Writed Monopolar Electrosurgical End Effectors”. Many of such systems, however, have in the past been unable to generate the magnitude of forces required to effectively cut and fasten tissue.

[0262] FIG. 54 depicts one version of a master controller 11001 that may be used in connection with a robotic arm slave cart 11100 of the type depicted in FIG. 55. Master controller 11001 and robotic arm slave cart 11100, as well as their respective components and control systems are collectively referred to herein as a robotic system 11000. Examples of such systems and devices are disclosed in U.S. Patent No. 7,524,320 which has been herein incorporated by reference. Thus, various details of such devices will not be described in detail herein beyond that which may be necessary to understand various embodiments and forms of the present invention. As is known, the master controller 11001 generally includes master controllers (generally represented as 11003 in FIG. 54) which are grasped by the surgeon and manipulated in space while the surgeon views the procedure via a stereo display 11002. The master controllers 11001 generally comprise manual input devices which preferably move with multiple degrees of freedom, and which often further have an actuatable handle for actuating tools (for example, for closing grasping saws, applying an electrical potential to an electrode, or the like).

[0263] As can be seen in FIG. 55, in one form, the robotic arm cart 11100 is configured to actuate a plurality of surgical tools, generally designated as 11200. Various robotic surgery systems and methods employing master controller and robotic arm cart arrangements are disclosed in U.S. Patent No. 6,132,368, entitled “Multi-Component Telepresence System and Method”, the full disclosure of which is incorporated herein by reference. In various forms, the robotic arm cart 11100 includes a base 11002 from which, in the illustrated embodiment, three surgical tools 11200 are supported. In various forms, the surgical tools 11200 are each supported by a series of manually articulatable linkages, generally referred to as set-up joints 11104, and a robotic manipulator 11106. These structures are herein illustrated with protective covers extending over much of the robotic linkage. These protective covers may be optional, and may be limited in size or entirely eliminated in some embodiments to minimize the inertia that is encountered by the servo mechanisms used to manipulate such devices, to limit the volume of moving components so as to avoid collisions, and to limit the overall weight of the cart 11100. Cart 11100 will generally have dimensions suitable for transporting the cart 11100 between operating rooms. The cart 11100 may be configured to typically fit through standard operating room doors and onto standard hospital elevators. In

various forms, the cart 11100 would preferably have a weight and include a wheel (or other transportation) system that allows the cart 11100 to be positioned adjacent an operating table by a single attendant.

[0264] Referring now to FIG. 56, in at least one form, robotic manipulators 11106 may include a linkage 11108 that constrains movement of the surgical tool 11200. In various embodiments, linkage 11108 includes rigid links coupled together by rotational joints in a parallelogram arrangement so that the surgical tool 11200 rotates around a point in space 11110, as more fully described in issued U.S. Pat. No. 5,817,084, the full disclosure of which is herein incorporated by reference. The parallelogram arrangement constrains rotation to pivoting about an axis 11112a, sometimes called the pitch axis. The links supporting the parallelogram linkage are pivotally mounted to set-up joints 11104 (FIG. 55) so that the surgical tool 11200 further rotates about an axis 11112b, sometimes called the yaw axis. The pitch and yaw axes 11112a, 11112b intersect at the remote center 11114, which is aligned along a shaft 11208 of the surgical tool 11200. The surgical tool 11200 may have further degrees of driven freedom as supported by manipulator 11106, including sliding motion of the surgical tool 11200 along the longitudinal tool axis "LT-LT". As the surgical tool 11200 slides along the tool axis LT-LT relative to manipulator 11106 (arrow 11112c), remote center 11114 remains fixed relative to base 11116 of manipulator 11106. Hence, the entire manipulator is generally moved to re-position remote center 11114. Linkage 11108 of manipulator 11106 is driven by a series of motors 11120. These motors actively move linkage 11108 in response to commands from a processor of a control system. As will be discussed in further detail below, motors 11120 are also employed to manipulate the surgical tool 11200.

[0265] An alternative set-up joint structure is illustrated in FIG. 57. In this embodiment, a surgical tool 11200 is supported by an alternative manipulator structure 11106' between two tissue manipulation tools. Those of ordinary skill in the art will appreciate that various embodiments of the present invention may incorporate a wide variety of alternative robotic structures, including those described in U.S. Pat. No. 5,878,193, entitled "Automated Endoscope System For Optimal Positioning", the full disclosure of which is incorporated herein by reference. Additionally, while the data communication between a robotic component and the processor of the robotic surgical system is primarily described herein with reference to communication between the surgical tool 11200 and the master controller 11001, it should be understood that similar communication may take place between circuitry of a

manipulator, a set-up joint, an endoscope or other image capture device, or the like, and the processor of the robotic surgical system for component compatibility verification, component-type identification, component calibration (such as off-set or the like) communication, confirmation of coupling of the component to the robotic surgical system, or the like.

[0266] An exemplary non-limiting surgical tool 11200 that is well-adapted for use with a robotic system 11000 that has a tool drive assembly 11010 (FIG. 59) that is operatively coupled to a master controller 11001 that is operable by inputs from an operator (i.e., a surgeon) is depicted in FIG. 58. As can be seen in that Figure, the surgical tool 11200 includes a surgical end effector 12012 that comprises an endocutter. In at least one form, the surgical tool 11200 generally includes an elongated shaft assembly 12008 that has a proximal closure tube 12040 and a distal closure tube 12042 that are coupled together by an articulation joint 12011. The surgical tool 11200 is operably coupled to the manipulator by a tool mounting portion, generally designated as 11300. The surgical tool 11200 further includes an interface 11230 which mechanically and electrically couples the tool mounting portion 11300 to the manipulator. One form of interface 11230 is illustrated in FIGS. 59-63. In various embodiments, the tool mounting portion 11300 includes a tool mounting plate 11302 that operably supports a plurality of (four are shown in FIG. 63) rotatable body portions, driven discs or elements 11304, that each include a pair of pins 11306 that extend from a surface of the driven element 11304. One pin 11306 is closer to an axis of rotation of each driven element 11304 than the other pin 11306 on the same driven element 11304, which helps to ensure positive angular alignment of the driven element 11304. Interface 11230 includes an adaptor portion 11240 that is configured to mountingly engage the mounting plate 11302 as will be further discussed below. The adaptor portion 11240 may include an array of electrical connecting pins 11242 (FIG. 61) which may be coupled to a memory structure by a circuit board within the tool mounting portion 11300. While interface 11230 is described herein with reference to mechanical, electrical, and magnetic coupling elements, it should be understood that a wide variety of telemetry modalities might be used, including infrared, inductive coupling, or the like.

[0267] As can be seen in FIGS. 59-62, the adaptor portion 11240 generally includes a tool side 11244 and a holder side 11246. In various forms, a plurality of rotatable bodies 11250 are mounted to a floating plate 11248 which has a limited range of movement relative to the surrounding adaptor structure normal to the major surfaces of the adaptor 11240. Axial

movement of the floating plate 11248 helps decouple the rotatable bodies 11250 from the tool mounting portion 11300 when the levers 11303 along the sides of the tool mounting portion housing 11301 are actuated (See FIG. 58). Other mechanisms/arrangements may be employed for releasably coupling the tool mounting portion 11300 to the adaptor 11240. In at least one form, rotatable bodies 11250 are resiliently mounted to floating plate 11248 by resilient radial members which extend into a circumferential indentation about the rotatable bodies 1250. The rotatable bodies 11250 can move axially relative to plate 11248 by deflection of these resilient structures. When disposed in a first axial position (toward tool side 11244) the rotatable bodies 11250 are free to rotate without angular limitation. However, as the rotatable bodies 11250 move axially toward tool side 11244, tabs 11252 (extending radially from the rotatable bodies 11250) laterally engage detents on the floating plates so as to limit angular rotation of the rotatable bodies 11250 about their axes. This limited rotation can be used to help drivingly engage the rotatable bodies 11250 with drive pins 11272 of a corresponding tool holder portion 11270 of the robotic system 11000, as the drive pins 11272 will push the rotatable bodies 11250 into the limited rotation position until the pins 11234 are aligned with (and slide into) openings 11256'. Openings 11256 on the tool side 11244 and openings 11256' on the holder side 11246 of rotatable bodies 11250 are configured to accurately align the driven elements 11304 (FIG. 63) of the tool mounting portion 11300 with the drive elements 11271 of the tool holder 11270. As described above regarding inner and outer pins 11306 of driven elements 11304, the openings 11256, 11256' are at differing distances from the axis of rotation on their respective rotatable bodies 11250 so as to ensure that the alignment is not 180 degrees from its intended position. Additionally, each of the openings 11256 is slightly radially elongated so as to fittingly receive the pins 11306 in the circumferential orientation. This allows the pins 11306 to slide radially within the openings 11256, 11256' and accommodate some axial misalignment between the tool 11200 and tool holder 11270, while minimizing any angular misalignment and backlash between the drive and driven elements. Openings 11256 on the tool side 11244 are offset by about 90 degrees from the openings 11256' (shown in broken lines) on the holder side 11246, as can be seen most clearly in FIG. 62.

[0268] Various embodiments may further include an array of electrical connector pins 11242 located on holder side 11246 of adaptor 11240, and the tool side 11244 of the adaptor 11240 may include slots 11258 (FIG. 62) for receiving a pin array (not shown) from the tool mounting portion 11300. In addition to transmitting electrical signals between the surgical

tool 11200 and the tool holder 11270, at least some of these electrical connections may be coupled to an adaptor memory device 11260 (FIG. 61) by a circuit board of the adaptor 11240.

[0269] A detachable latch arrangement 11239 may be employed to releasably affix the adaptor 11240 to the tool holder 11270. As used herein, the term “tool drive assembly” when used in the context of the robotic system 11000, at least encompasses various embodiments of the adaptor 11240 and tool holder 11270 and which has been generally designated as 11010 in FIG. 59. For example, as can be seen in FIG. 59, the tool holder 11270 may include a first latch pin arrangement 11274 that is sized to be received in corresponding clevis slots 11241 provided in the adaptor 11240. In addition, the tool holder 11270 may further have second latch pins 11276 that are sized to be retained in corresponding latch clevises 11243 in the adaptor 11240. See FIG. 61. In at least one form, a latch assembly 11245 is movably supported on the adaptor 11240 and is biasable between a first latched position wherein the latch pins 11276 are retained within their respective latch clevis 11243 and an unlatched position wherein the second latch pins 11276 may be into or removed from the latch clevises 11243. A spring or springs (not shown) are employed to bias the latch assembly into the latched position. A lip on the tool side 11244 of adaptor 11240 may slidably receive laterally extending tabs of tool mounting housing 11301.

[0270] Turning next to FIGS. 63-70, in at least one embodiment, the surgical tool 11200 includes a surgical end effector 12012 that comprises in this example, among other things, at least one component 12024 that is selectively movable between first and second positions relative to at least one other component 12022 in response to various control motions applied thereto as will be discussed in further detail below. In various embodiments, component 12022 comprises an elongated channel 12022 configured to operably support a surgical staple cartridge 12034 therein and component 12024 comprises a pivotally translatable clamping member, such as an anvil 12024. Various embodiments of the surgical end effector 12012 are configured to maintain the anvil 12024 and elongated channel 12022 at a spacing that assures effective stapling and severing of tissue clamped in the surgical end effector 12012. As can be seen in FIG. 69, the surgical end effector 12012 further includes a cutting instrument 12032 and a sled 12033. The cutting instrument 12032 may be, for example, a knife. The surgical staple cartridge 12034 operably houses a plurality of surgical staples (not shown) therein that are supported on movable staple drivers (not shown). As the cutting instrument 12032 is driven distally through a centrally-disposed slot (not shown) in the

surgical staple cartridge 12034, it forces the sled 12033 distally as well. As the sled 12033 is driven distally, its “wedge-shaped” configuration contacts the movable staple drivers and drives them vertically toward the closed anvil 12024. The surgical staples are formed as they are driven into the forming surface located on the underside of the anvil 12024. The sled 12033 may be part of the surgical staple cartridge 12034, such that when the cutting instrument 12032 is retracted following the cutting operation, the sled 12033 does not retract. The anvil 12024 may be pivotably opened and closed at a pivot point 12025 located at the proximal end of the elongated channel 12022. The anvil 12024 may also include a tab 12027 at its proximal end that interacts with a component of the mechanical closure system (described further below) to facilitate the opening of the anvil 12024. The elongated channel 12022 and the anvil 12024 may be made of an electrically conductive material (such as metal) so that they may serve as part of an antenna that communicates with sensor(s) in the end effector, as described above. The surgical staple cartridge 12034 could be made of a nonconductive material (such as plastic) and the sensor may be connected to or disposed in the surgical staple cartridge 12034, as was also described above.

[0271] As can be seen in FIGS. 63-70, the surgical end effector 12012 is attached to the tool mounting portion 11300 by an elongated shaft assembly 12008 according to various embodiments. As shown in the illustrated embodiment, the shaft assembly 12008 includes an articulation joint generally indicated as 12011 that enables the surgical end effector 12012 to be selectively articulated about an articulation axis AA-AA that is substantially transverse to a longitudinal tool axis LT-LT. See FIG. 64. In other embodiments, the articulation joint is omitted. In various embodiments, the shaft assembly 12008 may include a closure tube assembly 12009 that comprises a proximal closure tube 12040 and a distal closure tube 12042 that are pivotably linked by a pivot links 12044 and operably supported on a spine assembly generally depicted as 12049. In the illustrated embodiment, the spine assembly 12049 comprises a distal spine portion 12050 that is attached to the elongated channel 12022 and is pivotally coupled to the proximal spine portion 12052. The closure tube assembly 12009 is configured to axially slide on the spine assembly 12049 in response to actuation motions applied thereto. The distal closure tube 12042 includes an opening 12045 into which the tab 12027 on the anvil 12024 is inserted in order to facilitate opening of the anvil 12024 as the distal closure tube 12042 is moved axially in the proximal direction “PD”. The closure tubes 12040, 12042 may be made of electrically conductive material (such as metal) so that they may serve as part of the antenna, as described above. Components of the main drive shaft

assembly (e.g., the drive shafts 12048, 12050) may be made of a nonconductive material (such as plastic).

[0272] In use, it may be desirable to rotate the surgical end effector 12012 about the longitudinal tool axis LT-LT. In at least one embodiment, the tool mounting portion 11300 includes a rotational transmission assembly 12069 that is configured to receive a corresponding rotary output motion from the tool drive assembly 11010 of the robotic system 11000 and convert that rotary output motion to a rotary control motion for rotating the elongated shaft assembly 12008 (and surgical end effector 12012) about the longitudinal tool axis LT-LT. In various embodiments, for example, the proximal end 12060 of the proximal closure tube 12040 is rotatably supported on the tool mounting plate 11302 of the tool mounting portion 11300 by a forward support cradle 11309 and a closure sled 12100 that is also movably supported on the tool mounting plate 11302. In at least one form, the rotational transmission assembly 12069 includes a tube gear segment 12062 that is formed on (or attached to) the proximal end 12060 of the proximal closure tube 12040 for operable engagement by a rotational gear assembly 12070 that is operably supported on the tool mounting plate 11302. As can be seen in FIG. 66, the rotational gear assembly 12070, in at least one embodiment, comprises a rotation drive gear 12072 that is coupled to a corresponding first one of the driven discs or elements 11304 on the adapter side 11307 of the tool mounting plate 11302 when the tool mounting portion 11300 is coupled to the tool drive assembly 11010. See FIG. 63. The rotational gear assembly 12070 further comprises a rotary driven gear 12074 that is rotatably supported on the tool mounting plate 11302 in meshing engagement with the tube gear segment 12062 and the rotation drive gear 12072. Application of a first rotary output motion from the tool drive assembly 11010 of the robotic system 11000 to the corresponding driven element 11304 will thereby cause rotation of the rotation drive gear 12072. Rotation of the rotation drive gear 12072 ultimately results in the rotation of the elongated shaft assembly 12008 (and the surgical end effector 12012) about the longitudinal tool axis LT-LT (represented by arrow "R" in FIG. 66). It will be appreciated that the application of a rotary output motion from the tool drive assembly 11010 in one direction will result in the rotation of the elongated shaft assembly 12008 and surgical end effector 12012 about the longitudinal tool axis LT-LT in a first direction and an application of the rotary output motion in an opposite direction will result in the rotation of the elongated shaft assembly 12008 and surgical end effector 12012 in a second direction that is opposite to the first direction.

[0273] In at least one embodiment, the closure of the anvil 12024 relative to the staple cartridge 12034 is accomplished by axially moving the closure tube assembly 12009 in the distal direction “DD” on the spine assembly 12049. As indicated above, in various embodiments, the proximal end 12060 of the proximal closure tube 12040 is supported by the closure sled 12100 which comprises a portion of a closure transmission, generally depicted as 12099. In at least one form, the closure sled 12100 is configured to support the closure tube 12009 on the tool mounting plate 11320 such that the proximal closure tube 12040 can rotate relative to the closure sled 12100, yet travel axially with the closure sled 12100. In particular, as can be seen in FIG. 71, the closure sled 12100 has an upstanding tab 12101 that extends into a radial groove 12063 in the proximal end portion of the proximal closure tube 12040. In addition, as can be seen in FIGS. 68 and 71, the closure sled 12100 has a tab portion 12102 that extends through a slot 11305 in the tool mounting plate 11302. The tab portion 12102 is configured to retain the closure sled 12100 in sliding engagement with the tool mounting plate 11302. In various embodiments, the closure sled 12100 has an upstanding portion 12104 that has a closure rack gear 12106 formed thereon. The closure rack gear 12106 is configured for driving engagement with a closure gear assembly 12110. See FIG. 68.

[0274] In various forms, the closure gear assembly 12110 includes a closure spur gear 12112 that is coupled to a corresponding second one of the driven discs or elements 11304 on the adapter side 11307 of the tool mounting plate 11302. See FIG. 63. Thus, application of a second rotary output motion from the tool drive assembly 11010 of the robotic system 11000 to the corresponding second driven element 11304 will cause rotation of the closure spur gear 12112 when the tool mounting portion 11300 is coupled to the tool drive assembly 11010. The closure gear assembly 12110 further includes a closure reduction gear set 12114 that is supported in meshing engagement with the closure spur gear 12112. As can be seen in FIGS. 67 and 68, the closure reduction gear set 12114 includes a driven gear 12116 that is rotatably supported in meshing engagement with the closure spur gear 12112. The closure reduction gear set 12114 further includes a first closure drive gear 12118 that is in meshing engagement with a second closure drive gear 12120 that is rotatably supported on the tool mounting plate 11302 in meshing engagement with the closure rack gear 12106. Thus, application of a second rotary output motion from the tool drive assembly 11010 of the robotic system 11000 to the corresponding second driven element 11304 will cause rotation of the closure spur gear 12112 and the closure transmission 12110 and ultimately drive the closure sled 12100 and

closure tube assembly 12009 axially. The axial direction in which the closure tube assembly 12009 moves ultimately depends upon the direction in which the second driven element 11304 is rotated. For example, in response to one rotary output motion received from the tool drive assembly 11010 of the robotic system 11000, the closure sled 12100 will be driven in the distal direction "DD" and ultimately drive the closure tube assembly 11009 in the distal direction. As the distal closure tube 12042 is driven distally, the end of the closure tube segment 12042 will engage a portion of the anvil 12024 and cause the anvil 12024 to pivot to a closed position. Upon application of an "opening" out put motion from the tool drive assembly 11010 of the robotic system 11000, the closure sled 12100 and shaft assembly 12008 will be driven in the proximal direction "PD". As the distal closure tube 12042 is driven in the proximal direction, the opening 12045 therein interacts with the tab 12027 on the anvil 12024 to facilitate the opening thereof. In various embodiments, a spring (not shown) may be employed to bias the anvil to the open position when the distal closure tube 12042 has been moved to its starting position. In various embodiments, the various gears of the closure gear assembly 12110 are sized to generate the necessary closure forces needed to satisfactorily close the anvil 12024 onto the tissue to be cut and stapled by the surgical end effector 12012. For example, the gears of the closure transmission 12110 may be sized to generate approximately 70-120 pounds.

[0275] In various embodiments, the cutting instrument 12032 is driven through the surgical end effector 12012 by a knife bar 12200. See FIGS. 69 and 71. In at least one form, the knife bar 12200 may be fabricated from, for example, stainless steel or other similar material and has a substantially rectangular cross-sectional shape. Such knife bar configuration is sufficiently rigid to push the cutting instrument 12032 through tissue clamped in the surgical end effector 12012, while still being flexible enough to enable the surgical end effector 12012 to articulate relative to the proximal closure tube 12040 and the proximal spine portion 12052 about the articulation axis AA-AA as will be discussed in further detail below. As can be seen in FIGS. 72 and 73, the proximal spine portion 12052 has a rectangular-shaped passage 12054 extending therethrough to provide support to the knife bar 12200 as it is axially pushed therethrough. The proximal spine portion 12052 has a proximal end 12056 that is rotatably mounted to a spine mounting bracket 12057 attached to the tool mounting plate 11032. See Fig. 71. Such arrangement permits the proximal spine portion 12052 to rotate, but not move axially, within the proximal closure tube 12040.

[0276] As shown in FIG. 69, the distal end 12202 of the knife bar 12200 is attached to the cutting instrument 12032. The proximal end 12204 of the knife bar 12200 is rotatably affixed to a knife rack gear 12206 such that the knife bar 12200 is free to rotate relative to the knife rack gear 12206. See FIG. 71. As can be seen in FIGS. 65-70, the knife rack gear 12206 is slidably supported within a rack housing 12210 that is attached to the tool mounting plate 11302 such that the knife rack gear 12206 is retained in meshing engagement with a knife gear assembly 12220. More specifically and with reference to FIG. 68, in at least one embodiment, the knife gear assembly 12220 includes a knife spur gear 12222 that is coupled to a corresponding third one of the driven discs or elements 11304 on the adapter side 11307 of the tool mounting plate 11302. See FIG. 63. Thus, application of another rotary output motion from the robotic system 11000 through the tool drive assembly 11010 to the corresponding third driven element 11304 will cause rotation of the knife spur gear 12222. The knife gear assembly 12220 further includes a knife gear reduction set 12224 that includes a first knife driven gear 12226 and a second knife drive gear 12228. The knife gear reduction set 12224 is rotatably mounted to the tool mounting plate 11302 such that the first knife driven gear 12226 is in meshing engagement with the knife spur gear 12222. Likewise, the second knife drive gear 12228 is in meshing engagement with a third knife drive gear 12230 that is rotatably supported on the tool mounting plate 11302 in meshing engagement with the knife rack gear 12206. In various embodiments, the gears of the knife gear assembly 12220 are sized to generate the forces needed to drive the cutting element 12032 through the tissue clamped in the surgical end effector 12012 and actuate the staples therein. For example, the gears of the knife drive assembly 12230 may be sized to generate approximately 40 to 100 pounds. It will be appreciated that the application of a rotary output motion from the tool drive assembly 11010 in one direction will result in the axial movement of the cutting instrument 12032 in a distal direction and application of the rotary output motion in an opposite direction will result in the axial travel of the cutting instrument 12032 in a proximal direction.

[0277] In various embodiments, the surgical tool 11200 employs an articulation system 12007 that includes an articulation joint 12011 that enables the surgical end effector 12012 to be articulated about an articulation axis AA-AA that is substantially transverse to the longitudinal tool axis LT-LT. In at least one embodiment, the surgical tool 11200 includes first and second articulation bars 12250a, 12250b that are slidably supported within corresponding passages 12053 provided through the proximal spine portion 12052. See

FIGS. 71 and 73. In at least one form, the first and second articulation bars 12250a, 12250b are actuated by an articulation transmission generally designated as 12249 that is operably supported on the tool mounting plate 11032. Each of the articulation bars 12250a, 12250b has a proximal end 12252 that has a guide rod protruding therefrom which extend laterally through a corresponding slot in the proximal end portion of the proximal spine portion 12052 and into a corresponding arcuate slot in an articulation nut 12260 which comprises a portion of the articulation transmission. FIG. 72 illustrates articulation bar 12250a. It will be understood that articulation bar 12250b is similarly constructed. As can be seen in FIG. 72, for example, the articulation bar 12250a has a guide rod 12254 which extends laterally through a corresponding slot 12058 in the proximal end portion 12056 of the distal spine portion 12050 and into a corresponding arcuate slot 12262 in the articulation nut 12260. In addition, the articulation bar 12250a has a distal end 12251a that is pivotally coupled to the distal spine portion 12050 by, for example, a pin 12253a and articulation bar 12250b has a distal end 12251b that is pivotally coupled to the distal spine portion 12050 by, for example, a pin 12253b. In particular, the articulation bar 12250a is laterally offset in a first lateral direction from the longitudinal tool axis LT-LT and the articulation bar 12250b is laterally offset in a second lateral direction from the longitudinal tool axis LT-LT. Thus, axial movement of the articulation bars 12250a and 12250b in opposing directions will result in the articulation of the distal spine portion 12050 as well as the surgical end effector 12012 attached thereto about the articulation axis AA-AA as will be discussed in further detail below.

[0278] Articulation of the surgical end effector 12012 is controlled by rotating the articulation nut 12260 about the longitudinal tool axis LT-LT. The articulation nut 12260 is rotatably journaled on the proximal end portion 12056 of the distal spine portion 12050 and is rotatably driven thereon by an articulation gear assembly 12270. More specifically and with reference to FIG. 66, in at least one embodiment, the articulation gear assembly 12270 includes an articulation spur gear 12272 that is coupled to a corresponding fourth one of the driven discs or elements 11304 on the adapter side 11307 of the tool mounting plate 11302. See FIG. 63. Thus, application of another rotary input motion from the robotic system 11000 through the tool drive assembly 11010 to the corresponding fourth driven element 11304 will cause rotation of the articulation spur gear 12272 when the interface 11230 is coupled to the tool holder 11270. An articulation drive gear 12274 is rotatably supported on the tool mounting plate 11302 in meshing engagement with the articulation spur gear 12272 and a

gear portion 12264 of the articulation nut 12260 as shown. As can be seen in FIGS. 71 and 72, the articulation nut 12260 has a shoulder 12266 formed thereon that defines an annular groove 12267 for receiving retaining posts 12268 therein. Retaining posts 12268 are attached to the tool mounting plate 11302 and serve to prevent the articulation nut 12260 from moving axially on the proximal spine portion 12052 while maintaining the ability to be rotated relative thereto. Thus, rotation of the articulation nut 12260 in a first direction, will result in the axial movement of the articulation bar 12250a in a distal direction "DD" and the axial movement of the articulation bar 12250b in a proximal direction "PD" because of the interaction of the guide rods 12254 with the spiral slots 12262 in the articulation gear 12260. Similarly, rotation of the articulation nut 12260 in a second direction that is opposite to the first direction will result in the axial movement of the articulation bar 12250a in the proximal direction "PD" as well as cause articulation bar 2250b to axially move in the distal direction "DD". Thus, the surgical end effector 12012 may be selectively articulated about articulation axis "AA-AA" in a first direction "FD" by simultaneously moving the articulation bar 12250a in the distal direction "DD" and the articulation bar 12250b in the proximal direction "PD". Likewise, the surgical end effector 12012 may be selectively articulated about the articulation axis "AA-AA" in a second direction "SD" by simultaneously moving the articulation bar 12250a in the proximal direction "PD" and the articulation bar 12250b in the distal direction "DD." See FIG. 64.

[0279] The tool embodiment described above employs an interface arrangement that is particularly well-suited for mounting the robotically controllable medical tool onto at least one form of robotic arm arrangement that generates at least four different rotary control motions. Those of ordinary skill in the art will appreciate that such rotary output motions may be selectively controlled through the programmable control systems employed by the robotic system/controller. For example, the tool arrangement described above may be well-suited for use with those robotic systems manufactured by Intuitive Surgical, Inc. of Sunnyvale, California, U.S.A., many of which may be described in detail in various patents incorporated herein by reference. The unique and novel aspects of various embodiments of the present invention serve to utilize the rotary output motions supplied by the robotic system to generate specific control motions having sufficient magnitudes that enable end effectors to cut and staple tissue. Thus, the unique arrangements and principles of various embodiments of the present invention may enable a variety of different forms of the tool systems disclosed and claimed herein to be effectively employed in connection with other types and forms of

robotic systems that supply programmed rotary or other output motions. In addition, as will become further apparent as the present Detailed Description proceeds, various end effector embodiments of the present invention that require other forms of actuation motions may also be effectively actuated utilizing one or more of the control motions generated by the robotic system.

[0280] FIGS. 75-79 illustrate yet another surgical tool 12300 that may be effectively employed in connection with the robotic system 11000 that has a tool drive assembly that is operably coupled to a controller of the robotic system that is operable by inputs from an operator and which is configured to provide at least one rotary output motion to at least one rotatable body portion supported on the tool drive assembly. In various forms, the surgical tool 12300 includes a surgical end effector 12312 that includes an elongated channel 12322 and a pivotally translatable clamping member, such as an anvil 12324, which are maintained at a spacing that assures effective stapling and severing of tissue clamped in the surgical end effector 12312. As shown in the illustrated embodiment, the surgical end effector 12312 may include, in addition to the previously-mentioned elongated channel 12322 and anvil 12324, a cutting instrument 12332 that has a sled portion 12333 formed thereon, a surgical staple cartridge 12334 that is seated in the elongated channel 12322, and a rotary end effector drive shaft 12336 that has a helical screw thread formed thereon. The cutting instrument 12332 may be, for example, a knife. As will be discussed in further detail below, rotation of the end effector drive shaft 12336 will cause the cutting instrument 12332 and sled portion 12333 to axially travel through the surgical staple cartridge 2334 to move between a starting position and an ending position. The direction of axial travel of the cutting instrument 12332 depends upon the direction in which the end effector drive shaft 12336 is rotated. The anvil 12324 may be pivotably opened and closed at a pivot point 12325 connected to the proximate end of the elongated channel 12322. The anvil 12324 may also include a tab 12327 at its proximate end that operably interfaces with a component of the mechanical closure system (described further below) to open and close the anvil 12324. When the end effector drive shaft 12336 is rotated, the cutting instrument 12332 and sled 12333 will travel longitudinally through the surgical staple cartridge 12334 from the starting position to the ending position, thereby cutting tissue clamped within the surgical end effector 12312. The movement of the sled 12333 through the surgical staple cartridge 12334 causes the staples therein to be driven through the severed tissue and against the closed anvil 12324, which turns the staples to fasten the severed tissue. In one form, the elongated channel 12322 and the anvil 12324 may

be made of an electrically conductive material (such as metal) so that they may serve as part of the antenna that communicates with sensor(s) in the end effector, as described above. The surgical staple cartridge 12334 could be made of a nonconductive material (such as plastic) and the sensor may be connected to or disposed in the surgical staple cartridge 12334, as described above.

[0281] It should be noted that although the embodiments of the surgical tool 12300 described herein employ a surgical end effector 12312 that staples the severed tissue, in other embodiments different techniques for fastening or sealing the severed tissue may be used. For example, end effectors that use RF energy or adhesives to fasten the severed tissue may also be used. U.S. Patent No. 5,709,680, entitled “Electrosurgical Hemostatic Device” to Yates et al., and U.S. Patent No. 5,688,270, entitled “Electrosurgical Hemostatic Device With Recessed And/Or Offset Electrodes” to Yates et al., which are incorporated herein by reference, discloses cutting instruments that use RF energy to fasten the severed tissue. U.S. Patent Application Serial No. 11/267,811 to Morgan et al. and U.S. Patent Application Serial No. 11/267,363 to Shelton et al., which are also incorporated herein by reference, disclose cutting instruments that use adhesives to fasten the severed tissue. Accordingly, although the description herein refers to cutting/stapling operations and the like, it should be recognized that this is an exemplary embodiment and is not meant to be limiting. Other tissue-fastening techniques may also be used.

[0282] In the illustrated embodiment, the surgical end effector 12312 is coupled to an elongated shaft assembly 12308 that is coupled to a tool mounting portion 12460 and defines a longitudinal tool axis LT-LT. In this embodiment, the elongated shaft assembly 12308 does not include an articulation joint. Those of ordinary skill in the art will understand that other embodiments may have an articulation joint therein. In at least one embodiment, the elongated shaft assembly 12308 comprises a hollow outer tube 12340 that is rotatably supported on a tool mounting plate 12462 of a tool mounting portion 12460 as will be discussed in further detail below. In various embodiments, the elongated shaft assembly 12308 further includes a distal spine shaft 12350. Distal spine shaft 12350 has a distal end portion 12354 that is coupled to, or otherwise integrally formed with, a distal stationary base portion 12360 that is non-movably coupled to the channel 12322. See FIGS. 76-78.

[0283] As shown in FIG. 76, the distal spine shaft 12350 has a proximal end portion 12351 that is slidably received within a slot 12355 in a proximal spine shaft 12353 that is non-movably supported within the hollow outer tube 12340 by at least one support collar 12357.

As can be further seen in FIGS. 76 and 77, the surgical tool 12300 includes a closure tube 12370 that is constrained to only move axially relative to the distal stationary base portion 12360. The closure tube 12370 has a proximal end 12372 that has an internal thread 12374 formed therein that is in threaded engagement with a transmission arrangement, generally depicted as 12375 that is operably supported on the tool mounting plate 12462. In various forms, the transmission arrangement 12375 includes a rotary drive shaft assembly, generally designated as 12381. When rotated, the rotary drive shaft assembly 12381 will cause the closure tube 12370 to move axially as will be describe in further detail below. In at least one form, the rotary drive shaft assembly 12381 includes a closure drive nut 12382 of a closure clutch assembly generally designated as 12380. More specifically, the closure drive nut 12382 has a proximal end portion 12384 that is rotatably supported relative to the outer tube 12340 and is in threaded engagement with the closure tube 12370. For assembly purposes, the proximal end portion 12384 may be threadably attached to a retention ring 12386. Retention ring 12386, in cooperation with an end 12387 of the closure drive nut 12382, defines an annular slot 12388 into which a shoulder 12392 of a locking collar 12390 extends. The locking collar 12390 is non-movably attached (e.g., welded, glued, etc.) to the end of the outer tube 12340. Such arrangement serves to affix the closure drive nut 12382 to the outer tube 12340 while enabling the closure drive nut 12382 to rotate relative to the outer tube 12340. The closure drive nut 12382 further has a distal end 12383 that has a threaded portion 12385 that threadably engages the internal thread 12374 of the closure tube 12370. Thus, rotation of the closure drive nut 12382 will cause the closure tube 12370 to move axially as represented by arrow "D" in FIG. 77.

[0284] Closure of the anvil 12324 and actuation of the cutting instrument 12332 are accomplished by control motions that are transmitted by a hollow drive sleeve 12400. As can be seen in FIGS. 76 and 77, the hollow drive sleeve 12400 is rotatably and slidably received on the distal spine shaft 12350. The drive sleeve 12400 has a proximal end portion 12401 that is rotatably mounted to the proximal spine shaft 12353 that protrudes from the tool mounting portion 12460 such that the drive sleeve 12400 may rotate relative thereto. See FIG. 76. As can also be seen in FIGS. 76-78, the drive sleeve 12400 is rotated about the longitudinal tool axis "LT-LT" by a drive shaft 12440. The drive shaft 12440 has a drive gear 12444 that is attached to its distal end 12442 and is in meshing engagement with a driven gear 12450 that is attached to the drive sleeve 12400.

[0285] The drive sleeve 12400 further has a distal end portion 12402 that is coupled to a closure clutch 12410 portion of the closure clutch assembly 12380 that has a proximal face 12412 and a distal face 12414. The proximal face 12412 has a series of proximal teeth 12416 formed thereon that are adapted for selective engagement with corresponding proximal teeth cavities 12418 formed in the proximal end portion 12384 of the closure drive nut 12382. Thus, when the proximal teeth 12416 are in meshing engagement with the proximal teeth cavities 12418 in the closure drive nut 12382, rotation of the drive sleeve 12400 will result in rotation of the closure drive nut 12382 and ultimately cause the closure tube 12370 to move axially as will be discussed in further detail below.

[0286] As can be most particularly seen in FIGS. 76 and 77, the distal face 12414 of the drive clutch portion 12410 has a series of distal teeth 12415 formed thereon that are adapted for selective engagement with corresponding distal teeth cavities 12426 formed in a face plate portion 12424 of a knife drive shaft assembly 12420. In various embodiments, the knife drive shaft assembly 12420 comprises a hollow knife shaft segment 12430 that is rotatably received on a corresponding portion of the distal spine shaft 12350 that is attached to or protrudes from the stationary base 12360. When the distal teeth 12415 of the closure clutch portion 12410 are in meshing engagement with the distal teeth cavities 12426 in the face plate portion 12424, rotation of the drive sleeve 12400 will result in rotation of the drive shaft segment 12430 about the stationary shaft 12350. As can be seen in FIGS. 76-77, a knife drive gear 12432 is attached to the drive shaft segment 12430 and is in meshing engagement with a drive knife gear 12434 that is attached to the end effector drive shaft 12336. Thus, rotation of the drive shaft segment 12430 will result in the rotation of the end effector drive shaft 12336 to drive the cutting instrument 12332 and sled 12333 distally through the surgical staple cartridge 12334 to cut and staple tissue clamped within the surgical end effector 12312. The sled 12333 may be made of, for example, plastic, and may have a sloped distal surface. As the sled 12333 traverses the elongated channel 12322, the sloped forward surface of the sled 12333 pushes up or “drive” the staples in the surgical staple cartridge 12334 through the clamped tissue and against the anvil 12324. The anvil 12324 turns or “forms” the staples, thereby stapling the severed tissue. As used herein, the term “fire” refers to the initiation of actions required to drive the cutting instrument and sled portion in a distal direction through the surgical staple cartridge to cut the tissue clamped in the surgical end effector and drive the staples through the severed tissue.

[0287] In use, it may be desirable to rotate the surgical end effector 12312 about the longitudinal tool axis LT-LT. In at least one embodiment, the transmission arrangement 12375 includes a rotational transmission assembly 12465 that is configured to receive a corresponding rotary output motion from the tool drive assembly 11010 of the robotic system 11000 and convert that rotary output motion to a rotary control motion for rotating the elongated shaft assembly 12308 (and surgical end effector 12312) about the longitudinal tool axis LT-LT. As can be seen in FIG. 79, a proximal end 12341 of the outer tube 12340 is rotatably supported within a cradle arrangement 12343 attached to the tool mounting plate 12462 of the tool mounting portion 12460. A rotation gear 12345 is formed on or attached to the proximal end 12341 of the outer tube 12340 of the elongated shaft assembly 12308 for meshing engagement with a rotation gear assembly 12470 operably supported on the tool mounting plate 12462. In at least one embodiment, a rotation drive gear 12472 is coupled to a corresponding first one of the driven discs or elements 11304 on the adapter side of the tool mounting plate 12462 when the tool mounting portion 12460 is coupled to the tool drive assembly 11010. See FIGS. 63 and 79. The rotation drive assembly 12470 further comprises a rotary driven gear 12474 that is rotatably supported on the tool mounting plate 12462 in meshing engagement with the rotation gear 12345 and the rotation drive gear 12472. Application of a first rotary output motion from the robotic system 11000 through the tool drive assembly 11010 to the corresponding driven element 11304 will thereby cause rotation of the rotation drive gear 12472 by virtue of being operably coupled thereto. Rotation of the rotation drive gear 12472 ultimately results in the rotation of the elongated shaft assembly 12308 (and the end effector 12312) about the longitudinal tool axis LT-LT (primary rotary motion).

[0288] Closure of the anvil 12324 relative to the staple cartridge 12034 is accomplished by axially moving the closure tube 12370 in the distal direction "DD". Axial movement of the closure tube 12370 in the distal direction "DD" is accomplished by applying a rotary control motion to the closure drive nut 12382. To apply the rotary control motion to the closure drive nut 12382, the closure clutch 12410 must first be brought into meshing engagement with the proximal end portion 12384 of the closure drive nut 12382. In various embodiments, the transmission arrangement 12375 further includes a shifter drive assembly 12480 that is operably supported on the tool mounting plate 12462. More specifically and with reference to FIG. 79, it can be seen that a proximal end portion 12359 of the proximal spine portion 12353 extends through the rotation gear 12345 and is rotatably coupled to a shifter gear rack

12481 that is slidably affixed to the tool mounting plate 12462 through slots 12482. The shifter drive assembly 12480 further comprises a shifter drive gear 12483 that is coupled to a corresponding second one of the driven discs or elements 11304 on the adapter side of the tool mounting plate 12462 when the tool mounting portion 12460 is coupled to the tool holder 11270. See FIGS. 63 and 79. The shifter drive assembly 12480 further comprises a shifter driven gear 12478 that is rotatably supported on the tool mounting plate 12462 in meshing engagement with the shifter drive gear 12483 and the shifter rack gear 12482. Application of a second rotary output motion from the robotic system 11000 through the tool drive assembly 11010 to the corresponding driven element 11304 will thereby cause rotation of the shifter drive gear 12483 by virtue of being operably coupled thereto. Rotation of the shifter drive gear 12483 ultimately results in the axial movement of the shifter gear rack 12482 and the proximal spine portion 12353 as well as the drive sleeve 12400 and the closure clutch 12410 attached thereto. The direction of axial travel of the closure clutch 12410 depends upon the direction in which the shifter drive gear 12483 is rotated by the robotic system 11000. Thus, rotation of the shifter drive gear 12483 in a first rotary direction will result in the axial movement of the closure clutch 12410 in the proximal direction "PD" to bring the proximal teeth 12416 into meshing engagement with the proximal teeth cavities 12418 in the closure drive nut 12382. Conversely, rotation of the shifter drive gear 12483 in a second rotary direction (opposite to the first rotary direction) will result in the axial movement of the closure clutch 12410 in the distal direction "DD" to bring the distal teeth 12415 into meshing engagement with corresponding distal teeth cavities 12426 formed in the face plate portion 12424 of the knife drive shaft assembly 12420.

[0289] Once the closure clutch 12410 has been brought into meshing engagement with the closure drive nut 12382, the closure drive nut 12382 is rotated by rotating the closure clutch 12410. Rotation of the closure clutch 12410 is controlled by applying rotary output motions to a rotary drive transmission portion 12490 of transmission arrangement 12375 that is operably supported on the tool mounting plate 12462 as shown in FIG. 79. In at least one embodiment, the rotary drive transmission 12490 includes a rotary drive assembly 12490' that includes a gear 12491 that is coupled to a corresponding third one of the driven discs or elements 11304 on the adapter side of the tool mounting plate 12462 when the tool mounting portion 12460 is coupled to the tool holder 11270. See FIGS. 63 and 79. The rotary drive transmission 12490 further comprises a first rotary driven gear 12492 that is rotatably supported on the tool mounting plate 12462 in meshing engagement with a second rotary

driven gear 12493 and the rotary drive gear 12491. The second rotary driven gear 12493 is coupled to a proximal end portion 12443 of the drive shaft 12440.

[0290] Rotation of the rotary drive gear 12491 in a first rotary direction will result in the rotation of the drive shaft 12440 in a first direction. Conversely, rotation of the rotary drive gear 12491 in a second rotary direction (opposite to the first rotary direction) will cause the drive shaft 12440 to rotate in a second direction. As indicated above, the drive shaft 12440 has a drive gear 12444 that is attached to its distal end 12442 and is in meshing engagement with a driven gear 12450 that is attached to the drive sleeve 12400. Thus, rotation of the drive shaft 12440 results in rotation of the drive sleeve 12400.

[0291] A method of operating the surgical tool 12300 will now be described. Once the tool mounting portion 12462 has been operably coupled to the tool holder 11270 of the robotic system 11000 and oriented into position adjacent the target tissue to be cut and stapled, if the anvil 12334 is not already in the open position (FIG. 76), the robotic system 11000 may apply the first rotary output motion to the shifter drive gear 12483 which results in the axial movement of the closure clutch 12410 into meshing engagement with the closure drive nut 12382 (if it is not already in meshing engagement therewith). See FIG. 77. Once the controller 11001 of the robotic system 11000 has confirmed that the closure clutch 12410 is in meshing engagement with the closure drive nut 12382 (e.g., by means of sensor(s) in the surgical end effector 12312 that are in communication with the robotic control system), the robotic controller 11001 may then apply a second rotary output motion to the rotary drive gear 12492 which, as was described above, ultimately results in the rotation of the rotary drive nut 12382 in the first direction which results in the axial travel of the closure tube 12370 in the distal direction "DD". As the closure tube 12370 moved in the distal direction, it contacts a portion of the anvil 12323 and causes the anvil 12324 to pivot to the closed position to clamp the target tissue between the anvil 12324 and the surgical staple cartridge 12334. Once the robotic controller 11001 determines that the anvil 12334 has been pivoted to the closed position by corresponding sensor(s) in the surgical end effector 12312 in communication therewith, the robotic system 11000 discontinues the application of the second rotary output motion to the rotary drive gear 12491. The robotic controller 11001 may also provide the surgeon with an indication that the anvil 12334 has been fully closed. The surgeon may then initiate the firing procedure. In alternative embodiments, the firing procedure may be automatically initiated by the robotic controller 11001. The robotic controller 11001 then applies the primary rotary control motion 12483 to the shifter drive

gear 12483 which results in the axial movement of the closure clutch 12410 into meshing engagement with the face plate portion 12424 of the knife drive shaft assembly 12420. See FIG. 78. Once the controller 11001 of the robotic system 11000 has confirmed that the closure clutch 12410 is meshing engagement with the face plate portion 12424 (by means of sensor(s) in the end effector 12312 that are in communication with the robotic controller 11001), the robotic controller 11001 may then apply the second rotary output motion to the rotary drive gear 12492 which, as was described above, ultimately results in the axial movement of the cutting instrument 12332 and sled portion 12333 in the distal direction “DD” through the surgical staple cartridge 12334. As the cutting instrument 12332 moves distally through the surgical staple cartridge 12334, the tissue clamped therein is severed. As the sled portion 12333 is driven distally, it causes the staples within the surgical staple cartridge to be driven through the severed tissue into forming contact with the anvil 12324. Once the robotic controller 11001 has determined that the cutting instrument 12324 has reached the end position within the surgical staple cartridge 12334 (by means of sensor(s) in the end effector 12312 that are in communication with the robotic controller 11001), the robotic controller 11001 discontinues the application of the second rotary output motion to the rotary drive gear 12491. Thereafter, the robotic controller 11001 applies the secondary rotary output motion to the rotary drive gear 12491 which ultimately results in the axial travel of the cutting instrument 12332 and sled portion 12333 in the proximal direction “PD” to the starting position. Once the robotic controller 11001 has determined that the cutting instrument 12324 has reached the starting position by means of sensor(s) in the surgical end effector 12312 that are in communication with the robotic controller 11001, the robotic controller 11001 discontinues the application of the secondary rotary output motion to the rotary drive gear 12491. Thereafter, the robotic controller 11001 applies the primary rotary output motion to the shifter drive gear 12483 to cause the closure clutch 12410 to move into engagement with the rotary drive nut 12382. Once the closure clutch 12410 has been moved into meshing engagement with the rotary drive nut 12382, the robotic controller 11001 then applies the secondary output motion to the rotary drive gear 12491 which ultimately results in the rotation of the rotary drive nut 12382 in the second direction to cause the closure tube 12370 to move in the proximal direction “PD”. As can be seen in FIGS. 76-78, the closure tube 12370 has an opening 12345 therein that engages the tab 12327 on the anvil 12324 to cause the anvil 12324 to pivot to the open position. In alternative embodiments, a spring may also be employed to pivot the anvil 12324 to the open position when the closure tube 12370 has been returned to the starting position (FIG. 76).

[0292] FIGS. 80-84 illustrate yet another surgical tool 12500 that may be effectively employed in connection with the robotic system 11000. In various forms, the surgical tool 12500 includes a surgical end effector 12512 that includes a “first portion” in the form of an elongated channel 12522 and a “second movable portion” in the form of a pivotally translatable clamping member, such as an anvil 12524, which are maintained at a spacing that assures effective stapling and severing of tissue clamped in the surgical end effector 12512. As shown in the illustrated embodiment, the surgical end effector 12512 may include, in addition to the previously-mentioned elongated channel 12522 and anvil 12524, a “third movable portion” in the form of a cutting instrument 12532, a sled (not shown), and a surgical staple cartridge 12534 that is removably seated in the elongated channel 12522. The cutting instrument 12532 may be, for example, a knife. The anvil 12524 may be pivotally opened and closed at a pivot point 12525 connected to the proximate end of the elongated channel 12522. The anvil 12524 may also include a tab 12527 at its proximate end that is configured to operably interface with a component of the mechanical closure system (described further below) to open and close the anvil 12524. When actuated, the knife 12532 and sled travel longitudinally along the elongated channel 12522, thereby cutting tissue clamped within the surgical end effector 12512. The movement of the sled along the elongated channel 12522 causes the staples of the surgical staple cartridge 12534 to be driven through the severed tissue and against the closed anvil 12524, which turns the staples to fasten the severed tissue. In one form, the elongated channel 12522 and the anvil 12524 may be made of an electrically conductive material (such as metal) so that they may serve as part of the antenna that communicates with sensor(s) in the surgical end effector, as described above. The surgical staple cartridge 12534 could be made of a nonconductive material (such as plastic) and the sensor may be connected to or disposed in the surgical staple cartridge 12534, as described above.

[0293] It should be noted that although the embodiments of the surgical tool 12500 described herein employ a surgical end effector 12512 that staples the severed tissue, in other embodiments different techniques for fastening or sealing the severed tissue may be used. For example, end effectors that use RF energy or adhesives to fasten the severed tissue may also be used. U.S. Patent No. 5,709,680, entitled “Electrosurgical Hemostatic Device” to Yates et al., and U.S. Patent No. 5,688,270, entitled “Electrosurgical Hemostatic Device With Recessed And/Or Offset Electrodes” to Yates et al., which are incorporated herein by reference, discloses cutting instruments that use RF energy to fasten the severed tissue. U.S.

Patent Application Serial No. 11/267,811 to Morgan et al. and U.S. Patent Application Serial No. 11/267,363 to Shelton et al., which are also incorporated herein by reference, disclose cutting instruments that use adhesives to fasten the severed tissue. Accordingly, although the description herein refers to cutting/stapling operations and the like, it should be recognized that this is an exemplary embodiment and is not meant to be limiting. Other tissue-fastening techniques may also be used.

[0294] In the illustrated embodiment, the elongated channel 12522 of the surgical end effector 12512 is coupled to an elongated shaft assembly 12508 that is coupled to a tool mounting portion 12600. In at least one embodiment, the elongated shaft assembly 12508 comprises a hollow spine tube 12540 that is non-movably coupled to a tool mounting plate 12602 of the tool mounting portion 12600. As can be seen in FIGS. 81 and 82, the proximal end 12523 of the elongated channel 12522 comprises a hollow tubular structure configured to be attached to the distal end 12541 of the spine tube 12540. In one embodiment, for example, the proximal end 12523 of the elongated channel 12522 is welded or glued to the distal end of the spine tube 12540.

[0295] As can be further seen in FIGS. 81 and 82, in at least one non-limiting embodiment, the surgical tool 12500 further includes an axially movable actuation member in the form of a closure tube 12550 that is constrained to move axially relative to the elongated channel 12522 and the spine tube 11540. The closure tube 12550 has a proximal end 12552 that has an internal thread 12554 formed therein that is in threaded engagement with a rotatably movable portion in the form of a closure drive nut 12560. More specifically, the closure drive nut 12560 has a proximal end portion 12562 that is rotatably supported relative to the elongated channel 12522 and the spine tube 12540. For assembly purposes, the proximal end portion 12562 is threadably attached to a retention ring 12570. The retention ring 12570 is received in a groove 12529 formed between a shoulder 12527 on the proximal end 12523 of the elongated channel 12522 and the distal end 12541 of the spine tube 11540. Such arrangement serves to rotatably support the closure drive nut 12560 within the elongated channel 12522. Rotation of the closure drive nut 12560 will cause the closure tube 12550 to move axially as represented by arrow "D" in FIG. 81.

[0296] Extending through the spine tube 12540 and the closure drive nut 12560 is a drive member which, in at least one embodiment, comprises a knife bar 12580 that has a distal end portion 12582 that is rotatably coupled to the cutting instrument 12532 such that the knife bar 12580 may rotate relative to the cutting instrument 12582. As can be seen in FIG. 81-83, the

closure drive nut 12560 has a slot 12564 therein through which the knife bar 12580 can slidably extend. Such arrangement permits the knife bar 12580 to move axially relative to the closure drive nut 12560. However, rotation of the knife bar 12580 about the longitudinal tool axis LT-LT will also result in the rotation of the closure drive nut 12560. The axial direction in which the closure tube 12550 moves ultimately depends upon the direction in which the knife bar 12580 and the closure drive nut 12560 are rotated. As the closure tube 12550 is driven distally, the distal end thereof will contact the anvil 12524 and cause the anvil 12524 to pivot to a closed position. Upon application of an opening rotary output motion from the robotic system 11000, the closure tube 12550 will be driven in the proximal direction "PD" and pivot the anvil 12524 to the open position by virtue of the engagement of the tab 12527 with the opening 12555 in the closure tube 12550.

[0297] In use, it may be desirable to rotate the surgical end effector 12512 about the longitudinal tool axis LT-LT. In at least one embodiment, the tool mounting portion 12600 is configured to receive a corresponding first rotary output motion from the robotic system 11000 and convert that first rotary output motion to a rotary control motion for rotating the elongated shaft assembly 12508 about the longitudinal tool axis LT-LT. As can be seen in FIG. 79, a proximal end 12542 of the hollow spine tube 12540 is rotatably supported within a cradle arrangement 12603 attached to a tool mounting plate 12602 of the tool mounting portion 12600. Various embodiments of the surgical tool 12500 further include a transmission arrangement, generally depicted as 12605, that is operably supported on the tool mounting plate 12602. In various forms the transmission arrangement 12605 include a rotation gear 12544 that is formed on or attached to the proximal end 12542 of the spine tube 12540 for meshing engagement with a rotation drive assembly 12610 that is operably supported on the tool mounting plate 12602. In at least one embodiment, a rotation drive gear 12612 is coupled to a corresponding first one of the rotational bodies, driven discs or elements 11304 on the adapter side of the tool mounting plate 12602 when the tool mounting portion 12600 is coupled to the tool holder 11270. See FIGS. 63 and 84. The rotation drive assembly 12610 further comprises a rotary driven gear 12614 that is rotatably supported on the tool mounting plate 12602 in meshing engagement with the rotation gear 12544 and the rotation drive gear 12612. Application of a first rotary output motion from the robotic system 11000 through the tool drive assembly 11010 to the corresponding driven rotational body 11304 will thereby cause rotation of the rotation drive gear 12612 by virtue of being operably coupled thereto. Rotation of the rotation drive gear 12612 ultimately results in the rotation of

the elongated shaft assembly 12508 (and the end effector 12512) about the longitudinal tool axis LT-LT.

[0298] Closure of the anvil 12524 relative to the surgical staple cartridge 12534 is accomplished by axially moving the closure tube 12550 in the distal direction “DD”. Axial movement of the closure tube 12550 in the distal direction “DD” is accomplished by applying a rotary control motion to the closure drive nut 12382. In various embodiments, the closure drive nut 12560 is rotated by applying a rotary output motion to the knife bar 12580.

Rotation of the knife bar 12580 is controlled by applying rotary output motions to a rotary closure system 12620 that is operably supported on the tool mounting plate 12602 as shown in FIG. 84. In at least one embodiment, the rotary closure system 12620 includes a closure drive gear 12622 that is coupled to a corresponding second one of the driven rotatable body portions discs or elements 11304 on the adapter side of the tool mounting plate 12462 when the tool mounting portion 12600 is coupled to the tool holder 11270. See FIGS. 63 and 84. The closure drive gear 12622, in at least one embodiment, is in meshing driving engagement with a closure gear train, generally depicted as 12623. The closure gear drive train 12623 comprises a first driven closure gear 12624 that is rotatably supported on the tool mounting plate 12602. The first closure driven gear 12624 is attached to a second closure driven gear 12626 by a drive shaft 12628. The second closure driven gear 12626 is in meshing engagement with a third closure driven gear 12630 that is rotatably supported on the tool mounting plate 12602. Rotation of the closure drive gear 12622 in a second rotary direction will result in the rotation of the third closure driven gear 12630 in a second direction. Conversely, rotation of the closure drive gear 12483 in a secondary rotary direction (opposite to the second rotary direction) will cause the third closure driven gear 12630 to rotate in a secondary direction.

[0299] As can be seen in FIG. 84, a drive shaft assembly 12640 is coupled to a proximal end of the knife bar 12580. In various embodiments, the drive shaft assembly 12640 includes a proximal portion 12642 that has a square cross-sectional shape. The proximal portion 12642 is configured to slideably engage a correspondingly shaped aperture in the third driven gear 12630. Such arrangement results in the rotation of the drive shaft assembly 12640 (and knife bar 12580) when the third driven gear 12630 is rotated. The drive shaft assembly 12640 is axially advanced in the distal and proximal directions by a knife drive assembly 12650. One form of the knife drive assembly 12650 comprises a rotary drive gear 12652 that is coupled to a corresponding third one of the driven rotatable body portions, discs or

elements 11304 on the adapter side of the tool mounting plate 12462 when the tool mounting portion 12600 is coupled to the tool holder 11270. See FIGS. 63 and 84. The rotary driven gear 12652 is in meshing driving engagement with a gear train, generally depicted as 12653. In at least one form, the gear train 12653 further comprises a first rotary driven gear assembly 12654 that is rotatably supported on the tool mounting plate 12602. The first rotary driven gear assembly 12654 is in meshing engagement with a third rotary driven gear assembly 12656 that is rotatably supported on the tool mounting plate 12602 and which is in meshing engagement with a fourth rotary driven gear assembly 12658 that is in meshing engagement with a threaded portion 12644 of the drive shaft assembly 12640. Rotation of the rotary drive gear 12652 in a third rotary direction will result in the axial advancement of the drive shaft assembly 12640 and knife bar 12580 in the distal direction "DD". Conversely, rotation of the rotary drive gear 12652 in a tertiary rotary direction (opposite to the third rotary direction) will cause the drive shaft assembly 12640 and the knife bar 12580 to move in the proximal direction.

[0300] A method of operating the surgical tool 12500 will now be described. Once the tool mounting portion 12600 has been operably coupled to the tool holder 11270 of the robotic system 11000, the robotic system 11000 can orient the surgical end effector 12512 in position adjacent the target tissue to be cut and stapled. If the anvil 12524 is not already in the open position (FIG. 81), the robotic system 11000 may apply the second rotary output motion to the closure drive gear 12622 which results in the rotation of the knife bar 12580 in a second direction. Rotation of the knife bar 12580 in the second direction results in the rotation of the closure drive nut 12560 in a second direction. As the closure drive nut 12560 rotates in the second direction, the closure tube 12550 moves in the proximal direction "PD". As the closure tube 12550 moves in the proximal direction "PD", the tab 12527 on the anvil 12524 interfaces with the opening 12555 in the closure tube 12550 and causes the anvil 12524 to pivot to the open position. In addition or in alternative embodiments, a spring (not shown) may be employed to pivot the anvil 12354 to the open position when the closure tube 12550 has been returned to the starting position (FIG. 81). The opened surgical end effector 12512 may then be manipulated by the robotic system 11000 to position the target tissue between the open anvil 12524 and the surgical staple cartridge 12534. Thereafter, the surgeon may initiate the closure process by activating the robotic control system 11000 to apply the second rotary output motion to the closure drive gear 12622 which, as was described above, ultimately results in the rotation of the closure drive nut 12382 in the second direction which

results in the axial travel of the closure tube 12250 in the distal direction “DD”. As the closure tube 12550 moves in the distal direction, it contacts a portion of the anvil 12524 and causes the anvil 12524 to pivot to the closed position to clamp the target tissue between the anvil 12524 and the staple cartridge 12534. Once the robotic controller 11001 determines that the anvil 12524 has been pivoted to the closed position by corresponding sensor(s) in the end effector 12512 that are in communication therewith, the robotic controller 11001 discontinues the application of the second rotary output motion to the closure drive gear 12622. The robotic controller 11001 may also provide the surgeon with an indication that the anvil 12524 has been fully closed. The surgeon may then initiate the firing procedure. In alternative embodiments, the firing procedure may be automatically initiated by the robotic controller 11001.

[0301] After the robotic controller 11001 has determined that the anvil 12524 is in the closed position, the robotic controller 11001 then applies the third rotary output motion to the rotary drive gear 12652 which results in the axial movement of the drive shaft assembly 12640 and knife bar 12580 in the distal direction “DD”. As the cutting instrument 12532 moves distally through the surgical staple cartridge 12534, the tissue clamped therein is severed. As the sled portion (not shown) is driven distally, it causes the staples within the surgical staple cartridge 12534 to be driven through the severed tissue into forming contact with the anvil 12524. Once the robotic controller 11001 has determined that the cutting instrument 12532 has reached the end position within the surgical staple cartridge 12534 by means of sensor(s) in the surgical end effector 12512 that are in communication with the robotic controller 11001, the robotic controller 11001 discontinues the application of the second rotary output motion to the rotary drive gear 12652. Thereafter, the robotic controller 11001 applies the secondary rotary control motion to the rotary drive gear 12652 which ultimately results in the axial travel of the cutting instrument 12532 and sled portion in the proximal direction “PD” to the starting position. Once the robotic controller 11001 has determined that the cutting instrument 12524 has reached the starting position by means of sensor(s) in the end effector 12512 that are in communication with the robotic controller 11001, the robotic controller 11001 discontinues the application of the secondary rotary output motion to the rotary drive gear 12652. Thereafter, the robotic controller 11001 may apply the secondary rotary output motion to the closure drive gear 12622 which results in the rotation of the knife bar 12580 in a secondary direction. Rotation of the knife bar 12580 in the secondary direction results in the rotation of the closure drive nut 12560 in a secondary

direction. As the closure drive nut 12560 rotates in the secondary direction, the closure tube 12550 moves in the proximal direction “PD” to the open position.

[0302] FIGS. 85-90B illustrate yet another surgical tool 12700 that may be effectively employed in connection with the robotic system 11000. In various forms, the surgical tool 12700 includes a surgical end effector 12712 that includes a “first portion” in the form of an elongated channel 12722 and a “second movable portion” in on form comprising a pivotally translatable clamping member, such as an anvil 12724, which are maintained at a spacing that assures effective stapling and severing of tissue clamped in the surgical end effector 12712. As shown in the illustrated embodiment, the surgical end effector 12712 may include, in addition to the previously-mentioned channel 12722 and anvil 12724, a “third movable portion” in the form of a cutting instrument 12732, a sled (not shown), and a surgical staple cartridge 12734 that is removably seated in the elongated channel 12722. The cutting instrument 12732 may be, for example, a knife. The anvil 12724 may be pivotally opened and closed at a pivot point 12725 connected to the proximal end of the elongated channel 12722. The anvil 12724 may also include a tab 12727 at its proximal end that interfaces with a component of the mechanical closure system (described further below) to open and close the anvil 12724. When actuated, the knife 12732 and sled to travel longitudinally along the elongated channel 12722, thereby cutting tissue clamped within the surgical end effector 12712. The movement of the sled along the elongated channel 12722 causes the staples of the surgical staple cartridge 12734 to be driven through the severed tissue and against the closed anvil 12724, which turns the staples to fasten the severed tissue. In one form, the elongated channel 12722 and the anvil 12724 may be made of an electrically conductive material (such as metal) so that they may serve as part of the antenna that communicates with sensor(s) in the surgical end effector, as described above. The surgical staple cartridge 12734 could be made of a nonconductive material (such as plastic) and the sensor may be connected to or disposed in the surgical staple cartridge 12734, as described above.

[0303] It should be noted that although the embodiments of the surgical tool 12500 described herein employ a surgical end effector 12712 that staples the severed tissue, in other embodiments different techniques for fastening or sealing the severed tissue may be used. For example, end effectors that use RF energy or adhesives to fasten the severed tissue may also be used. U.S. Patent No. 5,709,680, entitled “Electrosurgical Hemostatic Device” to Yates et al., and U.S. Patent No. 5,688,270, entitled “Electrosurgical Hemostatic Device With Recessed And/Or Offset Electrodes” to Yates et al., which are incorporated herein by

reference, discloses cutting instruments that use RF energy to fasten the severed tissue. U.S. Patent Application Serial No. 11/267,811 to Morgan et al. and U.S. Patent Application Serial No. 11/267,363 to Shelton et al., which are also incorporated herein by reference, disclose cutting instruments that use adhesives to fasten the severed tissue. Accordingly, although the description herein refers to cutting/stapling operations and the like, it should be recognized that this is an exemplary embodiment and is not meant to be limiting. Other tissue-fastening techniques may also be used.

[0304] In the illustrated embodiment, the elongated channel 12722 of the surgical end effector 12712 is coupled to an elongated shaft assembly 12708 that is coupled to a tool mounting portion 12900. Although not shown, the elongated shaft assembly 12708 may include an articulation joint to permit the surgical end effector 12712 to be selectively articulated about an axis that is substantially transverse to the tool axis LT-LT. In at least one embodiment, the elongated shaft assembly 12708 comprises a hollow spine tube 12740 that is non-movably coupled to a tool mounting plate 12902 of the tool mounting portion 12900. As can be seen in FIGS. 86 and 87, the proximal end 12723 of the elongated channel 12722 comprises a hollow tubular structure that is attached to the spine tube 12740 by means of a mounting collar 12790. A cross-sectional view of the mounting collar 12790 is shown in FIG. 88. In various embodiments, the mounting collar 12790 has a proximal flanged end 12791 that is configured for attachment to the distal end of the spine tube 12740. In at least one embodiment, for example, the proximal flanged end 12791 of the mounting collar 12790 is welded or glued to the distal end of the spine tube 12740. As can be further seen in FIGS. 86 and 87, the mounting collar 12790 further has a mounting hub portion 12792 that is sized to receive the proximal end 12723 of the elongated channel 12722 thereon. The proximal end 12723 of the elongated channel 12722 is non-movably attached to the mounting hub portion 12792 by, for example, welding, adhesive, etc.

[0305] As can be further seen in FIGS. 86 and 87, the surgical tool 12700 further includes an axially movable actuation member in the form of a closure tube 12750 that is constrained to move axially relative to the elongated channel 12722. The closure tube 12750 has a proximal end 12752 that has an internal thread 12754 formed therein that is in threaded engagement with a rotatably movable portion in the form of a closure drive nut 12760. More specifically, the closure drive nut 12760 has a proximal end portion 12762 that is rotatably supported relative to the elongated channel 12722 and the spine tube 12740. For assembly purposes, the proximal end portion 12762 is threadably attached to a retention ring 12770.

The retention ring 12770 is received in a groove 12729 formed between a shoulder 12727 on the proximal end 12723 of the channel 12722 and the mounting hub 12729 of the mounting collar 12790. Such arrangement serves to rotatably support the closure drive nut 12760 within the channel 12722. Rotation of the closure drive nut 12760 will cause the closure tube 12750 to move axially as represented by arrow “D” in FIG. 86.

[0306] Extending through the spine tube 12740, the mounting collar 12790, and the closure drive nut 12760 is a drive member, which in at least one embodiment, comprises a knife bar 12780 that has a distal end portion 12782 that is coupled to the cutting instrument 12732. As can be seen in FIGS. 86 and 87, the mounting collar 12790 has a passage 12793 therethrough for permitting the knife bar 12780 to slidably pass therethrough. Similarly, the closure drive nut 12760 has a slot 12764 therein through which the knife bar 12780 can slidably extend. Such arrangement permits the knife bar 12780 to move axially relative to the closure drive nut 12760.

[0307] Actuation of the anvil 12724 is controlled by a rotary driven closure shaft 12800. As can be seen in FIGS. 86 and 87, a distal end portion 12802 of the closure drive shaft 12800 extends through a passage 12794 in the mounting collar 12790 and a closure gear 12804 is attached thereto. The closure gear 12804 is configured for driving engagement with the inner surface 12761 of the closure drive nut 12760. Thus, rotation of the closure shaft 12800 will also result in the rotation of the closure drive nut 12760. The axial direction in which the closure tube 12750 moves ultimately depends upon the direction in which the closure shaft 12800 and the closure drive nut 12760 are rotated. For example, in response to one rotary closure motion received from the robotic system 11000, the closure tube 12750 will be driven in the distal direction “DD”. As the closure tube 12750 is driven distally, the opening 12745 will engage the tab 12727 on the anvil 12724 and cause the anvil 12724 to pivot to a closed position. Upon application of an opening rotary motion from the robotic system 11000, the closure tube 12750 will be driven in the proximal direction “PD” and pivot the anvil 12724 to the open position. In various embodiments, a spring (not shown) may be employed to bias the anvil 12724 to the open position (FIG. 86).

[0308] In use, it may be desirable to rotate the surgical end effector 12712 about the longitudinal tool axis LT-LT. In at least one embodiment, the tool mounting portion 12900 is configured to receive a corresponding first rotary output motion from the robotic system 11000 for rotating the elongated shaft assembly 12708 about the tool axis LT-LT. As can be seen in FIG. 90, a proximal end 12742 of the hollow spine tube 12740 is rotatably supported

within a cradle arrangement 12903 and a bearing assembly 12904 that are attached to a tool mounting plate 12902 of the tool mounting portion 12900. A rotation gear 12744 is formed on or attached to the proximal end 12742 of the spine tube 12740 for meshing engagement with a rotation drive assembly 12910 that is operably supported on the tool mounting plate 12902. In at least one embodiment, a rotation drive gear 12912 is coupled to a corresponding first one of the driven discs or elements 11304 on the adapter side of the tool mounting plate 12602 when the tool mounting portion 12600 is coupled to the tool holder 11270. See FIGS. 63 and 90. The rotation drive assembly 12910 further comprises a rotary driven gear 12914 that is rotatably supported on the tool mounting plate 12902 in meshing engagement with the rotation gear 12744 and the rotation drive gear 12912. Application of a first rotary control motion from the robotic system 11000 through the tool holder 11270 and the adapter 11240 to the corresponding driven element 11304 will thereby cause rotation of the rotation drive gear 12912 by virtue of being operably coupled thereto. Rotation of the rotation drive gear 12912 ultimately results in the rotation of the elongated shaft assembly 12708 (and the end effector 12712) about the longitudinal tool axis LT-LT (primary rotary motion).

[0309] Closure of the anvil 12724 relative to the staple cartridge 12734 is accomplished by axially moving the closure tube 12750 in the distal direction “DD”. Axial movement of the closure tube 12750 in the distal direction “DD” is accomplished by applying a rotary control motion to the closure drive nut 12760. In various embodiments, the closure drive nut 12760 is rotated by applying a rotary output motion to the closure drive shaft 12800. As can be seen in FIG. 90, a proximal end portion 12806 of the closure drive shaft 12800 has a driven gear 12808 thereon that is in meshing engagement with a closure drive assembly 12920. In various embodiments, the closure drive system 12920 includes a closure drive gear 12922 that is coupled to a corresponding second one of the driven rotational bodies or elements 11304 on the adapter side of the tool mounting plate 12462 when the tool mounting portion 12900 is coupled to the tool holder 11270. See FIGS. 63 and 90. The closure drive gear 12922 is supported in meshing engagement with a closure gear train, generally depicted as 12923. In at least one form, the closure gear train 12923 comprises a first driven closure gear 12924 that is rotatably supported on the tool mounting plate 12902. The first closure driven gear 12924 is attached to a second closure driven gear 12926 by a drive shaft 12928. The second closure driven gear 12926 is in meshing engagement with a planetary gear assembly 12930. In various embodiments, the planetary gear assembly 12930 includes a driven planetary closure gear 12932 that is rotatably supported within the bearing assembly 12904

that is mounted on tool mounting plate 12902. As can be seen in FIGS. 90 and 90B, the proximal end portion 12806 of the closure drive shaft 12800 is rotatably supported within the proximal end portion 12742 of the spine tube 12740 such that the driven gear 12808 is in meshing engagement with central gear teeth 12934 formed on the planetary gear 12932. As can also be seen in FIG. 90A, two additional support gears 12936 are attached to or rotatably supported relative to the proximal end portion 12742 of the spine tube 12740 to provide bearing support thereto. Such arrangement with the planetary gear assembly 12930 serves to accommodate rotation of the spine shaft 12740 by the rotation drive assembly 12910 while permitting the closure driven gear 12808 to remain in meshing engagement with the closure drive system 12920. In addition, rotation of the closure drive gear 12922 in a first direction will ultimately result in the rotation of the closure drive shaft 12800 and closure drive nut 12760 which will ultimately result in the closure of the anvil 12724 as described above. Conversely, rotation of the closure drive gear 12922 in a second opposite direction will ultimately result in the rotation of the closure drive nut 12760 in an opposite direction which results in the opening of the anvil 12724.

[0310] As can be seen in FIG. 84, the proximal end 12784 of the knife bar 12780 has a threaded shaft portion 12786 attached thereto which is in driving engagement with a knife drive assembly 12940. In various embodiments, the threaded shaft portion 12786 is rotatably supported by a bearing 12906 attached to the tool mounting plate 12902. Such arrangement permits the threaded shaft portion 12786 to rotate and move axially relative to the tool mounting plate 12902. The knife bar 12780 is axially advanced in the distal and proximal directions by the knife drive assembly 12940. One form of the knife drive assembly 12940 comprises a rotary drive gear 12942 that is coupled to a corresponding third one of the rotatable bodies, driven discs or elements 11304 on the adapter side of the tool mounting plate 12902 when the tool mounting portion 12900 is coupled to the tool holder 11270. See FIGS. 63 and 90. The rotary drive gear 12942 is in meshing engagement with a knife gear train, generally depicted as 12943. In various embodiments, the knife gear train 12943 comprises a first rotary driven gear assembly 12944 that is rotatably supported on the tool mounting plate 12902. The first rotary driven gear assembly 12944 is in meshing engagement with a third rotary driven gear assembly 12946 that is rotatably supported on the tool mounting plate 12902 and which is in meshing engagement with a fourth rotary driven gear assembly 12948 that is in meshing engagement with the threaded portion 12786 of the knife bar 12780. Rotation of the rotary drive gear 12942 in one direction will result in the

axial advancement of the knife bar 12780 in the distal direction “DD”. Conversely, rotation of the rotary drive gear 12942 in an opposite direction will cause the knife bar 12780 to move in the proximal direction. Tool 12700 may otherwise be used as described above.

[0311] FIGS. 91 and 92 illustrate a surgical tool embodiment 12700’ that is substantially identical to tool 12700 that was described in detail above. However tool 12700’ includes a pressure sensor 12950 that is configured to provide feedback to the robotic controller 11001 concerning the amount of clamping pressure experienced by the anvil 12724. In various embodiments, for example, the pressure sensor may comprise a spring biased contact switch. For a continuous signal, it would use either a cantilever beam with a strain gage on it or a dome button top with a strain gage on the inside. Another version may comprise an off switch that contacts only at a known desired load. Such arrangement would include a dome on the based wherein the dome is one electrical pole and the base is the other electrical pole. Such arrangement permits the robotic controller 11001 to adjust the amount of clamping pressure being applied to the tissue within the surgical end effector 12712 by adjusting the amount of closing pressure applied to the anvil 12724. Those of ordinary skill in the art will understand that such pressure sensor arrangement may be effectively employed with several of the surgical tool embodiments described herein as well as their equivalent structures.

[0312] FIG. 93 illustrates a portion of another surgical tool 3000 that may be effectively used in connection with a robotic system 11000. The surgical tool 3003 employs on-board motor(s) for powering various components of a surgical end effector cutting instrument. In at least one non-limiting embodiment for example, the surgical tool 3000 includes a surgical end effector in the form of an endocutter (not shown) that has an anvil (not shown) and surgical staple cartridge arrangement (not shown) of the types and constructions described above. The surgical tool 3000 also includes an elongated shaft (not shown) and anvil closure arrangement (not shown) of the types described above. Thus, this portion of the Detailed Description will not repeat the description of those components beyond that which is necessary to appreciate the unique and novel attributes of the various embodiments of surgical tool 3000.

[0313] In the depicted embodiment, the end effector includes a cutting instrument 3002 that is coupled to a knife bar 3003. As can be seen in FIG. 93, the surgical tool 3000 includes a tool mounting portion 3010 that includes a tool mounting plate 3012 that is configured to mountingly interface with the adaptor portion 11240’ which is coupled to the robotic system 11000 in the various manners described above. The tool mounting portion 3010 is

configured to operably support a transmission arrangement 3013 thereon. In at least one embodiment, the adaptor portion 11240' may be identical to the adaptor portion 11240 described in detail above without the powered rotation bodies and disc members employed by adapter 11240. In other embodiments, the adaptor portion 11240' may be identical to adaptor portion 11240. Still other modifications which are considered to be within the spirit and scope of the various forms of the present invention may employ one or more of the mechanical motions (i.e., rotary motion(s)) from the tool holder portion 11270 (as described hereinabove) to power/actuate the transmission arrangement 3013 while also employing one or more motors within the tool mounting portion 3010 to power one or more other components of the surgical end effector. In addition, while the end effector of the depicted embodiment comprises an endocutter, those of ordinary skill in the art will understand that the unique and novel attributes of the depicted embodiment may be effectively employed in connection with other types of surgical end effectors without departing from the spirit and scope of various forms of the present invention.

[0314] In various embodiments, the tool mounting plate 3012 is configured to at least house a first firing motor 3011 for supplying firing and retraction motions to the knife bar 3003 which is coupled to or otherwise operably interfaces with the cutting instrument 3002. The tool mounting plate 3012 has an array of electrical connecting pins 3014 which are configured to interface with the slots 11258 (FIG. 62) in the adapter 11240'. Such arrangement permits the controller 11001 of the robotic system 11000 to provide control signals to the electronic control circuit 3020 of the surgical tool 3000. While the interface is described herein with reference to mechanical, electrical, and magnetic coupling elements, it should be understood that a wide variety of telemetry modalities might be used, including infrared, inductive coupling, or the like.

[0315] Control circuit 3020 is shown in schematic form in FIG. 93. In one form or embodiment, the control circuit 3020 includes a power supply in the form of a battery 3022 that is coupled to an on-off solenoid powered switch 3024. Control circuit 3020 further includes an on/off firing solenoid 3026 that is coupled to a double pole switch 3028 for controlling the rotational direction of the motor 3011. Thus, when the controller 11001 of the robotic system 11000 supplies an appropriate control signal, switch 3024 will permit battery 3022 to supply power to the double pole switch 3028. The controller 11001 of the robotic system 11000 will also supply an appropriate signal to the double pole switch 3028 to supply power to the motor 3011. When it is desired to fire the surgical end effector (i.e., drive the

cutting instrument 3002 distally through tissue clamped in the surgical end effector, the double pole switch 3028 will be in a first position. When it is desired to retract the cutting instrument 3002 to the starting position, the double pole switch 3028 will be moved to the second position by the controller 11001.

[0316] Various embodiments of the surgical tool 3000 also employ a gear box 3030 that is sized, in cooperation with a firing gear train 3031 that, in at least one non-limiting embodiment, comprises a firing drive gear 3032 that is in meshing engagement with a firing driven gear 3034 for generating a desired amount of driving force necessary to drive the cutting instrument 3002 through tissue and to drive and form staples in the various manners described herein. In the embodiment depicted in FIG. 93, the driven gear 3034 is coupled to a screw shaft 3036 that is in threaded engagement with a screw nut arrangement 3038 that is constrained to move axially (represented by arrow “D”). The screw nut arrangement 3038 is attached to the firing bar 3003. Thus, by rotating the screw shaft 3036 in a first direction, the cutting instrument 3002 is driven in the distal direction “DD” and rotating the screw shaft in an opposite second direction, the cutting instrument 3002 may be retracted in the proximal direction “PD”.

[0317] FIG. 94 illustrates a portion of another surgical tool 3000' that is substantially identical to tool 3000 described above, except that the driven gear 3034 is attached to a drive shaft 3040. The drive shaft 3040 is attached to a second driver gear 3042 that is in meshing engagement with a third driven gear 3044 that is in meshing engagement with a screw 3046 coupled to the firing bar 3003.

[0318] FIG. 95 illustrates another surgical tool 3200 that may be effectively used in connection with a robotic system 11000. In this embodiment, the surgical tool 3200 includes a surgical end effector 3212 that in one non-limiting form, comprises a component portion that is selectively movable between first and second positions relative to at least one other end effector component portion. As will be discussed in further detail below, the surgical tool 3200 employs on-board motors for powering various components of a transmission arrangement 3305. The surgical end effector 3212 includes an elongated channel 3222 that operably supports a surgical staple cartridge 3234. The elongated channel 3222 has a proximal end 3223 that slidably extends into a hollow elongated shaft assembly 3208 that is coupled to a tool mounting portion 3300. In addition, the surgical end effector 3212 includes an anvil 3224 that is pivotally coupled to the elongated channel 3222 by a pair of trunnions 3225 that are received within corresponding openings 3229 in the elongated channel 3222. A

distal end portion 3209 of the shaft assembly 3208 includes an opening 3245 into which a tab 3227 on the anvil 3224 is inserted in order to open the anvil 3224 as the elongated channel 3222 is moved axially in the proximal direction "PD" relative to the distal end portion 3209 of the shaft assembly 3208. In various embodiments, a spring (not shown) may be employed to bias the anvil 3224 to the open position.

[0319] As indicated above, the surgical tool 3200 includes a tool mounting portion 3300 that includes a tool mounting plate 3302 that is configured to operably support the transmission arrangement 3305 and to mountingly interface with the adaptor portion 11240' which is coupled to the robotic system 11000 in the various manners described above. In at least one embodiment, the adaptor portion 11240' may be identical to the adaptor portion 11240 described in detail above without the powered disc members employed by adapter 11240. In other embodiments, the adaptor portion 11240' may be identical to adaptor portion 11240. However, in such embodiments, because the various components of the surgical end effector 3212 are all powered by motor(s) in the tool mounting portion 3300, the surgical tool 3200 will not employ or require any of the mechanical (i.e., non-electrical) actuation motions from the tool holder portion 11270 to power the surgical end effector 3200 components. Still other modifications which are considered to be within the spirit and scope of the various forms of the present invention may employ one or more of the mechanical motions from the tool holder portion 11270 (as described hereinabove) to power/actuate one or more of the surgical end effector components while also employing one or more motors within the tool mounting portion to power one or more other components of the surgical end effector.

[0320] In various embodiments, the tool mounting plate 3302 is configured to support a first firing motor 3310 for supplying firing and retraction motions to the transmission arrangement 3305 to drive a knife bar 3335 that is coupled to a cutting instrument 3332 of the type described above. As can be seen in FIG. 95, the tool mounting plate 3212 has an array of electrical connecting pins 3014 which are configured to interface with the slots 11258 (FIG. 62) in the adapter 11240'. Such arrangement permits the controller 11001 of the robotic system 11000 to provide control signals to the electronic control circuits 3320, 3340 of the surgical tool 3200. While the interface is described herein with reference to mechanical, electrical, and magnetic coupling elements, it should be understood that a wide variety of telemetry modalities might be used, including infrared, inductive coupling, or the like.

[0321] In one form or embodiment, the first control circuit 3320 includes a first power supply in the form of a first battery 3322 that is coupled to a first on-off solenoid powered switch 3324. The first firing control circuit 3320 further includes a first on/off firing solenoid 3326 that is coupled to a first double pole switch 3328 for controlling the rotational direction of the first firing motor 3310. Thus, when the robotic controller 11001 supplies an appropriate control signal, the first switch 3324 will permit the first battery 3322 to supply power to the first double pole switch 3328. The robotic controller 11001 will also supply an appropriate signal to the first double pole switch 3328 to supply power to the first firing motor 3310. When it is desired to fire the surgical end effector (i.e., drive the cutting instrument 3232 distally through tissue clamped in the surgical end effector 3212, the first switch 3328 will be positioned in a first position by the robotic controller 11001. When it is desired to retract the cutting instrument 3232 to the starting position, the robotic controller 11001 will send the appropriate control signal to move the first switch 3328 to the second position.

[0322] Various embodiments of the surgical tool 3200 also employ a first gear box 3330 that is sized, in cooperation with a firing drive gear 3332 coupled thereto that operably interfaces with a firing gear train 3333. In at least one non-limiting embodiment, the firing gear train 3333 comprises a firing driven gear 3334 that is in meshing engagement with drive gear 3332, for generating a desired amount of driving force necessary to drive the cutting instrument 3232 through tissue and to drive and form staples in the various manners described herein. In the embodiment depicted in FIG. 95, the driven gear 3334 is coupled to a drive shaft 3335 that has a second driven gear 3336 coupled thereto. The second driven gear 3336 is supported in meshing engagement with a third driven gear 3337 that is in meshing engagement with a fourth driven gear 3338. The fourth driven gear 3338 is in meshing engagement with a threaded proximal portion 3339 of the knife bar 3235 that is constrained to move axially. Thus, by rotating the drive shaft 3335 in a first direction, the cutting instrument 3232 is driven in the distal direction "DD" and rotating the drive shaft 3335 in an opposite second direction, the cutting instrument 3232 may be retracted in the proximal direction "PD".

[0323] As indicated above, the opening and closing of the anvil 3224 is controlled by axially moving the elongated channel 3222 relative to the elongated shaft assembly 3208. The axial movement of the elongated channel 3222 is controlled by a closure control system 3339. In various embodiments, the closure control system 3339 includes a closure shaft 3340

which has a hollow threaded end portion 3341 that threadably engages a threaded closure rod 3342. The threaded end portion 3341 is rotatably supported in a spine shaft 3343 that operably interfaces with the tool mounting portion 3300 and extends through a portion of the shaft assembly 3208 as shown. The closure system 3339 further comprises a closure control circuit 3350 that includes a second power supply in the form of a second battery 3352 that is coupled to a second on-off solenoid powered switch 3354. Closure control circuit 3350 further includes a second on/off firing solenoid 3356 that is coupled to a second double pole switch 3358 for controlling the rotation of a second closure motor 3360. Thus, when the robotic controller 11001 supplies an appropriate control signal, the second switch 3354 will permit the second battery 3352 to supply power to the second double pole switch 3354. The robotic controller 11001 will also supply an appropriate signal to the second double pole switch 3358 to supply power to the second motor 3360. When it is desired to close the anvil 3224, the second switch 3348 will be in a first position. When it is desired to open the anvil 3224, the second switch 3348 will be moved to a second position.

[0324] Various embodiments of tool mounting portion 3300 also employ a second gear box 3362 that is coupled to a closure drive gear 3364. The closure drive gear 3364 is in meshing engagement with a closure gear train 3363. In various non-limiting forms, the closure gear train 3363 includes a closure driven gear 3365 that is attached to a closure drive shaft 3366. Also attached to the closure drive shaft 3366 is a closure drive gear 3367 that is in meshing engagement with a closure shaft gear 3360 attached to the closure shaft 3340. FIG. 95 depicts the end effector 3212 in the open position. As indicated above, when the threaded closure rod 3342 is in the position depicted in FIG. 95, a spring (not shown) biases the anvil 3224 to the open position. When it is desired to close the anvil 3224, the robotic controller 11001 will activate the second motor 3360 to rotate the closure shaft 3340 to draw the threaded closure rod 3342 and the channel 3222 in the proximal direction 'PD'. As the anvil 3224 contacts the distal end portion 3209 of the shaft 3208, the anvil 3224 is pivoted to the closed position.

[0325] A method of operating the surgical tool 3200 will now be described. Once the tool mounting portion 3302 has been operably coupled to the tool holder 11270 of the robotic system 11000, the robotic system 11000 can orient the end effector 3212 in position adjacent the target tissue to be cut and stapled. If the anvil 3224 is not already in the open position, the robotic controller 11001 may activate the second closure motor 3360 to drive the channel 3222 in the distal direction to the position depicted in FIG. 95. Once the robotic controller

11001 determines that the surgical end effector 3212 is in the open position by sensor(s) in the and effector and/or the tool mounting portion 3300, the robotic controller 11001 may provide the surgeon with a signal to inform the surgeon that the anvil 3224 may then be closed. Once the target tissue is positioned between the open anvil 3224 and the surgical staple cartridge 3234, the surgeon may then commence the closure process by activating the robotic controller 11001 to apply a closure control signal to the second closure motor 3360. The second closure motor 3360 applies a rotary motion to the closure shaft 3340 to draw the channel 3222 in the proximal direction "PD" until the anvil 3224 has been pivoted to the closed position. Once the robotic controller 11001 determines that the anvil 3224 has been moved to the closed position by sensor(s) in the surgical end effector 3212 and/or in the tool mounting portion 3300 that are in communication with the robotic control system, the motor 3360 may be deactivated. Thereafter, the firing process may be commenced either manually by the surgeon activating a trigger, button, etc. on the controller 11001 or the controller 11001 may automatically commence the firing process.

[0326] To commence the firing process, the robotic controller 11001 activates the firing motor 3310 to drive the firing bar 3235 and the cutting instrument 3232 in the distal direction "DD". Once robotic controller 11001 has determined that the cutting instrument 3232 has moved to the ending position within the surgical staple cartridge 3234 by means of sensors in the surgical end effector 3212 and/or the motor drive portion 3300, the robotic controller 11001 may provide the surgeon with an indication signal. Thereafter the surgeon may manually activate the first motor 3310 to retract the cutting instrument 3232 to the starting position or the robotic controller 11001 may automatically activate the first motor 3310 to retract the cutting element 3232.

[0327] The embodiment depicted in FIG. 95 does not include an articulation joint. FIGS. 96 and 97 illustrate surgical tools 3200' and 3200" that have end effectors 3212', 3212", respectively that may be employed with an elongated shaft embodiment that has an articulation joint of the various types disclosed herein. For example, as can be seen in FIG. 96, a threaded closure shaft 3342 is coupled to the proximal end 3223 of the elongated channel 3222 by a flexible cable or other flexible member 3345. The location of an articulation joint (not shown) within the elongated shaft assembly 3208 will coincide with the flexible member 3345 to enable the flexible member 3345 to accommodate such articulation. In addition, in the above-described embodiment, the flexible member 33345 is rotatably affixed to the proximal end portion 3223 of the elongated channel 3222 to enable the flexible

member 3345 to rotate relative thereto to prevent the flexible member 3229 from “winding up” relative to the channel 3222. Although not shown, the cutting element may be driven in one of the above described manners by a knife bar that can also accommodate articulation of the elongated shaft assembly. FIG. 97 depicts a surgical end effector 3212” that is substantially identical to the surgical end effector 3212 described above, except that the threaded closure rod 3342 is attached to a closure nut 3347 that is constrained to only move axially within the elongated shaft assembly 3208. The flexible member 3345 is attached to the closure nut 3347. Such arrangement also prevents the threaded closure rod 3342 from winding-up the flexible member 3345. A flexible knife bar 3235’ may be employed to facilitate articulation of the surgical end effector 3212”.

[0328] The surgical tools 3200, 3200’, and 3200” described above may also employ anyone of the cutting instrument embodiments described herein. As described above, the anvil of each of the end effectors of these tools is closed by drawing the elongated channel into contact with the distal end of the elongated shaft assembly. Thus, once the target tissue has been located between the staple cartridge 3234 and the anvil 3224, the robotic controller 11001 can start to draw the channel 3222 inward into the shaft assembly 3208. In various embodiments, however, to prevent the end effector 3212, 3212’, 3212” from moving the target tissue with the end effector during this closing process, the controller 11001 may simultaneously move the tool holder and ultimately the tool such to compensate for the movement of the elongated channel 3222 so that, in effect, the target tissue is clamped between the anvil and the elongated channel without being otherwise moved.

[0329] FIGS. 98-100 depict another surgical tool embodiment 3201 that is substantially identical to surgical tool 3200” described above, except for the differences discussed below. In this embodiment, the threaded closure rod 3342’ has variable pitched grooves. More specifically, as can be seen in FIG. 99, the closure rod 3342’ has a distal groove section 3380 and a proximal groove section 3382. The distal and proximal groove sections 3380, 3382 are configured for engagement with a lug 3390 supported within the hollow threaded end portion 3341’. As can be seen in FIG. 99, the distal groove section 3380 has a finer pitch than the groove section 3382. Thus, such variable pitch arrangement permits the elongated channel 3222 to be drawn into the shaft 3208 at a first speed or rate by virtue of the engagement between the lug 3390 and the proximal groove segment 3382. When the lug 3390 engages the distal groove segment, the channel 3222 will be drawn into the shaft 3208 at a second speed or rate. Because the proximal groove segment 3382 is coarser than the distal groove

segment 3380, the first speed will be greater than the second speed. Such arrangement serves to speed up the initial closing of the end effector for tissue manipulation and then after the tissue has been properly positioned therein, generate the amount of closure forces to properly clamp the tissue for cutting and sealing. Thus, the anvil 3234 initially closes fast with a lower force and then applies a higher closing force as the anvil closes more slowly.

[0330] The surgical end effector opening and closing motions are employed to enable the user to use the end effector to grasp and manipulate tissue prior to fully clamping it in the desired location for cutting and sealing. The user may, for example, open and close the surgical end effector numerous times during this process to orient the end effector in a proper position which enables the tissue to be held in a desired location. Thus, in at least some embodiments, to produce the high loading for firing, the fine thread may require as many as 5-10 full rotations to generate the necessary load. In some cases, for example, this action could take as long as 2-5 seconds. If it also took an equally long time to open and close the end effector each time during the positioning/tissue manipulation process, just positioning the end effector may take an undesirably long time. If that happens, it is possible that a user may abandon such use of the end effector for use of a conventional grasper device. Use of graspers, etc. may undesirably increase the costs associated with completing the surgical procedure.

[0331] The above-described embodiments employ a battery or batteries to power the motors used to drive the end effector components. Activation of the motors is controlled by the robotic system 11000. In alternative embodiments, the power supply may comprise alternating current "AC" that is supplied to the motors by the robotic system 11000. That is, the AC power would be supplied from the system powering the robotic system 11000 through the tool holder and adapter. In still other embodiments, a power cord or tether may be attached to the tool mounting portion 3300 to supply the requisite power from a separate source of alternating or direct current.

[0332] In use, the controller 11001 may apply an initial rotary motion to the closure shaft 3340 (FIG. 95) to draw the elongated channel 3222 axially inwardly into the elongated shaft assembly 3208 and move the anvil from a first position to an intermediate position at a first rate that corresponds with the point wherein the distal groove section 3380 transitions to the proximal groove section 3382. Further application of rotary motion to the closure shaft 3340 will cause the anvil to move from the intermediate position to the closed position relative to

the surgical staple cartridge. When in the closed position, the tissue to be cut and stapled is properly clamped between the anvil and the surgical staple cartridge.

[0333] FIGS. 101-104 illustrate another surgical tool embodiment 3400 of the present invention. This embodiment includes an elongated shaft assembly 3408 that extends from a tool mounting portion 3500. The elongated shaft assembly 3408 includes a rotatable proximal closure tube segment 3410 that is rotatably journaled on a proximal spine member 3420 that is rigidly coupled to a tool mounting plate 3502 of the tool mounting portion 3500. The proximal spine member 3420 has a distal end 3422 that is coupled to an elongated channel portion 3522 of a surgical end effector 3412. For example, in at least one embodiment, the elongated channel portion 3522 has a distal end portion 3523 that “hookingly engages” the distal end 3422 of the spine member 3420. The elongated channel 3522 is configured to support a surgical staple cartridge 3534 therein. This embodiment may employ one of the various cutting instrument embodiments disclosed herein to sever tissue that is clamped in the surgical end effector 3412 and fire the staples in the staple cartridge 3534 into the severed tissue.

[0334] Surgical end effector 3412 has an anvil 3524 that is pivotally coupled to the elongated channel 3522 by a pair of trunnions 3525 that are received in corresponding openings 3529 in the elongated channel 3522. The anvil 3524 is moved between the open (FIG. 101) and closed positions (FIGS. 102-104) by a distal closure tube segment 3430. A distal end portion 3432 of the distal closure tube segment 3430 includes an opening 3445 into which a tab 3527 on the anvil 3524 is inserted in order to open and close the anvil 3524 as the distal closure tube segment 3430 moves axially relative thereto. In various embodiments, the opening 3445 is shaped such that as the closure tube segment 3430 is moved in the proximal direction, the closure tube segment 3430 causes the anvil 3524 to pivot to an open position. In addition or in the alternative, a spring (not shown) may be employed to bias the anvil 3524 to the open position.

[0335] As can be seen in FIGS. 101-104, the distal closure tube segment 3430 includes a lug 3442 that extends from its distal end 3440 into threaded engagement with a variable pitch groove/thread 3414 formed in the distal end 3412 of the rotatable proximal closure tube segment 3410. The variable pitch groove/thread 3414 has a distal section 3416 and a proximal section 3418. The pitch of the distal groove/thread section 3416 is finer than the pitch of the proximal groove/thread section 3418. As can also be seen in FIGS. 101-104, the distal closure tube segment 3430 is constrained for axial movement relative to the spine

member 3420 by an axial retainer pin 3450 that is received in an axial slot 3424 in the distal end of the spine member 3420.

[0336] As indicated above, the anvil 12524 is open and closed by rotating the proximal closure tube segment 3410. The variable pitch thread arrangement permits the distal closure tube segment 3430 to be driven in the distal direction “DD” at a first speed or rate by virtue of the engagement between the lug 3442 and the proximal groove/thread section 3418. When the lug 3442 engages the distal groove/thread section 3416, the distal closure tube segment 3430 will be driven in the distal direction at a second speed or rate. Because the proximal groove/thread section 3418 is coarser than the distal groove/thread segment 3416, the first speed will be greater than the second speed.

[0337] In at least one embodiment, the tool mounting portion 3500 is configured to receive a corresponding first rotary motion from the robotic controller 11001 and convert that first rotary motion to a primary rotary motion for rotating the rotatable proximal closure tube segment 3410 about a longitudinal tool axis LT-LT. As can be seen in FIG. 105, a proximal end 3460 of the proximal closure tube segment 3410 is rotatably supported within a cradle arrangement 3504 attached to a tool mounting plate 3502 of the tool mounting portion 3500. A rotation gear 3462 is formed on or attached to the proximal end 3460 of the closure tube segment 3410 for meshing engagement with a rotation drive assembly 3470 that is operably supported on the tool mounting plate 3502. In at least one embodiment, a rotation drive gear 3472 is coupled to a corresponding first one of the driven discs or elements 11304 on the adapter side of the tool mounting plate 3502 when the tool mounting portion 3500 is coupled to the tool holder 11270. See FIGS. 63 and 105. The rotation drive assembly 3470 further comprises a rotary driven gear 3474 that is rotatably supported on the tool mounting plate 3502 in meshing engagement with the rotation gear 3462 and the rotation drive gear 3472. Application of a first rotary control motion from the robotic controller 11001 through the tool holder 11270 and the adapter 11240 to the corresponding driven element 11304 will thereby cause rotation of the rotation drive gear 3472 by virtue of being operably coupled thereto. Rotation of the rotation drive gear 3472 ultimately results in the rotation of the closure tube segment 3410 to open and close the anvil 3524 as described above.

[0338] As indicated above, the surgical end effector 3412 employs a cutting instrument of the type and constructions described above. FIG. 105 illustrates one form of knife drive assembly 3480 for axially advancing a knife bar 3492 that is attached to such cutting instrument. One form of the knife drive assembly 3480 comprises a rotary drive gear 3482

that is coupled to a corresponding third one of the driven discs or elements 11304 on the adapter side of the tool mounting plate 3502 when the tool drive portion 3500 is coupled to the tool holder 11270. See FIGS. 63 and 105. The knife drive assembly 3480 further comprises a first rotary driven gear assembly 3484 that is rotatably supported on the tool mounting plate 5200. The first rotary driven gear assembly 3484 is in meshing engagement with a third rotary driven gear assembly 3486 that is rotatably supported on the tool mounting plate 3502 and which is in meshing engagement with a fourth rotary driven gear assembly 3488 that is in meshing engagement with a threaded portion 3494 of drive shaft assembly 3490 that is coupled to the knife bar 3492. Rotation of the rotary drive gear 3482 in a second rotary direction will result in the axial advancement of the drive shaft assembly 3490 and knife bar 3492 in the distal direction "DD". Conversely, rotation of the rotary drive gear 3482 in a secondary rotary direction (opposite to the second rotary direction) will cause the drive shaft assembly 3490 and the knife bar 3492 to move in the proximal direction.

[0339] FIGS. 106-115 illustrate another surgical tool 3600 embodiment of the present invention that may be employed in connection with a robotic system 11000. As can be seen in FIG. 106, the tool 3600 includes an end effector in the form of a disposable loading unit 3612. Various forms of disposable loading units that may be employed in connection with tool 3600 are disclosed, for example, in U.S. Patent Application Publication No. US 2009/0206131 A1, entitled "End Effector Arrangements For a Surgical Cutting and Stapling Instrument", the disclosure of which is herein incorporated by reference in its entirety.

[0340] In at least one form, the disposable loading unit 3612 includes an anvil assembly 3620 that is supported for pivotal travel relative to a carrier 3630 that operably supports a staple cartridge 3640 therein. A mounting assembly 3650 is pivotally coupled to the cartridge carrier 3630 to enable the carrier 3630 to pivot about an articulation axis AA-AA relative to a longitudinal tool axis LT-LT. Referring to FIG. 111, mounting assembly 3650 includes upper and lower mounting portions 3652 and 3654. Each mounting portion includes a threaded bore 3656 on each side thereof dimensioned to receive threaded bolts (not shown) for securing the proximal end of carrier 3630 thereto. A pair of centrally located pivot members 3658 extends between upper and lower mounting portions via a pair of coupling members 3660 which engage a distal end of a housing portion 3662. Coupling members 3660 each include an interlocking proximal portion 3664 configured to be received in grooves 3666 formed in the proximal end of housing portion 3662 to retain mounting assembly 3650 and housing portion 3662 in a longitudinally fixed position in relation thereto.

[0341] In various forms, housing portion 3662 of disposable loading unit 3614 includes an upper housing half 3670 and a lower housing half 3672 contained within an outer casing 3674. The proximal end of housing half 3670 includes engagement nubs 3676 for releasably engaging an elongated shaft 3700 and an insertion tip 3678. Nubs 3676 form a bayonet-type coupling with the distal end of the elongated shaft 3700 which will be discussed in further detail below. Housing halves 3670, 3672 define a channel 3674 for slidably receiving axial drive assembly 3680. A second articulation link 3690 is dimensioned to be slidably positioned within a slot 3679 formed between housing halves 3670, 3672. A pair of blow out plates 3691 are positioned adjacent the distal end of housing portion 3662 adjacent the distal end of axial drive assembly 3680 to prevent outward bulging of drive assembly 3680 during articulation of carrier 3630.

[0342] In various embodiments, the second articulation link 3690 includes at least one elongated metallic plate. Preferably, two or more metallic plates are stacked to form link 3690. The proximal end of articulation link 3690 includes a hook portion 3692 configured to engage first articulation link 3710 extending through the elongated shaft 3700. The distal end of the second articulation link 3690 includes a loop 3694 dimensioned to engage a projection formed on mounting assembly 3650. The projection is laterally offset from pivot pin 3658 such that linear movement of second articulation link 3690 causes mounting assembly 3650 to pivot about pivot pins 3658 to articulate the carrier 3630.

[0343] In various forms, axial drive assembly 3680 includes an elongated drive beam 3682 including a distal working head 3684 and a proximal engagement section 3685. Drive beam 3682 may be constructed from a single sheet of material or, preferably, multiple stacked sheets. Engagement section 3685 includes a pair of engagement fingers which are dimensioned and configured to mountingly engage a pair of corresponding retention slots formed in drive member 3686. Drive member 3686 includes a proximal porthole 3687 configured to receive the distal end 3722 of control rod 12720 (See FIG. 115) when the proximal end of disposable loading unit 3614 is engaged with elongated shaft 3700 of surgical tool 3600.

[0344] Referring to FIGS. 106 and 113-115, to use the surgical tool 3600, a disposable loading unit 3612 is first secured to the distal end of elongated shaft 3700. It will be appreciated that the surgical tool 3600 may include an articulating or a non-articulating disposable loading unit. To secure the disposable loading unit 3612 to the elongated shaft 3700, the distal end 3722 of control rod 3720 is inserted into insertion tip 3678 of disposable

loading unit 3612, and insertion tip 3678 is slid longitudinally into the distal end of the elongated shaft 3700 in the direction indicated by arrow "A" in FIG. 113 such that hook portion 3692 of second articulation link 3690 slides within a channel 3702 in the elongated shaft 3700. Nubs 3676 will each be aligned in a respective channel (not shown) in elongated shaft 3700. When hook portion 3692 engages the proximal wall 3704 of channel 3702, disposable loading unit 3612 is rotated in the direction indicated by arrow "B" in FIGS. 112 and 113 to move hook portion 3692 of second articulation link 3690 into engagement with finger 3712 of first articulation link 3710. Nubs 3676 also form a "bayonet-type" coupling within annular channel 3703 in the elongated shaft 3700. During rotation of loading unit 3612, nubs 3676 engage cam surface 3732 (FIG. 113) of block plate 3730 to initially move plate 3730 in the direction indicated by arrow "C" in FIG. 113 to lock engagement member 3734 in recess 3721 of control rod 3720 to prevent longitudinal movement of control rod 3720 during attachment of disposable loading unit 3612. During the final degree of rotation, nubs 3676 disengage from cam surface 3732 to allow blocking plate 3730 to move in the direction indicated by arrow "D" in FIGS. 112 and 115 from behind engagement member 3734 to once again permit longitudinal movement of control rod 3720. While the above-described attachment method reflects that the disposable loading unit 3612 is manipulated relative to the elongated shaft 3700, the person of ordinary skill in the art will appreciate that the disposable loading unit 3612 may be supported in a stationary position and the robotic system 11000 may manipulate the elongated shaft portion 3700 relative to the disposable loading unit 3612 to accomplish the above-described coupling procedure.

[0345] FIG. 116 illustrates another disposable loading unit 3612' that is attachable in a bayonet-type arrangement with the elongated shaft 3700' that is substantially identical to shaft 3700 except for the differences discussed below. As can be seen in FIG. 116, the elongated shaft 3700' has slots 3705 that extend for at least a portion thereof and which are configured to receive nubs 3676 therein. In various embodiments, the disposable loading unit 3612' includes arms 3677 extending therefrom which, prior to the rotation of disposable loading unit 3612', can be aligned, or at least substantially aligned, with nubs 3676 extending from housing portion 3662. In at least one embodiment, arms 3677 and nubs 3676 can be inserted into slots 3705 in elongated shaft 3700', for example, when disposable loading unit 3612' is inserted into elongated shaft 3700'. When disposable loading unit 3612' is rotated, arms 3677 can be sufficiently confined within slots 3705 such that slots 3705 can hold them in position, whereas nubs 3676 can be positioned such that they are not

confined within slots 3705 and can be rotated relative to arms 3677. When rotated, the hook portion 3692 of the articulation link 3690 is engaged with the first articulation link 3710 extending through the elongated shaft 3700'.

[0346] Other methods of coupling the disposable loading units to the end of the elongated shaft may be employed. For example, as shown in FIGS. 117 and 118, disposable loading unit 3612" can include connector portion 3613 which can be configured to be engaged with connector portion 3740 of the elongated shaft 3700". In at least one embodiment, connector portion 3613 can include at least one projection and/or groove which can be mated with at least one projection and/or groove of connector portion 3740. In at least one such embodiment, the connector portions can include co-operating dovetail portions. In various embodiments, the connector portions can be configured to interlock with one another and prevent, or at least inhibit, distal and/or proximal movement of disposable loading unit 3612" along axis 3741. In at least one embodiment, the distal end of the axial drive assembly 3680' can include aperture 3681 which can be configured to receive projection 3721 extending from control rod 3720'. In various embodiments, such an arrangement can allow disposable loading unit 3612" to be assembled to elongated shaft 3700 in a direction which is not collinear with or parallel to axis 3741. Although not illustrated, axial drive assembly 3680' and control rod 3720 can include any other suitable arrangement of projections and apertures to operably connect them to each other. Also in this embodiment, the first articulation link 3710 which can be operably engaged with second articulation link 3690.

[0347] As can be seen in FIGS. 106 and 119, the surgical tool 3600 includes a tool mounting portion 3750. The tool mounting portion 3750 includes a tool mounting plate 3751 that is configured for attachment to the tool drive assembly 11010. The tool mounting portion operably supported a transmission arrangement 3752 thereon. In use, it may be desirable to rotate the disposable loading unit 3612 about the longitudinal tool axis defined by the elongated shaft 3700. In at least one embodiment, the transmission arrangement 3752 includes a rotational transmission assembly 3753 that is configured to receive a corresponding rotary output motion from the tool drive assembly 11010 of the robotic system 11000 and convert that rotary output motion to a rotary control motion for rotating the elongated shaft 3700 (and the disposable loading unit 3612) about the longitudinal tool axis LT-LT. As can be seen in FIG. 119, a proximal end 3701 of the elongated shaft 3700 is rotatably supported within a cradle arrangement 3754 that is attached to the tool mounting plate 3751 of the tool mounting portion 3750. A rotation gear 3755 is formed on or attached

to the proximal end 3701 of the elongated shaft 3700 for meshing engagement with a rotation gear assembly 3756 operably supported on the tool mounting plate 3751. In at least one embodiment, a rotation drive gear 3757 drivingly coupled to a corresponding first one of the driven discs or elements 11304 on the adapter side of the tool mounting plate 3751 when the tool mounting portion 3750 is coupled to the tool drive assembly 11010. The rotation transmission assembly 3753 further comprises a rotary driven gear 3758 that is rotatably supported on the tool mounting plate 3751 in meshing engagement with the rotation gear 3755 and the rotation drive gear 3757. Application of a first rotary output motion from the robotic system 11000 through the tool drive assembly 11010 to the corresponding driven element 11304 will thereby cause rotation of the rotation drive gear 3757 by virtue of being operably coupled thereto. Rotation of the rotation drive gear 3757 ultimately results in the rotation of the elongated shaft 3700 (and the disposable loading unit 3612) about the longitudinal tool axis LT-LT (primary rotary motion).

[0348] As can be seen in FIG. 119, a drive shaft assembly 3760 is coupled to a proximal end of the control rod 12720. In various embodiments, the control rod 12720 is axially advanced in the distal and proximal directions by a knife/closure drive transmission 3762. One form of the knife/closure drive assembly 3762 comprises a rotary drive gear 3763 that is coupled to a corresponding second one of the driven rotatable body portions, discs or elements 11304 on the adapter side of the tool mounting plate 3751 when the tool mounting portion 3750 is coupled to the tool holder 11270. The rotary driven gear 3763 is in meshing driving engagement with a gear train, generally depicted as 3764. In at least one form, the gear train 3764 further comprises a first rotary driven gear assembly 3765 that is rotatably supported on the tool mounting plate 3751. The first rotary driven gear assembly 3765 is in meshing engagement with a second rotary driven gear assembly 3766 that is rotatably supported on the tool mounting plate 3751 and which is in meshing engagement with a third rotary driven gear assembly 3767 that is in meshing engagement with a threaded portion 3768 of the drive shaft assembly 3760. Rotation of the rotary drive gear 3763 in a second rotary direction will result in the axial advancement of the drive shaft assembly 3760 and control rod 12720 in the distal direction "DD". Conversely, rotation of the rotary drive gear 3763 in a secondary rotary direction which is opposite to the second rotary direction will cause the drive shaft assembly 3760 and the control rod 12720 to move in the proximal direction. When the control rod 12720 moves in the distal direction, it drives the drive beam 3682 and the working head 3684 thereof distally through the surgical staple cartridge 3640. As the

working head 3684 is driven distally, it operably engages the anvil 3620 to pivot it to a closed position.

[0349] The cartridge carrier 3630 may be selectively articulated about articulation axis AA-AA by applying axial articulation control motions to the first and second articulation links 3710 and 3690. In various embodiments, the transmission arrangement 3752 further includes an articulation drive 3770 that is operably supported on the tool mounting plate 3751. More specifically and with reference to FIG. 119, it can be seen that a proximal end portion 3772 of an articulation drive shaft 3771 configured to operably engage with the first articulation link 3710 extends through the rotation gear 3755 and is rotatably coupled to a shifter rack gear 3774 that is slidably affixed to the tool mounting plate 3751 through slots 3775. The articulation drive 3770 further comprises a shifter drive gear 3776 that is coupled to a corresponding third one of the driven discs or elements 11304 on the adapter side of the tool mounting plate 3751 when the tool mounting portion 3750 is coupled to the tool holder 11270. The articulation drive assembly 3770 further comprises a shifter driven gear 3778 that is rotatably supported on the tool mounting plate 3751 in meshing engagement with the shifter drive gear 3776 and the shifter rack gear 3774. Application of a third rotary output motion from the robotic system 11000 through the tool drive assembly 11010 to the corresponding driven element 11304 will thereby cause rotation of the shifter drive gear 3776 by virtue of being operably coupled thereto. Rotation of the shifter drive gear 3776 ultimately results in the axial movement of the shifter gear rack 3774 and the articulation drive shaft 3771. The direction of axial travel of the articulation drive shaft 3771 depends upon the direction in which the shifter drive gear 3776 is rotated by the robotic system 11000. Thus, rotation of the shifter drive gear 3776 in a first rotary direction will result in the axial movement of the articulation drive shaft 3771 in the proximal direction "PD" and cause the cartridge carrier 3630 to pivot in a first direction about articulation axis AA-AA. Conversely, rotation of the shifter drive gear 3776 in a second rotary direction (opposite to the first rotary direction) will result in the axial movement of the articulation drive shaft 3771 in the distal direction "DD" to thereby cause the cartridge carrier 3630 to pivot about articulation axis AA-AA in an opposite direction.

[0350] FIG. 120 illustrates yet another surgical tool 3800 embodiment of the present invention that may be employed with a robotic system 11000. As can be seen in FIG. 120, the surgical tool 3800 includes a surgical end effector 3812 in the form of an endocutter 3814 that employs various cable-driven components. Various forms of cable driven endocutters

are disclosed, for example, in U.S. Patent No. 7,726,537, entitled "Surgical Stapler With Universal Articulation and Tissue Pre-Clamp" and U.S. Patent Application Publication No. US 2008/0308603A1, entitled "Cable Driven Surgical Stapling and Cutting Instrument With Improved Cable Attachment Arrangements", the disclosures of each are herein incorporated by reference in their respective entireties. Such endcutters 3814 may be referred to as a "disposable loading unit" because they are designed to be disposed of after a single use. However, the various unique and novel arrangements of various embodiments of the present invention may also be employed in connection with cable driven end effectors that are reusable.

[0351] As can be seen in FIG. 121, in at least one form, the endocutter 3814 includes an elongated channel 3822 that operably supports a surgical staple cartridge 3834 therein. An anvil 3824 is pivotally supported for movement relative to the surgical staple cartridge 3834. The anvil 3824 has a cam surface 3825 that is configured for interaction with a preclamping collar 3840 that is supported for axial movement relative thereto. The end effector 3814 is coupled to an elongated shaft assembly 3808 that is attached to a tool mounting portion 3900. In various embodiments, a closure cable 3850 is employed to move pre-clamping collar 3840 distally onto and over cam surface 3825 to close the anvil 3824 relative to the surgical staple cartridge 3834 and compress the tissue therebetween. Preferably, closure cable 3850 attaches to the pre-clamping collar 3840 at or near point 3841 and is fed through a passageway in anvil 3824 (or under a proximal portion of anvil 3824) and fed proximally through shaft 3808. Actuation of closure cable 3850 in the proximal direction "PD" forces pre-clamping collar 3840 distally against cam surface 3825 to close anvil 3824 relative to staple cartridge assembly 3834. A return mechanism, e.g., a spring, cable system or the like, may be employed to return pre-clamping collar 3840 to a pre-clamping orientation which re-opens the anvil 3824.

[0352] The elongated shaft assembly 3808 may be cylindrical in shape and define a channel 3811 which may be dimensioned to receive a tube adapter 3870. See FIG. 121. In various embodiments, the tube adapter 3870 may be slidingly received in friction-fit engagement with the internal channel of elongated shaft 3808. The outer surface of the tube adapter 3870 may further include at least one mechanical interface, e.g., a cutout or notch 3871, oriented to mate with a corresponding mechanical interface, e.g., a radially inwardly extending protrusion or detent (not shown), disposed on the inner periphery of internal channel 3811 to lock the tube adapter 3870 to the elongated shaft 3808. In various embodiments, the distal

end of tube adapter 3870 may include a pair of opposing flanges 3872a and 3872b which define a cavity for pivotably receiving a pivot block 3873 therein. Each flange 3872a and 3872b may include an aperture 3874a and 3874b that is oriented to receive a pivot pin 3875 that extends through an aperture in pivot block 3873 to allow pivotable movement of pivot block 3873 about an axis that is perpendicular to longitudinal tool axis "LT-LT". The channel 3822 may be formed with two upwardly extending flanges 3823a, 3823b that have apertures therein, which are dimensioned to receive a pivot pin 3827. In turn, pivot pin 3875 mounts through apertures in pivot block 3873 to permit rotation of the surgical end effector 3814 about the "Y" axis as needed during a given surgical procedure. Rotation of pivot block 3873 about pin 3875 along "Z" axis rotates the surgical end effector 3814 about the "Z" axis. See FIG. 121. Other methods of fastening the elongated channel 3822 to the pivot block 3873 may be effectively employed without departing from the spirit and scope of the present invention.

[0353] The surgical staple cartridge 3834 can be assembled and mounted within the elongated channel 3822 during the manufacturing or assembly process and sold as part of the surgical end effector 3812, or the surgical staple cartridge 3834 may be designed for selective mounting within the elongated channel 3822 as needed and sold separately, e.g., as a single use replacement, replaceable or disposable staple cartridge assembly. It is within the scope of this disclosure that the surgical end effector 3812 may be pivotally, operatively, or integrally attached, for example, to distal end 3809 of the elongated shaft assembly 3808 of a disposable surgical stapler. As is known, a used or spent disposable loading unit 3814 can be removed from the elongated shaft assembly 3808 and replaced with an unused disposable unit. The endocutter 3814 may also preferably include an actuator, preferably a dynamic clamping member 3860, a sled 3862, as well as staple pushers (not shown) and staples (not shown) once an unspent or unused cartridge 3834 is mounted in the elongated channel 3822. See FIG. 121.

[0354] In various embodiments, the dynamic clamping member 3860 is associated with, e.g., mounted on and rides on, or with or is connected to or integral with and/or rides behind sled 3862. It is envisioned that dynamic clamping member 3860 can have cam wedges or cam surfaces attached or integrally formed or be pushed by a leading distal surface thereof. In various embodiments, dynamic clamping member 3860 may include an upper portion 3863 having a transverse aperture 3864 with a pin 3865 mountable or mounted therein, a central support or upward extension 3866 and substantially T-shaped bottom flange 3867

which cooperate to slidingly retain dynamic clamping member 3860 along an ideal cutting path during longitudinal, distal movement of sled 3862. The leading cutting edge 3868, here, knife blade 3869, is dimensioned to ride within slot 3835 of staple cartridge assembly 3834 and separate tissue once stapled. As used herein, the term "knife assembly" may include the aforementioned dynamic clamping member 3860, knife 3869, and sled 3862 or other knife/beam/sled drive arrangements and cutting instrument arrangements. In addition, the various embodiments of the present invention may be employed with knife assembly/cutting instrument arrangements that may be entirely supported in the staple cartridge 3834 or partially supported in the staple cartridge 3834 and elongated channel 3822 or entirely supported within the elongated channel 3822.

[0355] In various embodiments, the dynamic clamping member 3860 may be driven in the proximal and distal directions by a cable drive assembly 3870. In one non-limiting form, the cable drive assembly comprises a pair of advance cables 3880, 3882 and a firing cable 3884. FIGS. 122 and 123 illustrate the cables 3880, 3882, 3884 in diagrammatic form. As can be seen in those Figures, a first advance cable 3880 is operably supported on a first distal cable transition support 3885 which may comprise, for example, a pulley, rod, capstan, etc. that is attached to the distal end of the elongated channel 3822 and a first proximal cable transition support 3886 which may comprise, for example, a pulley, rod, capstan, etc. that is operably supported by the elongated channel 3822. A distal end 3881 of the first advance cable 3880 is affixed to the dynamic clamping assembly 3860. The second advance cable 3882 is operably supported on a second distal cable transition support 3887 which may, for example, comprise a pulley, rod, capstan etc. that is mounted to the distal end of the elongated channel 3822 and a second proximal cable transition support 3888 which may, for example, comprise a pulley, rod, capstan, etc. mounted to the proximal end of the elongated channel 3822. The proximal end 3883 of the second advance cable 3882 may be attached to the dynamic clamping assembly 3860. Also in these embodiments, an endless firing cable 3884 is employed and journaled on a support 3889 that may comprise a pulley, rod, capstan, etc. mounted within the elongated shaft 3808. In one embodiment, the retract cable 3884 may be formed in a loop and coupled to a connector 3889' that is fixedly attached to the first and second advance cables 3880, 3882.

[0356] Various non-limiting embodiments of the present invention include a cable drive transmission 3920 that is operably supported on a tool mounting plate 3902 of the tool mounting portion 3900. The tool mounting portion 3900 has an array of electrical connecting

pins 3904 which are configured to interface with the slots 11258 (FIG. 62) in the adapter 11240'. Such arrangement permits the robotic system 11000 to provide control signals to a control circuit 3910 of the tool 3800. While the interface is described herein with reference to mechanical, electrical, and magnetic coupling elements, it should be understood that a wide variety of telemetry modalities might be used, including infrared, inductive coupling, or the like.

[0357] Control circuit 3910 is shown in schematic form in FIG. 120. In one form or embodiment, the control circuit 3910 includes a power supply in the form of a battery 3912 that is coupled to an on-off solenoid powered switch 3914. In other embodiments, however, the power supply may comprise a source of alternating current. Control circuit 3910 further includes an on/off solenoid 3916 that is coupled to a double pole switch 3918 for controlling motor rotation direction. Thus, when the robotic system 11000 supplies an appropriate control signal, switch 3914 will permit battery 3912 to supply power to the double pole switch 3918. The robotic system 11000 will also supply an appropriate signal to the double pole switch 3918 to supply power to a shifter motor 3922.

[0358] Turning to FIGS. 124-129, at least one embodiment of the cable drive transmission 3920 comprises a drive pulley 3930 that is operably mounted to a drive shaft 3932 that is attached to a driven element 11304 of the type and construction described above that is designed to interface with a corresponding drive element 11250 of the adapter 11240. See FIGS. 62 and 127. Thus, when the tool mounting portion 3900 is operably coupled to the tool holder 11270, the robot system 11000 can apply rotary motion to the drive pulley 3930 in a desired direction. A first drive member or belt 3934 drivingly engages the drive pulley 3930 and a second drive shaft 3936 that is rotatably supported on a shifter yoke 3940. The shifter yoke 3940 is operably coupled to the shifter motor 3922 such that rotation of the shaft 3923 of the shifter motor 3922 in a first direction will shift the shifter yoke in a first direction "FD" and rotation of the shifter motor shaft 3923 in a second direction will shift the shifter yoke 3940 in a second direction "SD". Other embodiments of the present invention may employ a shifter solenoid arrangement for shifting the shifter yoke in said first and second directions.

[0359] As can be seen in FIGS. 124-127, a closure drive gear 3950 mounted to a second drive shaft 3936 and is configured to selectively mesh with a closure drive assembly, generally designated as 3951. Likewise a firing drive gear 3960 is also mounted to the second drive shaft 3936 and is configured to selectively mesh with a firing drive assembly

generally designated as 3961. Rotation of the second drive shaft 3936 causes the closure drive gear 3950 and the firing drive gear 3960 to rotate. In one non-limiting embodiment, the closure drive assembly 3951 comprises a closure driven gear 3952 that is coupled to a first closure pulley 3954 that is rotatably supported on a third drive shaft 3956. The closure cable 3850 is drivingly received on the first closure pulley 3954 such that rotation of the closure driven gear 3952 will drive the closure cable 3850. Likewise, the firing drive assembly 3961 comprises a firing driven gear 3962 that is coupled to a first firing pulley 3964 that is rotatably supported on the third drive shaft 3956. The first and second driving pulleys 3954 and 3964 are independently rotatable on the third drive shaft 3956. The firing cable 3884 is drivingly received on the first firing pulley 3964 such that rotation of the firing driven gear 3962 will drive the firing cable 3884.

[0360] Also in various embodiments, the cable drive transmission 3920 further includes a braking assembly 3970. In at least one embodiment, for example, the braking assembly 3970 includes a closure brake 3972 that comprises a spring arm 3973 that is attached to a portion of the transmission housing 3971. The closure brake 3972 has a gear lug 3974 that is sized to engage the teeth of the closure driven gear 3952 as will be discussed in further detail below. The braking assembly 3970 further includes a firing brake 3976 that comprises a spring arm 3977 that is attached to another portion of the transmission housing 3971. The firing brake 3976 has a gear lug 3978 that is sized to engage the teeth of the firing driven gear 3962.

[0361] At least one embodiment of the surgical tool 3800 may be used as follows. The tool mounting portion 3900 is operably coupled to the interface 11240 of the robotic system 11000. The controller or control unit of the robotic system is operated to locate the tissue to be cut and stapled between the open anvil 3824 and the staple cartridge 3834. When in that initial position, the braking assembly 3970 has locked the closure driven gear 3952 and the firing driven gear 3962 such that they cannot rotate. That is, as shown in FIG. 125, the gear lug 3974 is in locking engagement with the closure driven gear 3952 and the gear lug 3978 is in locking engagement with the firing driven gear 3962. Once the surgical end effector 3814 has been properly located, the controller 11001 of the robotic system 11000 will provide a control signal to the shifter motor 3922 (or shifter solenoid) to move the shifter yoke 3940 in the first direction. As the shifter yoke 3940 is moved in the first direction, the closure drive gear 3950 moves the gear lug 3974 out of engagement with the closure driven gear 3952 as it moves into meshing engagement with the closure driven gear 3952. As can be seen in FIG. 124, when in that position, the gear lug 3978 remains in locking engagement with the firing

driven gear 3962 to prevent actuation of the firing system. Thereafter, the robotic controller 11001 provides a first rotary actuation motion to the drive pulley 3930 through the interface between the driven element 11304 and the corresponding components of the tool holder 11240. As the drive pulley 3930 is rotated in the first direction, the closure cable 3850 is rotated to drive the preclamping collar 3840 into closing engagement with the cam surface 3825 of the anvil 3824 to move it to the closed position thereby clamping the target tissue between the anvil 3824 and the staple cartridge 3834. See FIG. 120. Once the anvil 3824 has been moved to the closed position, the robotic controller 11001 stops the application of the first rotary motion to the drive pulley 3930. Thereafter, the robotic controller 11001 may commence the firing process by sending another control signal to the shifter motor 3922 (or shifter solenoid) to cause the shifter yoke to move in the second direction "SD" as shown in FIG. 126. As the shifter yoke 3940 is moved in the second direction, the firing drive gear 3960 moves the gear lug 3978 out of engagement with the firing driven gear 3962 as it moves into meshing engagement with the firing driven gear 3962. As can be seen in FIG. 126, when in that position, the gear lug 3974 remains in locking engagement with the closure driven gear 3952 to prevent actuation of the closure system. Thereafter, the robotic controller 11001 is activated to provide the first rotary actuation motion to the drive pulley 3930 through the interface between the driven element 11304 and the corresponding components of the tool holder 11240. As the drive pulley 3930 is rotated in the first direction, the firing cable 3884 is rotated to drive the dynamic clamping member 3860 in the distal direction "DD" thereby firing the staples and cutting the tissue clamped in the end effector 3814. Once the robotic system 11000 determines that the dynamic clamping member 3860 has reached its distal most position – either through sensors or through monitoring the amount of rotary input applied to the drive pulley 3930, the controller 11001 may then apply a second rotary motion to the drive pulley 3930 to rotate the closure cable 3850 in an opposite direction to cause the dynamic clamping member 3860 to be retracted in the proximal direction "PD". Once the dynamic clamping member has been retracted to the starting position, the application of the second rotary motion to the drive pulley 3930 is discontinued. Thereafter, the shifter motor 3922 (or shifter solenoid) is powered to move the shifter yoke 3940 to the closure position (FIG 92.). Once the closure drive gear 3950 is in meshing engagement with the closure driven gear 3952, the robotic controller 11001 may once again apply the second rotary motion to the drive pulley 3930. Rotation of the drive pulley 3930 in the second direction causes the closure cable 3850 to retract the preclamping collar 3840 out of engagement with

the cam surface 3825 of the anvil 3824 to permit the anvil 3824 to move to an open position (by a spring or other means) to release the stapled tissue from the surgical end effector 3814.

[0362] FIG. 130 illustrates a surgical tool 4000 that employs a gear driven firing bar 4092 as shown in FIGS. 131-133. This embodiment includes an elongated shaft assembly 4008 that extends from a tool mounting portion 4100. The tool mounting portion 4100 includes a tool mounting plate 4102 that operable supports a transmission arrangement 4103 thereon. The elongated shaft assembly 4008 includes a rotatable proximal closure tube 4010 that is rotatably journaled on a proximal spine member 4020 that is rigidly coupled to the tool mounting plate 4102. The proximal spine member 4020 has a distal end that is coupled to an elongated channel portion 4022 of a surgical end effector 4012. The surgical effector 4012 may be substantially similar to surgical end effector 3412 described above. In addition, the anvil 4024 of the surgical end effector 4012 may be opened and closed by a distal closure tube 4030 that operably interfaces with the proximal closure tube 4010. Distal closure tube 4030 is identical to distal closure tube 3430 described above. Similarly, proximal closure tube 4010 is identical to proximal closure tube segment 3410 described above.

[0363] Anvil 4024 is opened and closed by rotating the proximal closure tube 4010 in manner described above with respect to distal closure tube 3410. In at least one embodiment, the transmission arrangement comprises a closure transmission, generally designated as 4011. As will be further discussed below, the closure transmission 4011 is configured to receive a corresponding first rotary motion from the robotic system 11000 and convert that first rotary motion to a primary rotary motion for rotating the rotatable proximal closure tube 4010 about the longitudinal tool axis LT-LT. As can be seen in FIG. 133, a proximal end 4060 of the proximal closure tube 4010 is rotatably supported within a cradle arrangement 4104 that is attached to a tool mounting plate 4102 of the tool mounting portion 4100. A rotation gear 4062 is formed on or attached to the proximal end 4060 of the closure tube segment 4010 for meshing engagement with a rotation drive assembly 4070 that is operably supported on the tool mounting plate 4102. In at least one embodiment, a rotation drive gear 4072 is coupled to a corresponding first one of the driven discs or elements 11304 on the adapter side of the tool mounting plate 4102 when the tool mounting portion 4100 is coupled to the tool holder 11270. See FIGS. 63 and 133. The rotation drive assembly 4070 further comprises a rotary driven gear 4074 that is rotatably supported on the tool mounting plate 4102 in meshing engagement with the rotation gear 4062 and the rotation drive gear 4072. Application of a first rotary control motion from the robotic system 11000 through the tool holder 11270 and

the adapter 11240 to the corresponding driven element 11304 will thereby cause rotation of the rotation drive gear 4072 by virtue of being operably coupled thereto. Rotation of the rotation drive gear 4072 ultimately results in the rotation of the closure tube segment 4010 to open and close the anvil 4024 as described above.

[0364] As indicated above, the end effector 4012 employs a cutting element 3860 as shown in FIGS. 131 and 132. In at least one non-limiting embodiment, the transmission arrangement 4103 further comprises a knife drive transmission that includes a knife drive assembly 4080. FIG. 133 illustrates one form of knife drive assembly 4080 for axially advancing the knife bar 4092 that is attached to such cutting element using cables as described above with respect to surgical tool 3800. In particular, the knife bar 4092 replaces the firing cable 3884 employed in an embodiment of surgical tool 3800. One form of the knife drive assembly 4080 comprises a rotary drive gear 4082 that is coupled to a corresponding second one of the driven discs or elements 11304 on the adapter side of the tool mounting plate 4102 when the tool mounting portion 4100 is coupled to the tool holder 11270. See FIGS. 63 and 133. The knife drive assembly 4080 further comprises a first rotary driven gear assembly 4084 that is rotatably supported on the tool mounting plate 4102. The first rotary driven gear assembly 4084 is in meshing engagement with a third rotary driven gear assembly 4086 that is rotatably supported on the tool mounting plate 4102 and which is in meshing engagement with a fourth rotary driven gear assembly 4088 that is in meshing engagement with a threaded portion 4094 of drive shaft assembly 4090 that is coupled to the knife bar 4092. Rotation of the rotary drive gear 4082 in a second rotary direction will result in the axial advancement of the drive shaft assembly 4090 and knife bar 4092 in the distal direction "DD". Conversely, rotation of the rotary drive gear 4082 in a secondary rotary direction (opposite to the second rotary direction) will cause the drive shaft assembly 4090 and the knife bar 4092 to move in the proximal direction. Movement of the firing bar 4092 in the proximal direction "PD" will drive the cutting element 3860 in the distal direction "DD". Conversely, movement of the firing bar 4092 in the distal direction "DD" will result in the movement of the cutting element 3860 in the proximal direction "PD".

[0365] FIGS. 134-140 illustrate yet another surgical tool 5000 that may be effectively employed in connection with a robotic system 11000. In various forms, the surgical tool 5000 includes a surgical end effector 5012 in the form of a surgical stapling instrument that includes an elongated channel 5020 and a pivotally translatable clamping member, such as an

anvil 5070, which are maintained at a spacing that assures effective stapling and severing of tissue clamped in the surgical end effector 5012. As can be seen in FIG. 136, the elongated channel 5020 may be substantially U-shaped in cross-section and be fabricated from, for example, titanium, 203 stainless steel, 304 stainless steel, 416 stainless steel, 17-4 stainless steel, 17-7 stainless steel, 6061 or 7075 aluminum, chromium steel, ceramic, etc. A substantially U-shaped metal channel pan 5022 may be supported in the bottom of the elongated channel 5020 as shown.

[0366] Various embodiments include an actuation member in the form of a sled assembly 5030 that is operably supported within the surgical end effector 5012 and axially movable therein between a starting position and an ending position in response to control motions applied thereto. In some forms, the metal channel pan 5022 has a centrally-disposed slot 5024 therein to movably accommodate a base portion 5032 of the sled assembly 5030. The base portion 5032 includes a foot portion 5034 that is sized to be slidably received in a slot 5021 in the elongated channel 5020. See FIG. 136. As can be seen in FIGS. 135, 136, 139, and 140, the base portion 5032 of sled assembly 5030 includes an axially extending threaded bore 5036 that is configured to be threadedly received on a threaded drive shaft 5130 as will be discussed in further detail below. In addition, the sled assembly 5030 includes an upstanding support portion 5038 that supports a tissue cutting blade or tissue cutting instrument 5040. The upstanding support portion 5038 terminates in a top portion 5042 that has a pair of laterally extending retaining fins 5044 protruding therefrom. As shown in FIG. 136, the fins 5044 are positioned to be received within corresponding slots 5072 in anvil 5070. The fins 5044 and the foot 5034 serve to retain the anvil 5070 in a desired spaced closed position as the sled assembly 5030 is driven distally through the tissue clamped within the surgical end effector 5014. As can also be seen in FIGS. 138 and 140, the sled assembly 5030 further includes a reciprocatably or sequentially activatable drive assembly 5050 for driving staple pushers toward the closed anvil 5070.

[0367] More specifically and with reference to FIGS. 136 and 137, the elongated channel 5020 is configured to operably support a surgical staple cartridge 5080 therein. In at least one form, the surgical staple cartridge 5080 comprises a body portion 5082 that may be fabricated from, for example, Vectra, Nylon (6/6 or 6/12) and include a centrally disposed slot 5084 for accommodating the upstanding support portion 5038 of the sled assembly 5030. See FIG. 136. These materials could also be filled with glass, carbon, or mineral fill of 10%-40%. The surgical staple cartridge 5080 further includes a plurality of cavities 5086 for

movably supporting lines or rows of staple-supporting pushers 5088 therein. The cavities 5086 may be arranged in spaced longitudinally extending lines or rows 5090, 5092, 5094, 5096. For example, the rows 5090 may be referred to herein as first outboard rows. The rows 5092 may be referred to herein as first inboard rows. The rows 5094 may be referred to as second inboard rows and the rows 5096 may be referred to as second outboard rows. The first inboard row 5090 and the first outboard row 5092 are located on a first lateral side of the longitudinal slot 5084 and the second inboard row 5094 and the second outboard row 5096 are located on a second lateral side of the longitudinal slot 5084. The first staple pushers 5088 in the first inboard row 5092 are staggered in relationship to the first staple pushers 5088 in the first outboard row 5090. Similarly, the second staple pushers 5088 in the second outboard row 5096 are staggered in relationship to the second pushers 5088 in the second inboard row 5094. Each pusher 5088 operably supports a surgical staple 5098 thereon.

[0368] In various embodiments, the sequentially-activatable or reciprocatably-activatable drive assembly 5050 includes a pair of outboard drivers 5052 and a pair of inboard drivers 5054 that are each attached to a common shaft 5056 that is rotatably mounted within the base 5032 of the sled assembly 5030. The outboard drivers 5052 are oriented to sequentially or reciprocatingly engage a corresponding plurality of outboard activation cavities 5026 provided in the channel pan 5022. Likewise, the inboard drivers 5054 are oriented to sequentially or reciprocatingly engage a corresponding plurality of inboard activation cavities 5028 provided in the channel pan 5022. The inboard activation cavities 5028 are arranged in a staggered relationship relative to the adjacent outboard activation cavities 5026. See FIG. 137. As can also be seen in FIGS. 137 and 139, in at least one embodiment, the sled assembly 5030 further includes distal wedge segments 5060 and intermediate wedge segments 5062 located on each side of the bore 5036 to engage the pushers 5088 as the sled assembly 5030 is driven distally in the distal direction "DD". As indicated above, the sled assembly 5030 is threadedly received on a threaded portion 5132 of a drive shaft 5130 that is rotatably supported within the end effector 5012. In various embodiments, for example, the drive shaft 5130 has a distal end 5134 that is supported in a distal bearing 5136 mounted in the surgical end effector 5012. See FIGS. 136 and 137.

[0369] In various embodiments, the surgical end effector 5012 is coupled to a tool mounting portion 5200 by an elongated shaft assembly 5108. In at least one embodiment, the tool mounting portion 5200 operably supports a transmission arrangement generally designated as 5204 that is configured to receive rotary output motions from the robotic

system. The elongated shaft assembly 5108 includes an outer closure tube 5110 that is rotatable and axially movable on a spine member 5120 that is rigidly coupled to a tool mounting plate 5201 of the tool mounting portion 5200. The spine member 5120 also has a distal end 5122 that is coupled to the elongated channel portion 5020 of the surgical end effector 5012.

[0370] In use, it may be desirable to rotate the surgical end effector 5012 about a longitudinal tool axis LT-LT defined by the elongated shaft assembly 5008. In various embodiments, the outer closure tube 5110 has a proximal end 5112 that is rotatably supported on the tool mounting plate 5201 of the tool drive portion 5200 by a forward support cradle 5203. The proximal end 5112 of the outer closure tube 5110 is configured to operably interface with a rotation transmission portion 5206 of the transmission arrangement 5204. In various embodiments, the proximal end 5112 of the outer closure tube 5110 is also supported on a closure sled 5140 that is also movably supported on the tool mounting plate 5201. A closure tube gear segment 5114 is formed on the proximal end 5112 of the outer closure tube 5110 for meshing engagement with a rotation drive assembly 5150 of the rotation transmission 5206. As can be seen in FIG. 134, the rotation drive assembly 5150, in at least one embodiment, comprises a rotation drive gear 5152 that is coupled to a corresponding first one of the driven discs or elements 11304 on the adapter side 11307 of the tool mounting plate 5201 when the tool drive portion 5200 is coupled to the tool holder 11270. The rotation drive assembly 5150 further comprises a rotary driven gear 5154 that is rotatably supported on the tool mounting plate 5201 in meshing engagement with the closure tube gear segment 5114 and the rotation drive gear 5152. Application of a first rotary control motion from the robotic system 11000 through the tool holder 11270 and the adapter 11240 to the corresponding driven element 11304 will thereby cause rotation of the rotation drive gear 5152. Rotation of the rotation drive gear 5152 ultimately results in the rotation of the elongated shaft assembly 5108 (and the end effector 5012) about the longitudinal tool axis LT-LT (represented by arrow "R" in FIG. 134).

[0371] Closure of the anvil 5070 relative to the surgical staple cartridge 5080 is accomplished by axially moving the outer closure tube 5110 in the distal direction "DD". Such axial movement of the outer closure tube 5110 may be accomplished by a closure transmission portion 5144 of the transmission arrangement 5204. As indicated above, in various embodiments, the proximal end 5112 of the outer closure tube 5110 is supported by the closure sled 5140 which enables the proximal end 5112 to rotate relative thereto, yet

travel axially with the closure sled 5140. In particular, as can be seen in FIG. 134, the closure sled 5140 has an upstanding tab 5141 that extends into a radial groove 5115 in the proximal end portion 5112 of the outer closure tube 5110. In addition, as was described above, the closure sled 5140 is slidably mounted to the tool mounting plate 5201. In various embodiments, the closure sled 5140 has an upstanding portion 5142 that has a closure rack gear 5143 formed thereon. The closure rack gear 5143 is configured for driving engagement with the closure transmission 5144.

[0372] In various forms, the closure transmission 5144 includes a closure spur gear 5145 that is coupled to a corresponding second one of the driven discs or elements 11304 on the adapter side 11307 of the tool mounting plate 5201. Thus, application of a second rotary control motion from the robotic system 11000 through the tool holder 11270 and the adapter 11240 to the corresponding second driven element 11304 will cause rotation of the closure spur gear 5145 when the interface 11230 is coupled to the tool mounting portion 5200. The closure transmission 5144 further includes a driven closure gear set 5146 that is supported in meshing engagement with the closure spur gear 5145 and the closure rack gear 5143. Thus, application of a second rotary control motion from the robotic system 11000 through the tool holder 11270 and the adapter 11240 to the corresponding second driven element 11304 will cause rotation of the closure spur gear 5145 and ultimately drive the closure sled 5140 and the outer closure tube 5110 axially. The axial direction in which the closure tube 5110 moves ultimately depends upon the direction in which the second driven element 11304 is rotated. For example, in response to one rotary closure motion received from the robotic system 11000, the closure sled 5140 will be driven in the distal direction “DD” and ultimately the outer closure tube 5110 will be driven in the distal direction as well. The outer closure tube 5110 has an opening 5117 in the distal end 5116 that is configured for engagement with a tab 5071 on the anvil 5070 in the manners described above. As the outer closure tube 5110 is driven distally, the proximal end 5116 of the closure tube 5110 will contact the anvil 5070 and pivot it closed. Upon application of an “opening” rotary motion from the robotic system 11000, the closure sled 5140 and outer closure tube 5110 will be driven in the proximal direction “PD” and pivot the anvil 5070 to the open position in the manners described above.

[0373] In at least one embodiment, the drive shaft 5130 has a proximal end 5137 that has a proximal shaft gear 5138 attached thereto. The proximal shaft gear 5138 is supported in meshing engagement with a distal drive gear 5162 attached to a rotary drive bar 5160 that is rotatably supported with spine member 5120. Rotation of the rotary drive bar 5160 and

ultimately rotary drive shaft 5130 is controlled by a rotary knife transmission 5207 which comprises a portion of the transmission arrangement 5204 supported on the tool mounting plate 5210. In various embodiments, the rotary knife transmission 5207 comprises a rotary knife drive system 5170 that is operably supported on the tool mounting plate 5201. In various embodiments, the knife drive system 5170 includes a rotary drive gear 5172 that is coupled to a corresponding third one of the driven discs or elements 11304 on the adapter side of the tool mounting plate 5201 when the tool drive portion 5200 is coupled to the tool holder 11270. The knife drive system 5170 further comprises a first rotary driven gear 5174 that is rotatably supported on the tool mounting plate 5201 in meshing engagement with a second rotary driven gear 5176 and the rotary drive gear 5172. The second rotary driven gear 5176 is coupled to a proximal end portion 5164 of the rotary drive bar 5160.

[0374] Rotation of the rotary drive gear 5172 in a first rotary direction will result in the rotation of the rotary drive bar 5160 and rotary drive shaft 5130 in a first direction. Conversely, rotation of the rotary drive gear 5172 in a second rotary direction (opposite to the first rotary direction) will cause the rotary drive bar 5160 and rotary drive shaft 5130 to rotate in a second direction. Thus, rotation of the drive shaft 5130 results in rotation of the drive sleeve 12400.

[0375] One method of operating the surgical tool 5000 will now be described. The tool drive 5200 is operably coupled to the interface 11240 of the robotic system 11000. The controller 11001 of the robotic system 11000 is operated to locate the tissue to be cut and stapled between the open anvil 5070 and the surgical staple cartridge 5080. Once the surgical end effector 5012 has been positioned by the robot system 11000 such that the target tissue is located between the anvil 5070 and the surgical staple cartridge 5080, the controller 11001 of the robotic system 11000 may be activated to apply the second rotary output motion to the second driven element 11304 coupled to the closure spur gear 5145 to drive the closure sled 5140 and the outer closure tube 5110 axially in the distal direction to pivot the anvil 5070 closed in the manner described above. Once the robotic controller 11001 determines that the anvil 5070 has been closed by, for example, sensors in the surgical end effector 5012 and/or the tool drive portion 5200, the robotic controller 11001 system may provide the surgeon with an indication that signifies the closure of the anvil. Such indication may be, for example, in the form of a light and/or audible sound, tactile feedback on the control members, etc. Then the surgeon may initiate the firing process. In alternative embodiments, however, the robotic controller 11001 may automatically commence the firing process.

[0376] To commence the firing process, the robotic controller applies a third rotary output motion to the third driven disc or element 11304 coupled to the rotary drive gear 5172. Rotation of the rotary drive gear 5172 results in the rotation of the rotary drive bar 5160 and rotary drive shaft 5130 in the manner described above. Firing and formation of the surgical staples 5098 can be best understood from reference to FIGS. 135, 137, and 138. As the sled assembly 5030 is driven in the distal direction “DD” through the surgical staple cartridge 5080, the distal wedge segments 5060 first contact the staple pushers 5088 and start to move them toward the closed anvil 5070. As the sled assembly 5030 continues to move distally, the outboard drivers 5052 will drop into the corresponding activation cavity 5026 in the channel pan 5022. The opposite end of each outboard driver 5052 will then contact the corresponding outboard pusher 5088 that has moved up the distal and intermediate wedge segments 5060, 5062. Further distal movement of the sled assembly 5030 causes the outboard drivers 5052 to rotate and drive the corresponding pushers 5088 toward the anvil 5070 to cause the staples 5098 supported thereon to be formed as they are driven into the anvil 5070. It will be understood that as the sled assembly 5030 moves distally, the knife blade 5040 cuts through the tissue that is clamped between the anvil and the staple cartridge. Because the inboard drivers 5054 and outboard drivers 5052 are attached to the same shaft 5056 and the inboard drivers 5054 are radially offset from the outboard drivers 5052 on the shaft 5056, as the outboard drivers 5052 are driving their corresponding pushers 5088 toward the anvil 5070, the inboard drivers 5054 drop into their next corresponding activation cavity 5028 to cause them to rotatably or reciprocatingly drive the corresponding inboard pushers 5088 towards the closed anvil 5070 in the same manner. Thus, the laterally corresponding outboard staples 5098 on each side of the centrally disposed slot 5084 are simultaneously formed together and the laterally corresponding inboard staples 5098 on each side of the slot 5084 are simultaneously formed together as the sled assembly 5030 is driven distally. Once the robotic controller 11001 determines that the sled assembly 5030 has reached its distal most position – either through sensors or through monitoring the amount of rotary input applied to the drive shaft 5130 and/or the rotary drive bar 5160, the controller 11001 may then apply a third rotary output motion to the drive shaft 5130 to rotate the drive shaft 5130 in an opposite direction to retract the sled assembly 5030 back to its starting position. Once the sled assembly 5030 has been retracted to the starting position (as signaled by sensors in the end effector 5012 and/or the tool drive portion 5200), the application of the second rotary motion to the drive shaft 5130 is discontinued. Thereafter, the surgeon may manually activate the anvil opening process or it may be automatically commenced by the robotic

controller 11001. To open the anvil 5070, the second rotary output motion is applied to the closure spur gear 5145 to drive the closure sled 5140 and the outer closure tube 5110 axially in the proximal direction. As the closure tube 5110 moves proximally, the opening 5117 in the distal end 5116 of the closure tube 5110 contacts the tab 5071 on the anvil 5070 to pivot the anvil 5070 to the open position. A spring may also be employed to bias the anvil 5070 to the open position when the closure tube 5116 has been returned to the starting position.

Again, sensors in the surgical end effector 5012 and/or the tool mounting portion 5200 may provide the robotic controller 11001 with a signal indicating that the anvil 5070 is now open. Thereafter, the surgical end effector 5012 may be withdrawn from the surgical site.

[0377] FIGS. 141-146 diagrammatically depict the sequential firing of staples in a surgical tool assembly 5000' that is substantially similar to the surgical tool assembly 5000 described above. In this embodiment, the inboard and outboard drivers 5052', 5054' have a cam-like shape with a cam surface 5053 and an actuator protrusion 5055 as shown in FIGS. 141-147. The drivers 5052', 5054' are journaled on the same shaft 5056' that is rotatably supported by the sled assembly 5030'. In this embodiment, the sled assembly 5030' has distal wedge segments 5060' for engaging the pushers 5088. FIG. 141 illustrates an initial position of two inboard or outboard drivers 5052', 5054' as the sled assembly 5030' is driven in the distal direction "DD". As can be seen in that Figure, the pusher 5088a has advanced up the wedge segment 5060' and has contacted the driver 5052', 5054'. Further travel of the sled assembly 5030' in the distal direction causes the driver 5052', 5054' to pivot in the "P" direction (FIG. 110) until the actuator portion 5055 contacts the end wall 5029a of the activation cavity 5026, 5028 as shown in FIG. 143. Continued advancement of the sled assembly 5030' in the distal direction "DD" causes the driver 5052', 5054' to rotate in the "D" direction as shown in FIG. 144. As the driver 5052', 5054' rotates, the pusher 5088a rides up the cam surface 5053 to the final vertical position shown in FIG. 145. When the pusher 5088a reaches the final vertical position shown in FIGS. 145 and 146, the staple (not shown) supported thereon has been driven into the staple forming surface of the anvil to form the staple.

[0378] FIGS. 148-153 illustrate a surgical end effector 5312 that may be employed for example, in connection with the tool mounting portion 11300 and shaft 12008 described in detail above. In various forms, the surgical end effector 5312 includes an elongated channel 5322 that is constructed as described above for supporting a surgical staple cartridge 5330 therein. The surgical staple cartridge 5330 comprises a body portion 5332 that includes a centrally disposed slot 5334 for accommodating an upstanding support portion 5386 of a sled

assembly 5380. See FIGS. 148-150. The surgical staple cartridge body portion 5332 further includes a plurality of cavities 5336 for movably supporting staple-supporting pushers 5350 therein. The cavities 5336 may be arranged in spaced longitudinally extending rows 5340, 5342, 5344, 5346. The rows 5340, 5342 are located on one lateral side of the longitudinal slot 5334 and the rows 5344, 5346 are located on the other side of longitudinal slot 5334. In at least one embodiment, the pushers 5350 are configured to support two surgical staples 5352 thereon. In particular, each pusher 5350 located on one side of the elongated slot 5334 supports one staple 5352 in row 5340 and one staple 5352 in row 5342 in a staggered orientation. Likewise, each pusher 5350 located on the other side of the elongated slot 5334 supports one surgical staple 5352 in row 5344 and another surgical staple 5352 in row 5346 in a staggered orientation. Thus, every pusher 5350 supports two surgical staples 5352.

[0379] As can be further seen in FIGS. 148, 149, the surgical staple cartridge 5330 includes a plurality of rotary drivers 5360. More particularly, the rotary drivers 5360 on one side of the elongated slot 5334 are arranged in a single line 5370 and correspond to the pushers 5350 in lines 5340, 5342. In addition, the rotary drivers 5360 on the other side of the elongated slot 5334 are arranged in a single line 5372 and correspond to the pushers 5350 in lines 5344, 5346. As can be seen in FIG. 148, each rotary driver 5360 is rotatably supported within the staple cartridge body 5332. More particularly, each rotary driver 5360 is rotatably received on a corresponding driver shaft 5362. Each driver 5360 has an arcuate ramp portion 5364 formed thereon that is configured to engage an arcuate lower surface 5354 formed on each pusher 5350. See FIG. 153. In addition, each driver 5360 has a lower support portion 5366 extend therefrom to slidably support the pusher 5360 on the channel 5322. Each driver 5360 has a downwardly extending actuation rod 5368 that is configured for engagement with a sled assembly 5380.

[0380] As can be seen in FIG. 150, in at least one embodiment, the sled assembly 5380 includes a base portion 5382 that has a foot portion 5384 that is sized to be slidably received in a slot 5333 in the channel 5322. See FIG. 148. The sled assembly 5380 includes an upstanding support portion 5386 that supports a tissue cutting blade or tissue cutting instrument 5388. The upstanding support portion 5386 terminates in a top portion 5390 that has a pair of laterally extending retaining fins 5392 protruding therefrom. The fins 5392 are positioned to be received within corresponding slots (not shown) in the anvil (not shown). As with the above-described embodiments, the fins 5392 and the foot portion 5384 serve to retain the anvil (not shown) in a desired spaced closed position as the sled assembly 5380 is

driven distally through the tissue clamped within the surgical end effector 5312. The upstanding support portion 5386 is configured for attachment to a knife bar 12200 (FIG. 69). The sled assembly 5380 further has a horizontally-extending actuator plate 5394 that is shaped for actuating engagement with each of the actuation rods 5368 on the pushers 5360.

[0381] Operation of the surgical end effector 5312 will now be explained with reference to FIGS. 148 and 149. As the sled assembly 5380 is driven in the distal direction “DD” through the staple cartridge 5330, the actuator plate 5394 sequentially contacts the actuation rods 5368 on the pushers 5360. As the sled assembly 5380 continues to move distally, the actuator plate 5394 sequentially contacts the actuator rods 5368 of the drivers 5360 on each side of the elongated slot 5334. Such action causes the drivers 5360 to rotate from a first unactuated position to an actuated position wherein the pushers 5350 are driven towards the closed anvil. As the pushers 5350 are driven toward the anvil, the surgical staples 5352 thereon are driven into forming contact with the underside of the anvil. Once the robotic system 11000 determines that the sled assembly 5080 has reached its distal most position through sensors or other means, the control system of the robotic system 11000 may then retract the knife bar and sled assembly 5380 back to the starting position. Thereafter, the robotic control system may then activate the procedure for returning the anvil to the open position to release the stapled tissue.

[0382] FIGS. 154-158 depict one form of an automated reloading system embodiment of the present invention, generally designated as 5500. In one form, the automated reloading system 5500 is configured to replace a “spent” surgical end effector component in a manipulatable surgical tool portion of a robotic surgical system with a “new” surgical end effector component. As used herein, the term “surgical end effector component” may comprise, for example, a surgical staple cartridge, a disposable loading unit or other end effector components that, when used, are spent and must be replaced with a new component. Furthermore, the term “spent” means that the end effector component has been activated and is no longer useable for its intended purpose in its present state. For example, in the context of a surgical staple cartridge or disposable loading unit, the term “spent” means that at least some of the unformed staples that were previously supported therein have been “fired” therefrom. As used herein, the term “new” surgical end effector component refers to an end effector component that is in condition for its intended use. In the context of a surgical staple cartridge or disposable loading unit, for example, the term “new” refers to such a component that has unformed staples therein and which is otherwise ready for use.

[0383] In various embodiments, the automated reloading system 5500 includes a base portion 5502 that may be strategically located within a work envelope 11109 of a robotic arm cart 11100 (FIG. 55) of a robotic system 11000. As used herein, the term “manipulatable surgical tool portion” collectively refers to a surgical tool of the various types disclosed herein and other forms of surgical robotically-actuated tools that are operably attached to, for example, a robotic arm cart 11100 or similar device that is configured to automatically manipulate and actuate the surgical tool. The term “work envelope” as used herein refers to the range of movement of the manipulatable surgical tool portion of the robotic system. FIG. 55 generally depicts an area that may comprise a work envelope of the robotic arm cart 11100. Those of ordinary skill in the art will understand that the shape and size of the work envelope depicted therein is merely illustrative. The ultimate size, shape and location of a work envelope will ultimately depend upon the construction, range of travel limitations, and location of the manipulatable surgical tool portion. Thus, the term “work envelope” as used herein is intended to cover a variety of different sizes and shapes of work envelopes and should not be limited to the specific size and shape of the sample work envelope depicted in FIG. 55.

[0384] As can be seen in FIG. 154, the base portion 5502 includes a new component support section or arrangement 5510 that is configured to operably support at least one new surgical end effector component in a “loading orientation”. As used herein, the term “loading orientation” means that the new end effector component is supported in such away so as to permit the corresponding component support portion of the manipulatable surgical tool portion to be brought into loading engagement with (i.e., operably seated or operably attached to) the new end effector component (or the new end effector component to be brought into loading engagement with the corresponding component support portion of the manipulatable surgical tool portion) without human intervention beyond that which may be necessary to actuate the robotic system. As will be further appreciated as the present Detailed Description proceeds, in at least one embodiment, the preparation nurse will load the new component support section before the surgery with the appropriate length and color cartridges (some surgical staple cartridges may support certain sizes of staples the size of which may be indicated by the color of the cartridge body) required for completing the surgical procedure. However, no direct human interaction is necessary during the surgery to reload the robotic endocutter. In one form, the surgical end effector component comprises a staple cartridge 12034 that is configured to be operably seated within a component support portion (elongated

channel) of any of the various other end effector arrangements described above. For explanation purposes, new (unused) cartridges will be designated as “12034a” and spent cartridges will be designated as “12034b”. The Figures depict cartridges 12034a, 12034b designed for use with a surgical end effector 12012 that includes a channel 12022 and an anvil 12024, the construction and operation of which were discussed in detail above. Cartridges 12034a, 12034b are identical to cartridges 12034 described above. In various embodiments, the cartridges 12034a, 12034b are configured to be snappingly retained (i.e., loading engagement) within the channel 12022 of a surgical end effector 12012. As the present Detailed Description proceeds, however, those of ordinary skill in the art will appreciate that the unique and novel features of the automated cartridge reloading system 5500 may be effectively employed in connection with the automated removal and installation of other cartridge arrangements without departing from the spirit and scope of the present invention.

[0385] In the depicted embodiment, the term “loading orientation” means that the distal tip portion 12035a of the a new surgical staple cartridge 12034a is inserted into a corresponding support cavity 5512 in the new cartridge support section 5510 such that the proximal end portion 12037a of the new surgical staple cartridge 12034a is located in a convenient orientation for enabling the arm cart 11100 to manipulate the surgical end effector 12012 into a position wherein the new cartridge 12034a may be automatically loaded into the channel 12022 of the surgical end effector 12012. In various embodiments, the base 5502 includes at least one sensor 5504 which communicates with the control system 11003 of the robotic controller 11001 to provide the control system 11003 with the location of the base 5502 and/or the reload length and color doe each staged or new cartridge 12034a.

[0386] As can also be seen in the Figures, the base 5502 further includes a collection receptacle 5520 that is configured to collect spent cartridges 12034b that have been removed or disengaged from the surgical end effector 12012 that is operably attached to the robotic system 11000. In addition, in one form, the automated reloading system 5500 includes an extraction system 5530 for automatically removing the spent end effector component from the corresponding support portion of the end effector or manipulatable surgical tool portion without specific human intervention beyond that which may be necessary to activate the robotic system. In various embodiments, the extraction system 5530 includes an extraction hook member 5532. In one form, for example, the extraction hook member 5532 is rigidly supported on the base portion 5502. In one embodiment, the extraction hook member has at

least one hook 5534 formed thereon that is configured to hookingly engage the distal end 12035 of a spent cartridge 2034b when it is supported in the elongated channel 12022 of the surgical end effector 12012. In various forms, the extraction hook member 5532 is conveniently located within a portion of the collection receptacle 5520 such that when the spent end effector component (cartridge 12034b) is brought into extractive engagement with the extraction hook member 5532, the spent end effector component (cartridge 12034b) is dislodged from the corresponding component support portion (elongated channel 12022), and falls into the collection receptacle 5020. Thus, to use this embodiment, the manipulatable surgical tool portion manipulates the end effector attached thereto to bring the distal end 12035 of the spent cartridge 12034b therein into hooking engagement with the hook 5534 and then moves the end effector in such a way to dislodge the spent cartridge 12034b from the elongated channel 12022.

[0387] In other arrangements, the extraction hook member 5532 comprises a rotatable wheel configuration that has a pair of diametrically-opposed hooks 5334 protruding therefrom. See FIGS. 154 and 157. The extraction hook member 5532 is rotatably supported within the collection receptacle 5520 and is coupled to an extraction motor 5540 that is controlled by the controller 11001 of the robotic system. This form of the automated reloading system 5500 may be used as follows. FIG. 156 illustrates the introduction of the surgical end effector 12012 that is operably attached to the manipulatable surgical tool portion 11200. As can be seen in that Figure, the arm cart 11100 of the robotic system 11000 locates the surgical end effector 12012 in the shown position wherein the hook end 5534 of the extraction member 5532 hookingly engages the distal end 12035 of the spent cartridge 12034b in the surgical end effector 12012. The anvil 12024 of the surgical end effector 12012 is in the open position. After the distal end 12035 of the spent cartridge 12034b is engaged with the hook end 5532, the extraction motor 5540 is actuated to rotate the extraction wheel 5532 to disengage the spent cartridge 12034b from the channel 12022. To assist with the disengagement of the spent cartridge 12034b from the channel 12022 (or if the extraction member 5530 is stationary), the robotic system 11000 may move the surgical end effector 12012 in an upward direction (arrow "U" in FIG. 157). As the spent cartridge 12034b is dislodged from the channel 12022, the spent cartridge 12034b falls into the collection receptacle 5520. Once the spent cartridge 12034b has been removed from the surgical end effector 12012, the robotic system 11000 moves the surgical end effector 12012 to the position shown in FIG. 158.

[0388] In various embodiments, a sensor arrangement 5533 is located adjacent to the extraction member 5532 that is in communication with the controller 11001 of the robotic system 11000. The sensor arrangement 5533 may comprise a sensor that is configured to sense the presence of the surgical end effector 12012 and, more particularly the tip 12035b of the spent surgical staple cartridge 12034b thereof as the distal tip portion 12035b is brought into engagement with the extraction member 5532. In some embodiments, the sensor arrangement 5533 may comprise, for example, a light curtain arrangement. However, other forms of proximity sensors may be employed. In such arrangement, when the surgical end effector 12012 with the spent surgical staple cartridge 12034b is brought into extractive engagement with the extraction member 5532, the sensor senses the distal tip 12035b of the surgical staple cartridge 12034b (e.g., the light curtain is broken). When the extraction member 5532 spins and pops the surgical staple cartridge 12034b loose and it falls into the collection receptacle 5520, the light curtain is again unbroken. Because the surgical end effector 12012 was not moved during this procedure, the robotic controller 11001 is assured that the spent surgical staple cartridge 12034b has been removed therefrom. Other sensor arrangements may also be successfully employed to provide the robotic controller 11001 with an indication that the spent surgical staple cartridge 2034b has been removed from the surgical end effector 12012.

[0389] As can be seen in FIG. 158, the surgical end effector 12012 is positioned to grasp a new surgical staple cartridge 12034a between the channel 12022 and the anvil 12024. More specifically, as shown in FIGS. 155 and 158, each cavity 5512 has a corresponding upstanding pressure pad 5514 associated with it. The surgical end effector 12012 is located such that the pressure pad 5514 is located between the new cartridge 12034a and the anvil 12024. Once in that position, the robotic system 11000 closes the anvil 12024 onto the pressure pad 5514 which serves to push the new cartridge 12034a into snapping engagement with the channel 12022 of the surgical end effector 12012. Once the new cartridge 12034a has been snapped into position within the elongated channel 12022, the robotic system 11000 then withdraws the surgical end effector 12012 from the automated cartridge reloading system 5500 for use in connection with performing another surgical procedure.

[0390] FIGS. 159-163 depict another automated reloading system 5600 that may be used to remove a spent disposable loading unit 3612 from a manipulatable surgical tool arrangement 3600 (FIGS. 106-119) that is operably attached to an arm cart 11100 or other portion of a robotic system 11000 and reload a new disposable loading unit 3612 therein. As can be seen

in FIGS. 159 and 160, one form of the automated reloading system 5600 includes a housing 5610 that has a movable support assembly in the form of a rotary carousel top plate 5620 supported thereon which cooperates with the housing 5610 to form a hollow enclosed area 5612. The automated reloading system 5600 is configured to be operably supported within the work envelop of the manipulatable surgical tool portion of a robotic system as was described above. In various embodiments, the rotary carousel plate 5620 has a plurality of holes 5622 for supporting a plurality of orientation tubes 5660 therein. As can be seen in FIGS. 160 and 161, the rotary carousel plate 5620 is affixed to a spindle shaft 5624. The spindle shaft 5624 is centrally disposed within the enclosed area 5612 and has a spindle gear 5626 attached thereto. The spindle gear 5626 is in meshing engagement with a carousel drive gear 5628 that is coupled to a carousel drive motor 5630 that is in operative communication with the robotic controller 11001 of the robotic system 11000.

[0391] Various embodiments of the automated reloading system 5600 may also include a carousel locking assembly, generally designated as 5640. In various forms, the carousel locking assembly 5640 includes a cam disc 5642 that is affixed to the spindle shaft 5624. The spindle gear 5626 may be attached to the underside of the cam disc 5642 and the cam disc 5642 may be keyed onto the spindle shaft 5624. In alternative arrangements, the spindle gear 5626 and the cam disc 5642 may be independently non-rotatably affixed to the spindle shaft 5624. As can be seen in FIGS. 160 and 161, a plurality of notches 5644 are spaced around the perimeter of the cam disc 5642. A locking arm 5648 is pivotally mounted within the housing 5610 and is biased into engagement with the perimeter of the cam disc 5642 by a locking spring 5649. As can be seen in FIG. 159, the outer perimeter of the cam disc 5642 is rounded to facilitate rotation of the cam disc 5642 relative to the locking arm 5648. The edges of each notch 5644 are also rounded such that when the cam disc 5642 is rotated, the locking arm 5648 is cammed out of engagement with the notches 5644 by the perimeter of the cam disc 5642.

[0392] Various forms of the automated reloading system 5600 are configured to support a portable/replaceable tray assembly 5650 that is configured to support a plurality of disposable loading units 3612 in individual orientation tubes 5660. More specifically and with reference to FIGS. 160 and 161, the replaceable tray assembly 5650 comprises a tray 5652 that has a centrally-disposed locator spindle 5654 protruding from the underside thereof. The locator spindle 5654 is sized to be received within a hollow end 5625 of spindle shaft 5624. The tray 5652 has a plurality of holes 5656 therein that are configured to support an orientation tube

5660 therein. Each orientation tube 5660 is oriented within a corresponding hole 5656 in the replaceable tray assembly 5650 in a desired orientation by a locating fin 5666 on the orientation tube 5660 that is designed to be received within a corresponding locating slot 5658 in the tray assembly 5650. In at least one embodiment, the locating fin 5666 has a substantially V-shaped cross-sectional shape that is sized to fit within a V-shaped locating slot 5658. Such arrangement serves to orient the orientation tube 5660 in a desired starting position while enabling it to rotate within the hole 5656 when a rotary motion is applied thereto. That is, when a rotary motion is applied to the orientation tube 5660 the V-shaped locating fin 5666 will pop out of its corresponding locating slot enabling the tube 5660 to rotate relative to the tray 5652 as will be discussed in further detail below. As can also be seen in FIGS. 159-161, the replaceable tray 5652 may be provided with one or more handle portions 5653 to facilitate transport of the tray assembly 5652 when loaded with orientation tubes 5660.

[0393] As can be seen in FIG. 162, each orientation tube 5660 comprises a body portion 5662 that has a flanged open end 5664. The body portion 5662 defines a cavity 5668 that is sized to receive a portion of a disposable loading unit 3612 therein. To properly orient the disposable loading unit 3612 within the orientation tube 5660, the cavity 5668 has a flat locating surface 5670 formed therein. As can be seen in FIG. 163, the flat locating surface 5670 is configured to facilitate the insertion of the disposable loading unit into the cavity 5668 in a desired or predetermined non-rotatable orientation. In addition, the end 5669 of the cavity 5668 may include a foam or cushion material 5672 that is designed to cushion the distal end of the disposable loading unit 3612 within the cavity 5668. Also, the length of the locating surface may cooperate with a sliding support member 3689 of the axial drive assembly 3680 of the disposable loading unit 3612 to further locate the disposable loading unit 3612 at a desired position within the orientation tube 5660.

[0394] The orientation tubes 5660 may be fabricated from Nylon, polycarbonate, polyethylene, liquid crystal polymer, 6061 or 7075 aluminum, titanium, 300 or 400 series stainless steel, coated or painted steel, plated steel, etc. and, when loaded in the replaceable tray 5662 and the locator spindle 5654 is inserted into the hollow end 5625 of spindle shaft 5624, the orientation tubes 5660 extend through corresponding holes 5662 in the carousel top plate 5620. Each replaceable tray 5662 is equipped with a location sensor 5663 that communicates with the control system 11003 of the controller 11001 of the robotic system 11000. The sensor 5663 serves to identify the location of the reload system, and the number,

length, color and fired status of each reload housed in the tray. In addition, an optical sensor or sensors 5665 that communicate with the robotic controller 11001 may be employed to sense the type/size/length of disposable loading units that are loaded within the tray 5662.

[0395] Various embodiments of the automated reloading system 5600 further include a drive assembly 5680 for applying a rotary motion to the orientation tube 5660 holding the disposable loading unit 3612 to be attached to the shaft 3700 of the surgical tool 3600 (collectively the “manipulatable surgical tool portion”) that is operably coupled to the robotic system. The drive assembly 5680 includes a support yoke 5682 that is attached to the locking arm 5648. Thus, the support yoke 5682 pivots with the locking arm 5648. The support yoke 5682 rotatably supports a tube idler wheel 5684 and a tube drive wheel 5686 that is driven by a tube motor 5688 attached thereto. Tube motor 5688 communicates with the control system 11003 and is controlled thereby. The tube idler wheel 5684 and tube drive wheel 5686 are fabricated from, for example, natural rubber, sanoprene, isoplast, etc. such that the outer surfaces thereof create sufficient amount of friction to result in the rotation of an orientation tube 5660 in contact therewith upon activation of the tube motor 5688. The idler wheel 5684 and tube drive wheel 5686 are oriented relative to each other to create a cradle area 5687 therebetween for receiving an orientation tube 5060 in driving engagement therein.

[0396] In use, one or more of the orientation tubes 5660 loaded in the automated reloading system 5600 are left empty, while the other orientation tubes 5660 may operably support a corresponding new disposable loading unit 3612 therein. As will be discussed in further detail below, the empty orientation tubes 5660 are employed to receive a spent disposable loading unit 3612 therein.

[0397] The automated reloading system 5600 may be employed as follows after the system 5600 is located within the work envelope of the manipulatable surgical tool portion of a robotic system. If the manipulatable surgical tool portion has a spent disposable loading unit 3612 operably coupled thereto, one of the orientation tubes 5660 that are supported on the replaceable tray 5662 is left empty to receive the spent disposable loading unit 3612 therein. If, however, the manipulatable surgical tool portion does not have a disposable loading unit 3612 operably coupled thereto, each of the orientation tubes 5660 may be provided with a properly oriented new disposable loading unit 3612.

[0398] As described hereinabove, the disposable loading unit 3612 employs a rotary “bayonet-type” coupling arrangement for operably coupling the disposable loading unit 3612

to a corresponding portion of the manipulatable surgical tool portion. That is, to attach a disposable loading unit 3612 to the corresponding portion of the manipulatable surgical tool portion (3700 – see FIG. 112, 113), a rotary installation motion must be applied to the disposable loading unit 3612 and/or the corresponding portion of the manipulatable surgical tool portion when those components have been moved into loading engagement with each other. Such installation motions are collectively referred to herein as “loading motions”. Likewise, to decouple a spent disposable loading unit 3612 from the corresponding portion of the manipulatable surgical tool, a rotary decoupling motion must be applied to the spent disposable loading unit 3612 and/or the corresponding portion of the manipulatable surgical tool portion while simultaneously moving the spent disposable loading unit and the corresponding portion of the manipulatable surgical tool away from each other. Such decoupling motions are collectively referred to herein as “extraction motions”.

[0399] To commence the loading process, the robotic system 11000 is activated to manipulate the manipulatable surgical tool portion and/or the automated reloading system 5600 to bring the manipulatable surgical tool portion into loading engagement with the new disposable loading unit 3612 that is supported in the orientation tube 5660 that is in driving engagement with the drive assembly 5680. Once the robotic controller 11001 (FIG. 54) of the robotic control system 11000 has located the manipulatable surgical tool portion in loading engagement with the new disposable loading unit 3612, the robotic controller 11001 activates the drive assembly 5680 to apply a rotary loading motion to the orientation tube 5660 in which the new disposable loading unit 3612 is supported and/or applies another rotary loading motion to the corresponding portion of the manipulatable surgical tool portion. Upon application of such rotary loading motions(s), the robotic controller 11001 also causes the corresponding portion of the manipulatable surgical tool portion to be moved towards the new disposable loading unit 3612 into loading engagement therewith. Once the disposable loading unit 3612 is in loading engagement with the corresponding portion of the manipulatable tool portion, the loading motions are discontinued and the manipulatable surgical tool portion may be moved away from the automated reloading system 5600 carrying with it the new disposable loading unit 3612 that has been operably coupled thereto.

[0400] To decouple a spent disposable loading unit 3612 from a corresponding manipulatable surgical tool portion, the robotic controller 11001 of the robotic system manipulates the manipulatable surgical tool portion so as to insert the distal end of the spent disposable loading unit 3612 into the empty orientation tube 5660 that remains in driving

engagement with the drive assembly 5680. Thereafter, the robotic controller 11001 activates the drive assembly 5680 to apply a rotary extraction motion to the orientation tube 5660 in which the spent disposable loading unit 3612 is supported and/or applies a rotary extraction motion to the corresponding portion of the manipulatable surgical tool portion. The robotic controller 11001 also causes the manipulatable surgical tool portion to withdraw away from the spent rotary disposable loading unit 3612. Thereafter the rotary extraction motion(s) are discontinued.

[0401] After the spent disposable loading unit 3612 has been removed from the manipulatable surgical tool portion, the robotic controller 11001 may activate the carousel drive motor 5630 to index the carousel top plate 5620 to bring another orientation tube 5660 that supports a new disposable loading unit 3612 therein into driving engagement with the drive assembly 5680. Thereafter, the loading process may be repeated to attach the new disposable loading unit 3612 therein to the portion of the manipulatable surgical tool portion. The robotic controller 11001 may record the number of disposable loading units that have been used from a particular replaceable tray 5652. Once the controller 11001 determines that all of the new disposable loading units 3612 have been used from that tray, the controller 11001 may provide the surgeon with a signal (visual and/or audible) indicating that the tray 5652 supporting all of the spent disposable loading units 3612 must be replaced with a new tray 5652 containing new disposable loading units 3612.

[0402] FIGS. 164-169 depict another non-limiting embodiment of a surgical tool 6000 of the present invention that is well-adapted for use with a robotic system 11000 that has a tool drive assembly 11010 (FIG. 59) that is operatively coupled to a master controller 11001 that is operable by inputs from an operator (i.e., a surgeon). As can be seen in FIG. 164, the surgical tool 6000 includes a surgical end effector 6012 that comprises an endocutter. In at least one form, the surgical tool 6000 generally includes an elongated shaft assembly 6008 that has a proximal closure tube 6040 and a distal closure tube 6042 that are coupled together by an articulation joint 6100. The surgical tool 6000 is operably coupled to the manipulator by a tool mounting portion, generally designated as 6200. The surgical tool 6000 further includes an interface 6030 which may mechanically and electrically couple the tool mounting portion 6200 to the manipulator in the various manners described in detail above.

[0403] In at least one embodiment, the surgical tool 6000 includes a surgical end effector 6012 that comprises, among other things, at least one component 6024 that is selectively movable between first and second positions relative to at least one other component 6022 in

response to various control motions applied to component 6024 as will be discussed in further detail below to perform a surgical procedure. In various embodiments, component 6022 comprises an elongated channel 6022 configured to operably support a surgical staple cartridge 6034 therein and component 6024 comprises a pivotally translatable clamping member, such as an anvil 6024. Various embodiments of the surgical end effector 6012 are configured to maintain the anvil 6024 and elongated channel 6022 at a spacing that assures effective stapling and severing of tissue clamped in the surgical end effector 6012. Unless otherwise stated, the end effector 6012 is similar to the surgical end effector 12012 described above and includes a cutting instrument (not shown) and a sled (not shown). The anvil 6024 may include a tab 6027 at its proximal end that interacts with a component of the mechanical closure system (described further below) to facilitate the opening of the anvil 6024. The elongated channel 6022 and the anvil 6024 may be made of an electrically conductive material (such as metal) so that they may serve as part of an antenna that communicates with sensor(s) in the end effector, as described above. The surgical staple cartridge 6034 could be made of a nonconductive material (such as plastic) and the sensor may be connected to or disposed in the surgical staple cartridge 6034, as was also described above.

[0404] As can be seen in FIG. 164, the surgical end effector 6012 is attached to the tool mounting portion 6200 by the elongated shaft assembly 6008 according to various embodiments. As shown in the illustrated embodiment, the elongated shaft assembly 6008 includes an articulation joint generally designated as 6100 that enables the surgical end effector 6012 to be selectively articulated about a first tool articulation axis AA1-AA1 that is substantially transverse to a longitudinal tool axis LT-LT and a second tool articulation axis AA2-AA2 that is substantially transverse to the longitudinal tool axis LT-LT as well as the first articulation axis AA1-AA1. See FIG. 165. In various embodiments, the elongated shaft assembly 6008 includes a closure tube assembly 6009 that comprises a proximal closure tube 6040 and a distal closure tube 6042 that are pivotally linked by a pivot links 6044 and 6046. The closure tube assembly 6009 is movably supported on a spine assembly generally designated as 6102.

[0405] As can be seen in FIG. 166, the proximal closure tube 6040 is pivotally linked to an intermediate closure tube joint 6043 by an upper pivot link 6044U and a lower pivot link 6044L such that the intermediate closure tube joint 6043 is pivotable relative to the proximal closure tube 6040 about a first closure axis CA1-CA1 and a second closure axis CA2-CA2. In various embodiments, the first closure axis CA1-CA1 is substantially parallel to the second

closure axis CA2-CA2 and both closure axes CA1-CA1, CA2-CA2 are substantially transverse to the longitudinal tool axis LT-LT. As can be further seen in FIG. 134, the intermediate closure tube joint 6043 is pivotally linked to the distal closure tube 6042 by a left pivot link 6046L and a right pivot link 6046R such that the intermediate closure tube joint 6043 is pivotable relative to the distal closure tube 6042 about a third closure axis CA3-CA3 and a fourth closure axis CA4-CA4. In various embodiments, the third closure axis CA3-CA3 is substantially parallel to the fourth closure axis CA4-CA4 and both closure axes CA3-CA3, CA4-CA4 are substantially transverse to the first and second closure axes CA1-CA1, CA2-CA2 as well as to longitudinal tool axis LT-LT.

[0406] The closure tube assembly 6009 is configured to axially slide on the spine assembly 6102 in response to actuation motions applied thereto. The distal closure tube 6042 includes an opening 6045 which interfaces with the tab 6027 on the anvil 6024 to facilitate opening of the anvil 6024 as the distal closure tube 6042 is moved axially in the proximal direction "PD". The closure tubes 6040, 6042 may be made of electrically conductive material (such as metal) so that they may serve as part of the antenna, as described above. Components of the spine assembly 6102 may be made of a nonconductive material (such as plastic).

[0407] As indicated above, the surgical tool 6000 includes a tool mounting portion 6200 that is configured for operable attachment to the tool mounting assembly 11010 of the robotic system 11000 in the various manners described in detail above. As can be seen in FIG. 168, the tool mounting portion 6200 comprises a tool mounting plate 6202 that operably supports a transmission arrangement 6204 thereon. In various embodiments, the transmission arrangement 6204 includes an articulation transmission 6142 that comprises a portion of an articulation system 6140 for articulating the surgical end effector 6012 about a first tool articulation axis TA1-TA1 and a second tool articulation axis TA2-TA2. The first tool articulation axis TA1-TA1 is substantially transverse to the second tool articulation axis TA2-TA2 and both of the first and second tool articulation axes are substantially transverse to the longitudinal tool axis LT-LT. See FIG. 165.

[0408] To facilitate selective articulation of the surgical end effector 6012 about the first and second tool articulation axes TA1-TA1, TA2-TA2, the spine assembly 6102 comprises a proximal spine portion 6110 that is pivotally coupled to a distal spine portion 6120 by pivot pins 6122 for selective pivotal travel about TA1-TA1. Similarly, the distal spine portion 6120 is pivotally attached to the elongated channel 6022 of the surgical end effector 6012 by

pivot pins 6124 to enable the surgical end effector 6012 to selectively pivot about the second tool axis TA2-TA2 relative to the distal spine portion 6120.

[0409] In various embodiments, the articulation system 6140 further includes a plurality of articulation elements that operably interface with the surgical end effector 6012 and an articulation control arrangement 6160 that is operably supported in the tool mounting member 6200 as will be described in further detail below. In at least one embodiment, the articulation elements comprise a first pair of first articulation cables 6144 and 6146. The first articulation cables are located on a first or right side of the longitudinal tool axis. Thus, the first articulation cables are referred to herein as a right upper cable 6144 and a right lower cable 6146. The right upper cable 6144 and the right lower cable 6146 extend through corresponding passages 6147, 6148, respectively along the right side of the proximal spine portion 6110. See FIG. 169. The articulation system 6140 further includes a second pair of second articulation cables 6150, 6152. The second articulation cables are located on a second or left side of the longitudinal tool axis. Thus, the second articulation cables are referred to herein as a left upper articulation cable 6150 and a left lower articulation cable 6152. The left upper articulation cable 6150 and the left lower articulation cable 6152 extend through passages 6153, 6154, respectively in the proximal spine portion 6110.

[0410] As can be seen in FIG. 165, the right upper cable 6144 extends around an upper pivot joint 6123 and is attached to a left upper side of the elongated channel 6022 at a left pivot joint 6125. The right lower cable 6146 extends around a lower pivot joint 6126 and is attached to a left lower side of the elongated channel 6022 at left pivot joint 6125. The left upper cable 6150 extends around the upper pivot joint 6123 and is attached to a right upper side of the elongated channel 6022 at a right pivot joint 6127. The left lower cable 6152 extends around the lower pivot joint 6126 and is attached to a right lower side of the elongated channel 6022 at right pivot joint 6127. Thus, to pivot the surgical end effector 6012 about the first tool articulation axis TA1-TA1 to the left (arrow "L"), the right upper cable 6144 and the right lower cable 6146 must be pulled in the proximal direction "PD". To articulate the surgical end effector 6012 to the right (arrow "R") about the first tool articulation axis TA1-TA1, the left upper cable 6150 and the left lower cable 6152 must be pulled in the proximal direction "PD". To articulate the surgical end effector 6012 about the second tool articulation axis TA2-TA2, in an upward direction (arrow "U"), the right upper cable 6144 and the left upper cable 6150 must be pulled in the proximal direction "PD". To articulate the surgical end effector 6012 in the downward direction (arrow "DW") about the

second tool articulation axis TA2-TA2, the right lower cable 6146 and the left lower cable 6152 must be pulled in the proximal direction "PD".

[0411] The proximal ends of the articulation cables 6144, 6146, 6150, 6152 are coupled to the articulation control arrangement 6160 which comprises a ball joint assembly that is a part of the articulation transmission 6142. More specifically and with reference to FIG. 169, the ball joint assembly 6160 includes a ball-shaped member 6162 that is formed on a proximal portion of the proximal spine 6110. Movably supported on the ball-shaped member 6162 is an articulation control ring 6164. As can be further seen in FIG. 169, the proximal ends of the articulation cables 6144, 6146, 6150, 6152 are coupled to the articulation control ring 6164 by corresponding ball joint arrangements 6166. The articulation control ring 6164 is controlled by an articulation drive assembly 6170. As can be most particularly seen in FIG. 169, the proximal ends of the first articulation cables 6144, 6146 are attached to the articulation control ring 6164 at corresponding spaced first points 6149, 6151 that are located on plane 6159. Likewise, the proximal ends of the second articulation cables 6150, 6152 are attached to the articulation control ring 6164 at corresponding spaced second points 6153, 6155 that are also located along plane 6159. As the present Detailed Description proceeds, those of ordinary skill in the art will appreciate that such cable attachment configuration on the articulation control ring 6164 facilitates the desired range of articulation motions as the articulation control ring 6164 is manipulated by the articulation drive assembly 6170.

[0412] In various forms, the articulation drive assembly 6170 comprises a horizontal articulation assembly generally designated as 6171. In at least one form, the horizontal articulation assembly 6171 comprises a horizontal push cable 6172 that is attached to a horizontal gear arrangement 6180. The articulation drive assembly 6170 further comprises a vertical articulation assembly generally designated as 6173. In at least one form, the vertical articulation assembly 6173 comprises a vertical push cable 6174 that is attached to a vertical gear arrangement 6190. As can be seen in FIGS. 168 and 169, the horizontal push cable 6172 extends through a support plate 6167 that is attached to the proximal spine portion 6110. The distal end of the horizontal push cable 6174 is attached to the articulation control ring 6164 by a corresponding ball/pivot joint 6168. The vertical push cable 6174 extends through the support plate 6167 and the distal end thereof is attached to the articulation control ring 6164 by a corresponding ball/pivot joint 6169.

[0413] The horizontal gear arrangement 6180 includes a horizontal driven gear 6182 that is pivotally mounted on a horizontal shaft 6181 that is attached to a proximal portion of the

proximal spine portion 6110. The proximal end of the horizontal push cable 6172 is pivotally attached to the horizontal driven gear 6182 such that, as the horizontal driven gear 6172 is rotated about horizontal pivot axis HA, the horizontal push cable 6172 applies a first pivot motion to the articulation control ring 6164. Likewise, the vertical gear arrangement 6190 includes a vertical driven gear 6192 that is pivotally supported on a vertical shaft 6191 attached to the proximal portion of the proximal spine portion 6110 for pivotal travel about a vertical pivot axis VA. The proximal end of the vertical push cable 6174 is pivotally attached to the vertical driven gear 6192 such that as the vertical driven gear 6192 is rotated about vertical pivot axis VA, the vertical push cable 6174 applies a second pivot motion to the articulation control ring 6164.

[0414] The horizontal driven gear 6182 and the vertical driven gear 6192 are driven by an articulation gear train 6300 that operably interfaces with an articulation shifter assembly 6320. In at least one form, the articulation shifter assembly comprises an articulation drive gear 6322 that is coupled to a corresponding one of the driven discs or elements 11304 on the adapter side 11307 of the tool mounting plate 6202. See FIG. 63. Thus, application of a rotary input motion from the robotic system 11000 through the tool drive assembly 11010 to the corresponding driven element 11304 will cause rotation of the articulation drive gear 6322 when the interface 11230 is coupled to the tool holder 11270. An articulation driven gear 6324 is attached to a splined shifter shaft 6330 that is rotatably supported on the tool mounting plate 6202. The articulation driven gear 6324 is in meshing engagement with the articulation drive gear 6322 as shown. Thus, rotation of the articulation drive gear 6322 will result in the rotation of the shaft 6330. In various forms, a shifter driven gear assembly 6340 is movably supported on the splined portion 6332 of the shifter shaft 6330.

[0415] In various embodiments, the shifter driven gear assembly 6340 includes a driven shifter gear 6342 that is attached to a shifter plate 6344. The shifter plate 6344 operably interfaces with a shifter solenoid assembly 6350. The shifter solenoid assembly 6350 is coupled to corresponding pins 6352 by conductors 6352. See FIG. 168. Pins 6352 are oriented to electrically communicate with slots 11258 (FIG. 62) on the tool side 11244 of the adaptor 11240. Such arrangement serves to electrically couple the shifter solenoid assembly 6350 to the robotic controller 11001. Thus, activation of the shifter solenoid 6350 will shift the shifter driven gear assembly 6340 on the splined portion 6332 of the shifter shaft 6330 as represented by arrow "S" in FIGS. 168 and 169. Various embodiments of the articulation gear train 6300 further include a horizontal gear assembly 6360 that includes a first horizontal

drive gear 6362 that is mounted on a shaft 6361 that is rotatably attached to the tool mounting plate 6202. The first horizontal drive gear 6362 is supported in meshing engagement with a second horizontal drive gear 6364. As can be seen in FIG. 169, the horizontal driven gear 6182 is in meshing engagement with the distal face portion 6365 of the second horizontal driven gear 6364.

[0416] Various embodiments of the articulation gear train 6300 further include a vertical gear assembly 6370 that includes a first vertical drive gear 6372 that is mounted on a shaft 6371 that is rotatably supported on the tool mounting plate 6202. The first vertical drive gear 6372 is supported in meshing engagement with a second vertical drive gear 6374 that is concentrically supported with the second horizontal drive gear 6364. The second vertical drive gear 6374 is rotatably supported on the proximal spine portion 6110 for travel therearound. The second horizontal drive gear 6364 is rotatably supported on a portion of said second vertical drive gear 6374 for independent rotatable travel thereon. As can be seen in FIG. 169, the vertical driven gear 6192 is in meshing engagement with the distal face portion 6375 of the second vertical driven gear 6374.

[0417] In various forms, the first horizontal drive gear 6362 has a first diameter and the first vertical drive gear 6372 has a second diameter. As can be seen in FIGS. 168 and 169, the shaft 6361 is not on a common axis with shaft 6371. That is, the first horizontal driven gear 6362 and the first vertical driven gear 6372 do not rotate about a common axis. Thus, when the shifter gear 6342 is positioned in a center “locking” position such that the shifter gear 6342 is in meshing engagement with both the first horizontal driven gear 6362 and the first vertical drive gear 6372, the components of the articulation system 6140 are locked in position. Thus, the shiftable shifter gear 6342 and the arrangement of first horizontal and vertical drive gears 6362, 6372 as well as the articulation shifter assembly 6320 collectively may be referred to as an articulation locking system, generally designated as 6380.

[0418] In use, the robotic controller 11001 of the robotic system 11000 may control the articulation system 6140 as follows. To articulate the end effector 6012 to the left about the first tool articulation axis TA1-TA1, the robotic controller 11001 activates the shifter solenoid assembly 6350 to bring the shifter gear 6342 into meshing engagement with the first horizontal drive gear 6362. Thereafter, the controller 11001 causes a first rotary output motion to be applied to the articulation drive gear 6322 to drive the shifter gear in a first direction to ultimately drive the horizontal driven gear 6182 in another first direction. The horizontal driven gear 6182 is driven to pivot the articulation ring 6164 on the ball-shaped

portion 6162 to thereby pull right upper cable 6144 and the right lower cable 6146 in the proximal direction "PD". To articulate the end effector 6012 to the right about the first tool articulation axis TA1-TA1, the robotic controller 11001 activates the shifter solenoid assembly 6350 to bring the shifter gear 6342 into meshing engagement with the first horizontal drive gear 6362. Thereafter, the controller 11001 causes the first rotary output motion in an opposite direction to be applied to the articulation drive gear 6322 to drive the shifter gear 6342 in a second direction to ultimately drive the horizontal driven gear 6182 in another second direction. Such actions result in the articulation control ring 6164 moving in such a manner as to pull the left upper cable 6150 and the left lower cable 6152 in the proximal direction "PD". In various embodiments the gear ratios and frictional forces generated between the gears of the vertical gear assembly 6370 serve to prevent rotation of the vertical driven gear 6192 as the horizontal gear assembly 6360 is actuated.

[0419] To articulate the end effector 6012 in the upper direction about the second tool articulation axis TA2-TA2, the robotic controller 11001 activates the shifter solenoid assembly 6350 to bring the shifter gear 6342 into meshing engagement with the first vertical drive gear 6372. Thereafter, the controller 11001 causes the first rotary output motion to be applied to the articulation drive gear 6322 to drive the shifter gear 6342 in a first direction to ultimately drive the vertical driven gear 6192 in another first direction. The vertical driven gear 6192 is driven to pivot the articulation ring 6164 on the ball-shaped portion 6162 of the proximal spine portion 6110 to thereby pull right upper cable 6144 and the left upper cable 6150 in the proximal direction "PD". To articulate the end effector 6012 in the downward direction about the second tool articulation axis TA2-TA2, the robotic controller 11001 activates the shifter solenoid assembly 6350 to bring the shifter gear 6342 into meshing engagement with the first vertical drive gear 6372. Thereafter, the controller 11001 causes the first rotary output motion to be applied in an opposite direction to the articulation drive gear 6322 to drive the shifter gear 6342 in a second direction to ultimately drive the vertical driven gear 6192 in another second direction. Such actions thereby cause the articulation control ring 6164 to pull the right lower cable 6146 and the left lower cable 6152 in the proximal direction "PD". In various embodiments, the gear ratios and frictional forces generated between the gears of the horizontal gear assembly 6360 serve to prevent rotation of the horizontal driven gear 6182 as the vertical gear assembly 6370 is actuated.

[0420] In various embodiments, a variety of sensors may communicate with the robotic controller 11001 to determine the articulated position of the end effector 6012. Such sensors

may interface with, for example, the articulation joint 6100 or be located within the tool mounting portion 6200. For example, sensors may be employed to detect the position of the articulation control ring 6164 on the ball-shaped portion 6162 of the proximal spine portion 6110. Such feedback from the sensors to the controller 11001 permits the controller 11001 to adjust the amount of rotation and the direction of the rotary output to the articulation drive gear 6322. Further, as indicated above, when the shifter drive gear 6342 is centrally positioned in meshing engagement with the first horizontal drive gear 6362 and the first vertical drive gear 6372, the end effector 6012 is locked in the articulated position. Thus, after the desired amount of articulation has been attained, the controller 11001 may activate the shifter solenoid assembly 6350 to bring the shifter gear 6342 into meshing engagement with the first horizontal drive gear 6362 and the first vertical drive gear 6372. In alternative embodiments, the shifter solenoid assembly 6350 may be spring activated to the central locked position.

[0421] In use, it may be desirable to rotate the surgical end effector 6012 about the longitudinal tool axis LT-LT. In at least one embodiment, the transmission arrangement 6204 on the tool mounting portion includes a rotational transmission assembly 6400 that is configured to receive a corresponding rotary output motion from the tool drive assembly 11010 of the robotic system 11000 and convert that rotary output motion to a rotary control motion for rotating the elongated shaft assembly 6008 (and surgical end effector 6012) about the longitudinal tool axis LT-LT. In various embodiments, for example, a proximal end portion 6041 of the proximal closure tube 6040 is rotatably supported on the tool mounting plate 6202 of the tool mounting portion 6200 by a forward support cradle 6205 and a closure sled 6510 that is also movably supported on the tool mounting plate 6202. In at least one form, the rotational transmission assembly 6400 includes a tube gear segment 6402 that is formed on (or attached to) the proximal end 6041 of the proximal closure tube 6040 for operable engagement by a rotational gear assembly 6410 that is operably supported on the tool mounting plate 6202. As can be seen in FIG. 168, the rotational gear assembly 6410, in at least one embodiment, comprises a rotation drive gear 6412 that is coupled to a corresponding second one of the driven discs or elements 11304 on the adapter side 11307 of the tool mounting plate 6202 when the tool mounting portion 6200 is coupled to the tool drive assembly 11010. See FIG. 63. The rotational gear assembly 6410 further comprises a first rotary driven gear 6414 that is rotatably supported on the tool mounting plate 6202 in meshing engagement with the rotation drive gear 6412. The first rotary driven gear 6414 is

attached to a drive shaft 6416 that is rotatably supported on the tool mounting plate 6202. A second rotary driven gear 6418 is attached to the drive shaft 6416 and is in meshing engagement with tube gear segment 6402 on the proximal closure tube 6040. Application of a second rotary output motion from the tool drive assembly 11010 of the robotic system 11000 to the corresponding driven element 11304 will thereby cause rotation of the rotation drive gear 6412. Rotation of the rotation drive gear 6412 ultimately results in the rotation of the elongated shaft assembly 6008 (and the surgical end effector 6012) about the longitudinal tool axis LT-LT. It will be appreciated that the application of a rotary output motion from the tool drive assembly 11010 in one direction will result in the rotation of the elongated shaft assembly 6008 and surgical end effector 6012 about the longitudinal tool axis LT-LT in a first direction and an application of the rotary output motion in an opposite direction will result in the rotation of the elongated shaft assembly 6008 and surgical end effector 6012 in a second direction that is opposite to the first direction.

[0422] In at least one embodiment, the closure of the anvil 12024 relative to the staple cartridge 2034 is accomplished by axially moving a closure portion of the elongated shaft assembly 12008 in the distal direction “DD” on the spine assembly 12049. As indicated above, in various embodiments, the proximal end portion 6041 of the proximal closure tube 6040 is supported by the closure sled 6510 which comprises a portion of a closure transmission, generally depicted as 6512. As can be seen in FIG. 168, the proximal end portion 6041 of the proximal closure tube portion 6040 has a collar 6048 formed thereon. The closure sled 6510 is coupled to the collar 6048 by a yoke 6514 that engages an annular groove 6049 in the collar 6048. Such arrangement serves to enable the collar 6048 to rotate about the longitudinal tool axis LT-LT while still being coupled to the closure transmission 6512. In various embodiments, the closure sled 6510 has an upstanding portion 6516 that has a closure rack gear 6518 formed thereon. The closure rack gear 6518 is configured for driving engagement with a closure gear assembly 6520. See FIG. 168.

[0423] In various forms, the closure gear assembly 6520 includes a closure spur gear 6522 that is coupled to a corresponding second one of the driven discs or elements 11304 on the adapter side 11307 of the tool mounting plate 6202. See FIG. 63. Thus, application of a third rotary output motion from the tool drive assembly 11010 of the robotic system 11000 to the corresponding second driven element 11304 will cause rotation of the closure spur gear 6522 when the tool mounting portion 6202 is coupled to the tool drive assembly 11010. The closure gear assembly 6520 further includes a closure reduction gear set 6524 that is

supported in meshing engagement with the closure spur gear 6522 and the closure rack gear 2106. Thus, application of a third rotary output motion from the tool drive assembly 11010 of the robotic system 11000 to the corresponding second driven element 11304 will cause rotation of the closure spur gear 6522 and the closure transmission 6512 and ultimately drive the closure sled 6510 and the proximal closure tube 6040 axially on the proximal spine portion 6110. The axial direction in which the proximal closure tube 6040 moves ultimately depends upon the direction in which the third driven element 11304 is rotated. For example, in response to one rotary output motion received from the tool drive assembly 11010 of the robotic system 11000, the closure sled 6510 will be driven in the distal direction "DD" and ultimately drive the proximal closure tube 6040 in the distal direction "DD". As the proximal closure tube 6040 is driven distally, the distal closure tube 6042 is also driven distally by virtue of its connection with the proximal closure tube 6040. As the distal closure tube 6042 is driven distally, the end of the closure tube 6042 will engage a portion of the anvil 6024 and cause the anvil 6024 to pivot to a closed position. Upon application of an "opening" output motion from the tool drive assembly 11010 of the robotic system 11000, the closure sled 6510 and the proximal closure tube 6040 will be driven in the proximal direction "PD" on the proximal spine portion 6110. As the proximal closure tube 6040 is driven in the proximal direction "PD", the distal closure tube 6042 will also be driven in the proximal direction "PD". As the distal closure tube 6042 is driven in the proximal direction "PD", the opening 6045 therein interacts with the tab 6027 on the anvil 6024 to facilitate the opening thereof. In various embodiments, a spring (not shown) may be employed to bias the anvil 6024 to the open position when the distal closure tube 6042 has been moved to its starting position. In various embodiments, the various gears of the closure gear assembly 6520 are sized to generate the necessary closure forces needed to satisfactorily close the anvil 6024 onto the tissue to be cut and stapled by the surgical end effector 6012. For example, the gears of the closure transmission 6520 may be sized to generate approximately 70-120 pounds of closure forces.

[0424] In various embodiments, the cutting instrument is driven through the surgical end effector 6012 by a knife bar 6530. See FIG. 168. In at least one form, the knife bar 6530 is fabricated with a joint arrangement (not shown) and/or is fabricated from material that can accommodate the articulation of the surgical end effector 6102 about the first and second tool articulation axes while remaining sufficiently rigid so as to push the cutting instrument

through tissue clamped in the surgical end effector 6012. The knife bar 6530 extends through a hollow passage 6532 in the proximal spine portion 6110.

[0425] In various embodiments, a proximal end 6534 of the knife bar 6530 is rotatably affixed to a knife rack gear 6540 such that the knife bar 6530 is free to rotate relative to the knife rack gear 6540. The distal end of the knife bar 6530 is attached to the cutting instrument in the various manners described above. As can be seen in FIG. 168, the knife rack gear 6540 is slidably supported within a rack housing 6542 that is attached to the tool mounting plate 6202 such that the knife rack gear 6540 is retained in meshing engagement with a knife drive transmission portion 6550 of the transmission arrangement 6204. In various embodiments, the knife drive transmission portion 6550 comprises a knife gear assembly 6560. More specifically and with reference to FIG. 168, in at least one embodiment, the knife gear assembly 6560 includes a knife spur gear 6562 that is coupled to a corresponding fourth one of the driven discs or elements 11304 on the adapter side 11307 of the tool mounting plate 6202. See FIG. 63. Thus, application of another rotary output motion from the robotic system 11000 through the tool drive assembly 11010 to the corresponding fourth driven element 11304 will cause rotation of the knife spur gear 6562. The knife gear assembly 6560 further includes a knife gear reduction set 6564 that includes a first knife driven gear 6566 and a second knife drive gear 6568. The knife gear reduction set 6564 is rotatably mounted to the tool mounting plate 6202 such that the first knife driven gear 6566 is in meshing engagement with the knife spur gear 6562. Likewise, the second knife drive gear 6568 is in meshing engagement with a third knife drive gear assembly 6570. As shown in FIG. 168, the second knife driven gear 6568 is in meshing engagement with a fourth knife driven gear 6572 of the third knife drive gear assembly 6570. The fourth knife driven gear 6572 is in meshing engagement with a fifth knife driven gear assembly 6574 that is in meshing engagement with the knife rack gear 6540. In various embodiments, the gears of the knife gear assembly 6560 are sized to generate the forces needed to drive the cutting instrument through the tissue clamped in the surgical end effector 6012 and actuate the staples therein. For example, the gears of the knife gear assembly 6560 may be sized to generate approximately 40 to 100 pounds of driving force. It will be appreciated that the application of a rotary output motion from the tool drive assembly 11010 in one direction will result in the axial movement of the cutting instrument in a distal direction and application of the rotary output motion in an opposite direction will result in the axial travel of the cutting instrument in a proximal direction.

[0426] As can be appreciated from the foregoing description, the surgical tool 6000 represents a vast improvement over prior robotic tool arrangements. The unique and novel transmission arrangement employed by the surgical tool 6000 enables the tool to be operably coupled to a tool holder portion 11010 of a robotic system that only has four rotary output bodies, yet obtain the rotary output motions therefrom to: (i) articulate the end effector about two different articulation axes that are substantially transverse to each other as well as the longitudinal tool axis; (ii) rotate the end effector 6012 about the longitudinal tool axis; (iii) close the anvil 6024 relative to the surgical staple cartridge 6034 to varying degrees to enable the end effector 6012 to be used to manipulate tissue and then clamp it into position for cutting and stapling; and (iv) firing the cutting instrument to cut through the tissue clamped within the end effector 6012. The unique and novel shifter arrangements of various embodiments of the present invention described above enable two different articulation actions to be powered from a single rotatable body portion of the robotic system.

[0427] The various embodiments of the present invention have been described above in connection with cutting-type surgical instruments. It should be noted, however, that in other embodiments, the inventive surgical instrument disclosed herein need not be a cutting-type surgical instrument, but rather could be used in any type of surgical instrument including remote sensor transponders. For example, it could be a non-cutting endoscopic instrument, a grasper, a stapler, a clip applier, an access device, a drug/gene therapy delivery device, an energy device using ultrasound, RF, laser, etc. In addition, the present invention may be in laparoscopic instruments, for example. The present invention also has application in conventional endoscopic and open surgical instrumentation as well as robotic-assisted surgery.

[0428] FIG. 170 depicts use of various aspects of certain embodiments of the present invention in connection with a surgical tool 7000 that has an ultrasonically powered end effector 7012. The end effector 7012 is operably attached to a tool mounting portion 7100 by an elongated shaft assembly 7008. The tool mounting portion 7100 may be substantially similar to the various tool mounting portions described hereinabove. In one embodiment, the end effector 7012 includes an ultrasonically powered jaw portion 7014 that is powered by alternating current or direct current in a known manner. Such ultrasonically-powered devices are disclosed, for example, in U.S. Patent No. 6,783,524, entitled "Robotic Surgical Tool With Ultrasound Cauterizing and Cutting Instrument", the entire disclosure of which is herein incorporated by reference. In the illustrated embodiment, a separate power cord 7020 is

shown. It will be understood, however, that the power may be supplied thereto from the robotic controller 11001 through the tool mounting portion 7100. The surgical end effector 7012 further includes a movable jaw 7016 that may be used to clamp tissue onto the ultrasonic jaw portion 7014. The movable jaw portion 7016 may be selectively actuated by the robotic controller 11001 through the tool mounting portion 7100 in anyone of the various manners herein described.

[0429] FIG. 171 illustrates use of various aspects of certain embodiments of the present invention in connection with a surgical tool 8000 that has an end effector 8012 that comprises a linear stapling device. The end effector 8012 is operably attached to a tool mounting portion 8100 by an elongated shaft assembly 3700 of the type and construction describe above. However, the end effector 8012 may be attached to the tool mounting portion 8100 by a variety of other elongated shaft assemblies described herein. In one embodiment, the tool mounting portion 8100 may be substantially similar to tool mounting portion 3750. However, various other tool mounting portions and their respective transmission arrangements describe in detail herein may also be employed. Such linear stapling head portions are also disclosed, for example, in U.S. Patent No. 7,673,781, entitled "Surgical Stapling Device With Staple Driver That Supports Multiple Wire Diameter Staples", the entire disclosure of which is herein incorporated by reference.

[0430] Various sensor embodiments described in U.S. Patent Publication No. 2011/0062212 A1 to Shelton, IV et al., the disclosure of which is herein incorporated by reference in its entirety, may be employed with many of the surgical tool embodiments disclosed herein. As was indicated above, the master controller 11001 generally includes master controllers (generally represented by 11003) which are grasped by the surgeon and manipulated in space while the surgeon views the procedure via a stereo display 11002. See FIG. 54. The master controllers 11001 are manual input devices which preferably move with multiple degrees of freedom, and which often further have an actuatable handle for actuating the surgical tools. Some of the surgical tool embodiments disclosed herein employ a motor or motors in their tool drive portion to supply various control motions to the tool's end effector. Such embodiments may also obtain additional control motion(s) from the motor arrangement employed in the robotic system components. Other embodiments disclosed herein obtain all of the control motions from motor arrangements within the robotic system.

[0431] Such motor powered arrangements may employ various sensor arrangements that are disclosed in the published US patent application cited above to provide the surgeon with a

variety of forms of feedback without departing from the spirit and scope of the present invention. For example, those master controller arrangements 11003 that employ a manually actuatable firing trigger can employ run motor sensor(s) to provide the surgeon with feedback relating to the amount of force applied to or being experienced by the cutting member. The run motor sensor(s) may be configured for communication with the firing trigger portion to detect when the firing trigger portion has been actuated to commence the cutting/stapling operation by the end effector. The run motor sensor may be a proportional sensor such as, for example, a rheostat or variable resistor. When the firing trigger is drawn in, the sensor detects the movement, and sends an electrical signal indicative of the voltage (or power) to be supplied to the corresponding motor. When the sensor is a variable resistor or the like, the rotation of the motor may be generally proportional to the amount of movement of the firing trigger. That is, if the operator only draws or closes the firing trigger in a small amount, the rotation of the motor is relatively low. When the firing trigger is fully drawn in (or in the fully closed position), the rotation of the motor is at its maximum. In other words, the harder the surgeon pulls on the firing trigger, the more voltage is applied to the motor causing greater rates of rotation. Other arrangements may provide the surgeon with a feed back meter 11005 that may be viewed through the display 11002 and provide the surgeon with a visual indication of the amount of force being applied to the cutting instrument or dynamic clamping member. Other sensor arrangements may be employed to provide the master controller 11001 with an indication as to whether a staple cartridge has been loaded into the end effector, whether the anvil has been moved to a closed position prior to firing, etc.

[0432] In still other embodiments, the various robotic systems and tools disclosed herein may employ many of the sensor/transponder arrangements disclosed above. Such sensor arrangements may include, but are not limited to, run motor sensors, reverse motor sensors, stop motor sensors, end-of-stroke sensors, beginning-of-stroke sensors, cartridge lockout sensors, sensor transponders, etc. The sensors may be employed in connection with any of the surgical tools disclosed herein that are adapted for use with a robotic system. The sensors may be configured to communicate with the robotic system controller. In other embodiments, components of the shaft/end effector may serve as antennas to communicate between the sensors and the robotic controller. In still other embodiments, the various remote programming device arrangements described above may also be employed with the robotic controller.

[0433] In alternative embodiments, a motor-controlled interface may be employed in connection with the controller 11001 that limit the maximum trigger pull based on the amount of loading (e.g., clamping force, cutting force, etc.) experienced by the surgical end effector. For example, the harder it is to drive the cutting instrument through the tissue clamped within the end effector, the harder it would be to pull/actuate the activation trigger. In still other embodiments, the trigger on the controller 11001 is arranged such that the trigger pull location is proportionate to the end effector-location/condition. For example, the trigger is only fully depressed when the end effector is fully fired.

[0434] The devices disclosed herein can be designed to be disposed of after a single use, or they can be designed to be used multiple times. In either case, however, the device can be reconditioned for reuse after at least one use. Reconditioning can include any combination of the steps of disassembly of the device, followed by cleaning or replacement of particular pieces, and subsequent reassembly. In particular, the device can be disassembled, and any number of the particular pieces or parts of the device can be selectively replaced or removed in any combination. Upon cleaning and/or replacement of particular parts, the device can be reassembled for subsequent use either at a reconditioning facility, or by a surgical team immediately prior to a surgical procedure. Those skilled in the art will appreciate that reconditioning of a device can utilize a variety of techniques for disassembly, cleaning/replacement, and reassembly. Use of such techniques, and the resulting reconditioned device, are all within the scope of the present application.

[0435] Although the present invention has been described herein in connection with certain disclosed embodiments, many modifications and variations to those embodiments may be implemented. For example, different types of end effectors may be employed. Also, where materials are disclosed for certain components, other materials may be used. The foregoing description and following claims are intended to cover all such modification and variations.

[0436] Any patent, publication, or other disclosure material, in whole or in part, that is said to be incorporated by reference herein is incorporated herein only to the extent that the incorporated materials does not conflict with existing definitions, statements, or other disclosure material set forth in this disclosure. As such, and to the extent necessary, the disclosure as explicitly set forth herein supersedes any conflicting material incorporated herein by reference. Any material, or portion thereof, that is said to be incorporated by reference herein, but which conflicts with existing definitions, statements, or other disclosure

material set forth herein will only be incorporated to the extent that no conflict arises between that incorporated material and the existing disclosure material.

CLAIMS

We claim:

1. A surgical cutting and fastening instrument comprising:
 - a end effector having a moveable cutting implement operably supported therein;
 - a main drive shaft assembly operably interfacing with the end effector for transmitting an actuation motion to the movable cutting implement therein;
 - a gear drive train connected to the main drive shaft assembly;
 - a motor for actuating the gear drive train, said motor configured to receive control signals from a robotic system; and
 - a sensor arrangement operably interfacing with said end effector and said robotic system to communicate forces experienced by said end effector to said robotic system.

2. The surgical cutting and fastening instrument of claim 1, further comprising:
 - a reverse motor sensor for sensing an end of a cutting stroke of the cutting implement such that when the reverse motor sensor senses the end of the cutting stroke, the motor is signaled to reverse rotate to retract the cutting implement;
 - a stop motor sensor for sensing retraction of the cutting implement such that when the stop motor sensor senses retraction of the cutting implement, the motor is signaled to stop rotating.

3. The surgical cutting and fastening instrument of claim 1, wherein the end effector includes a staple cartridge.

4. The surgical cutting and fastening instrument of claim 1, wherein the end effector includes a helical drive screw, such that forward rotation of the helical drive screw causes the cutting implement to undertake the cutting stroke, and reverse rotation of the helical drive screw causes the cutting implement to retract.

5. The surgical cutting and fastening instrument of claim 1, wherein the main drive shaft includes articulation means for articulating the end effector.

6. The surgical cutting and fastening instrument of claim 1, wherein said end effector has an anvil movably supported thereon.
7. The surgical cutting and fastening instrument of claim 6 further comprising a closure actuator interfacing with said main drive shaft assembly to selectively apply opening and closing motions to said anvil.
8. The surgical cutting and fastening instrument of claim 1, wherein the end effector comprises:
 - an elongate channel for carrying the cutting instrument; and
 - a clamping member pivotably connected to the elongate channel.
9. The surgical cutting and fastening instrument of claim 7 wherein said main drive shaft assembly further comprises a closure tube movably interfacing with said anvil such that movement of said closure tube in a distal direction causes said anvil to move to a closed position and movement of said closure tube in a proximal direction, said closure tube causes said anvil to open.
10. The surgical cutting and fastening instrument of claim 1, wherein the motor comprises a DC brushed motor.
11. The surgical cutting and fastening instrument of claim 1 wherein said robotic system has a manually actuatable portion that communicates with said sensor arrangement to provide a person actuating said manually actuatable portion with an indication of at least one of said forces experienced by the end effector.
12. The surgical cutting and fastening instrument of claim 11 wherein said indication of at least one of said forces experienced by the end effector comprises a haptic indication.

13. The surgical cutting and fastening instrument of claim 11 wherein said indication of at least one of said forces experienced by the end effector comprises a visual indication on a controller portion of said robotic system.
14. A surgical instrument, comprising:
an end effector comprising:
an elongated channel configured to operably support a staple cartridge therein;
an anvil movably supported relative to said elongated channel and being movable to an open position relative to a staple cartridge within said elongated channel upon application of an opening motion thereto, said anvil being movable to a closed position relative to the staple cartridge upon application of a closing motion to said anvil; and
a tissue cutting implement operably supported for reciprocable movement within said elongated channel upon application of actuation and retraction motions thereto and wherein said surgical instrument further comprises:
a shaft assembly connected to the end effector, said shaft assembly comprising:
a drive shaft operably interfacing with said tissue cutting implement for transmitting said actuation and retraction motions thereto;
a gear drive train operably interfacing with said drive shaft;
a motor for actuating the gear drive train, said motor configured to receive control signals from a robotic system; and
means for communicating forces experienced by said end effector to said robotic system.
15. The surgical cutting and fastening instrument of claim 14 wherein said shaft assembly further comprises a closure tube movably interfacing with said anvil such that movement of said closure tube in a distal direction causes said anvil to move to a closed position and movement of said closure tube in a proximal direction, said closure tube causes said anvil to open.

16. The surgical cutting and fastening instrument of claim 15 further comprising means for applying closure control motions to said closure tube.

17. The surgical cutting and fastening instrument of claim 16 wherein said means for applying closure control motions comprises a second motor operably interfacing with said robotic system and said closure tube to apply said closure control motions thereto.

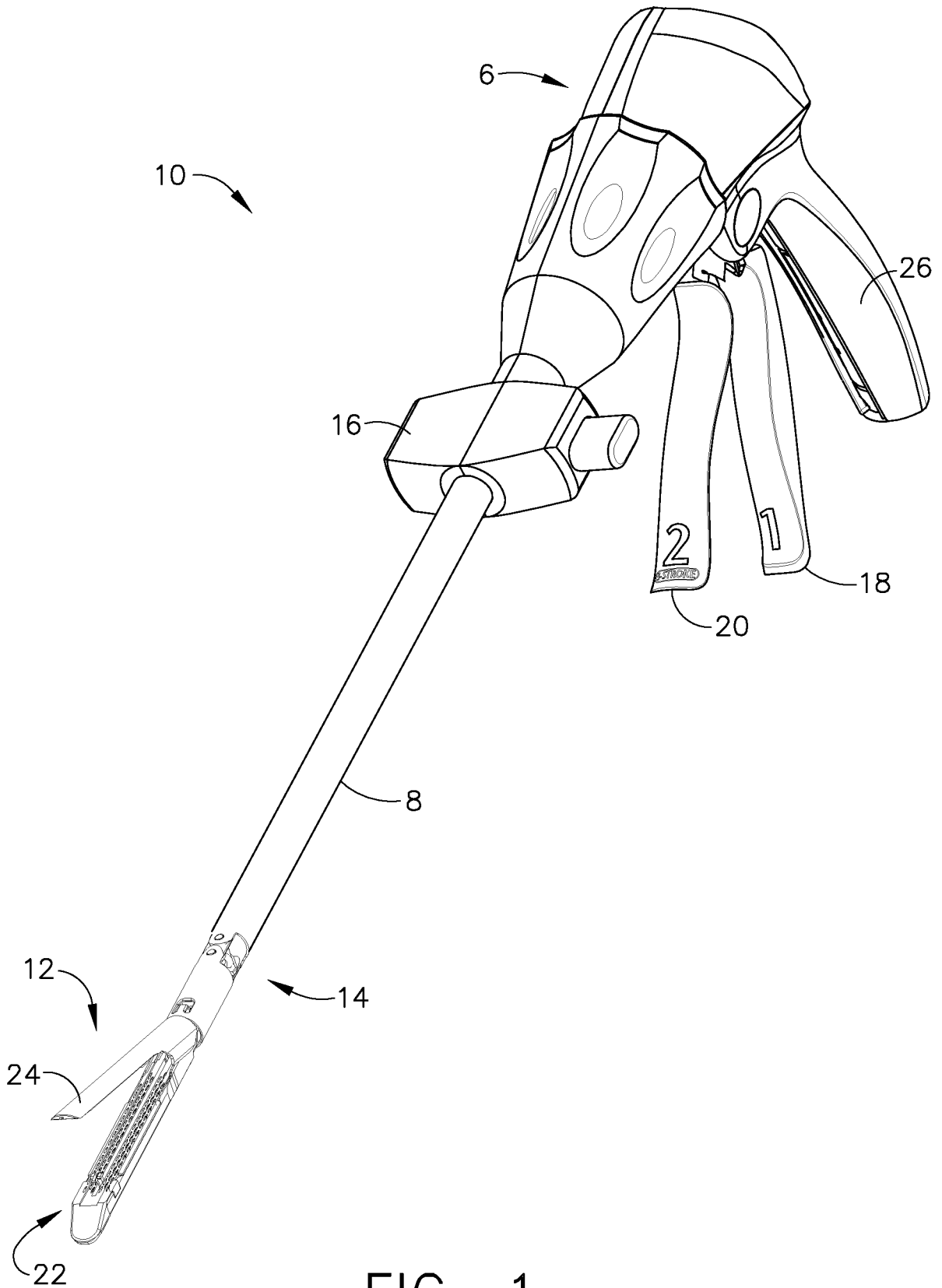


FIG. 1

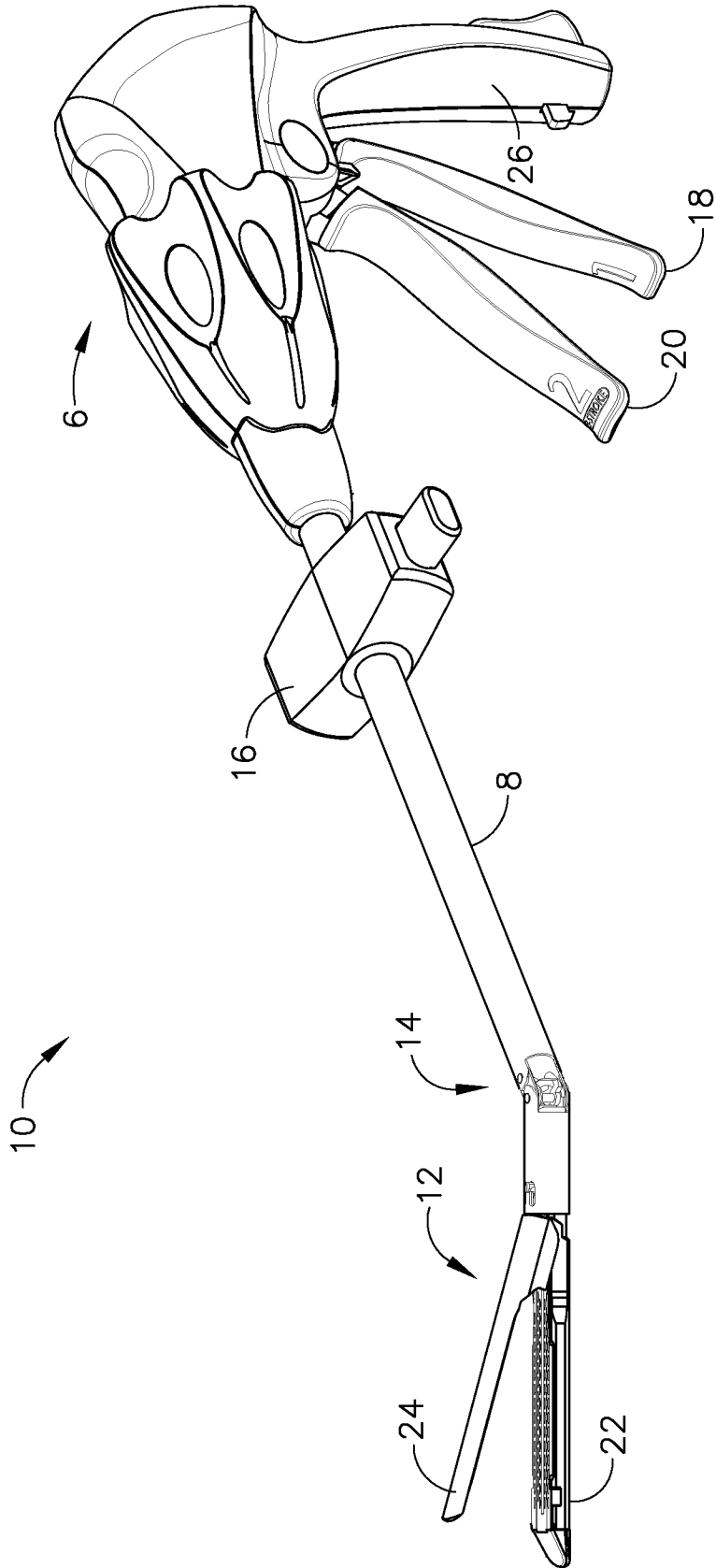


FIG. 2

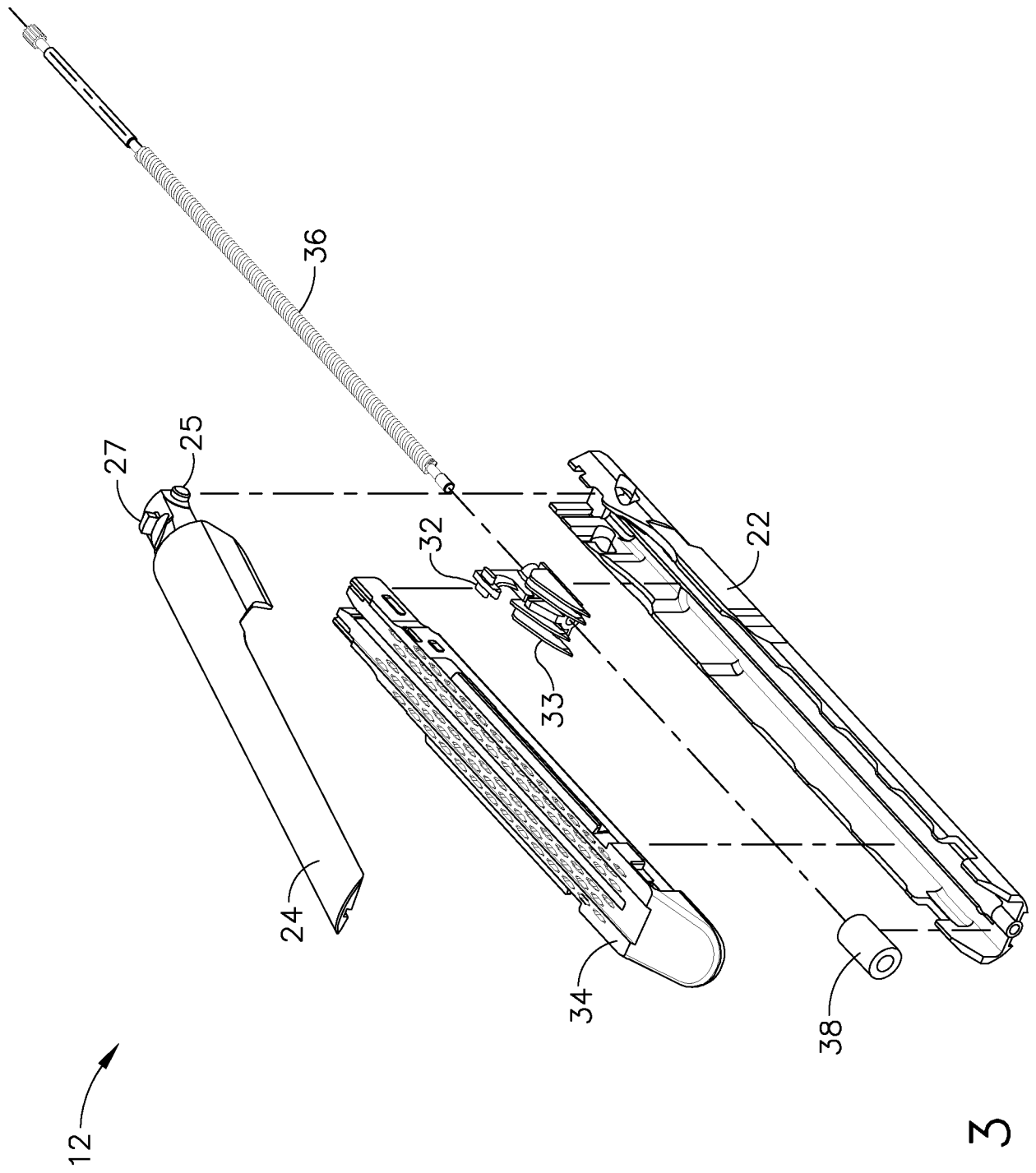


FIG. 3

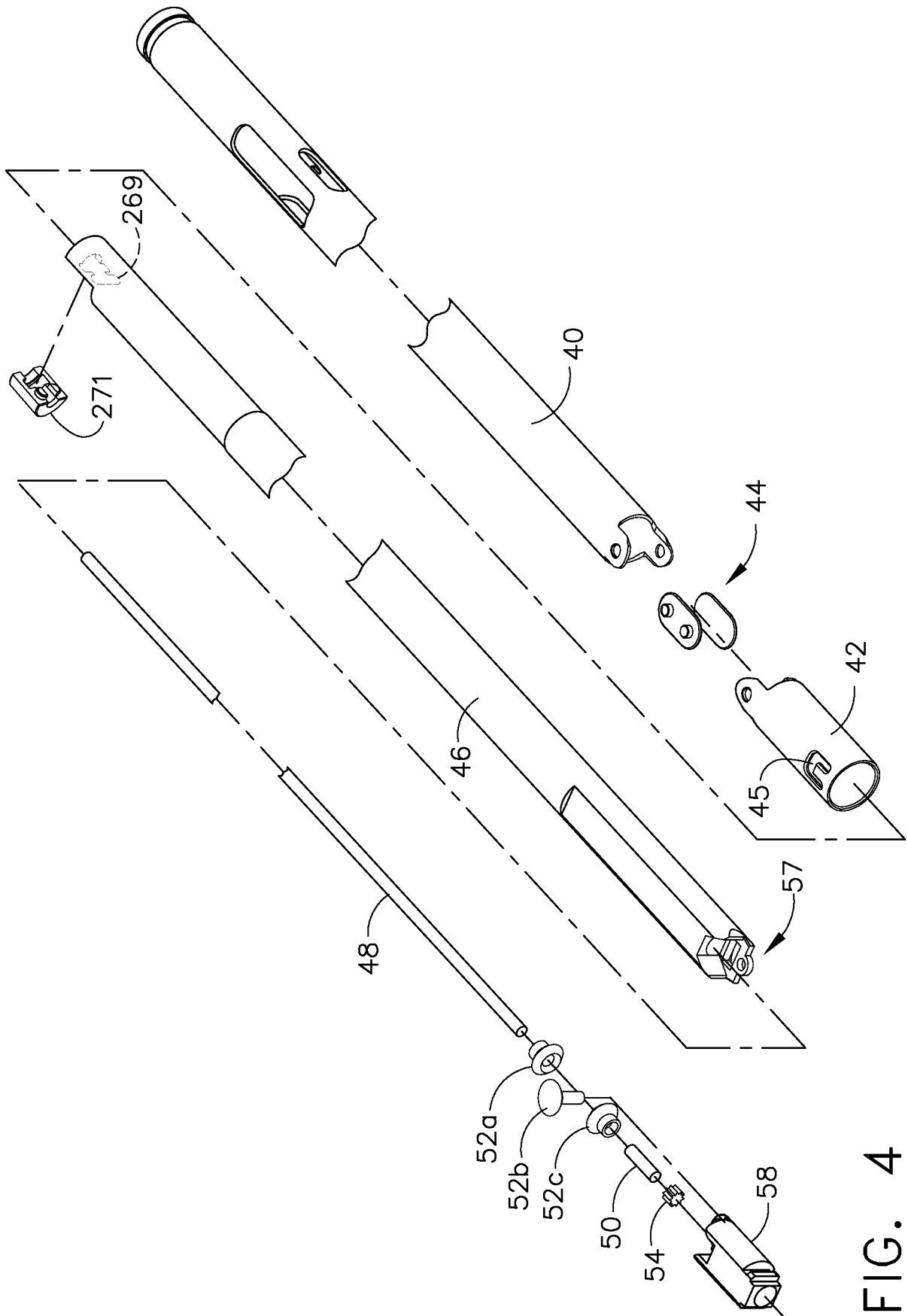


FIG. 4

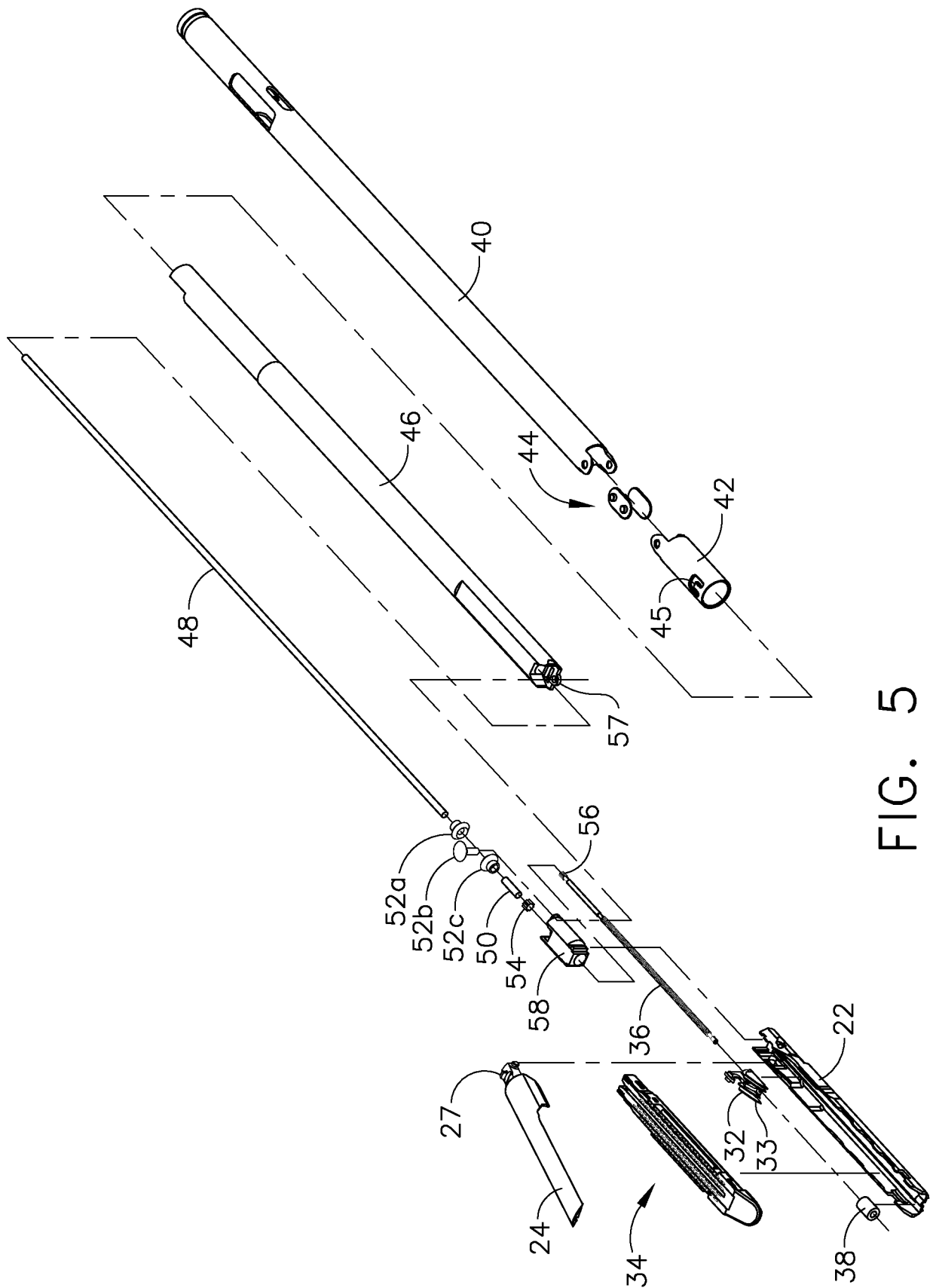


FIG. 5

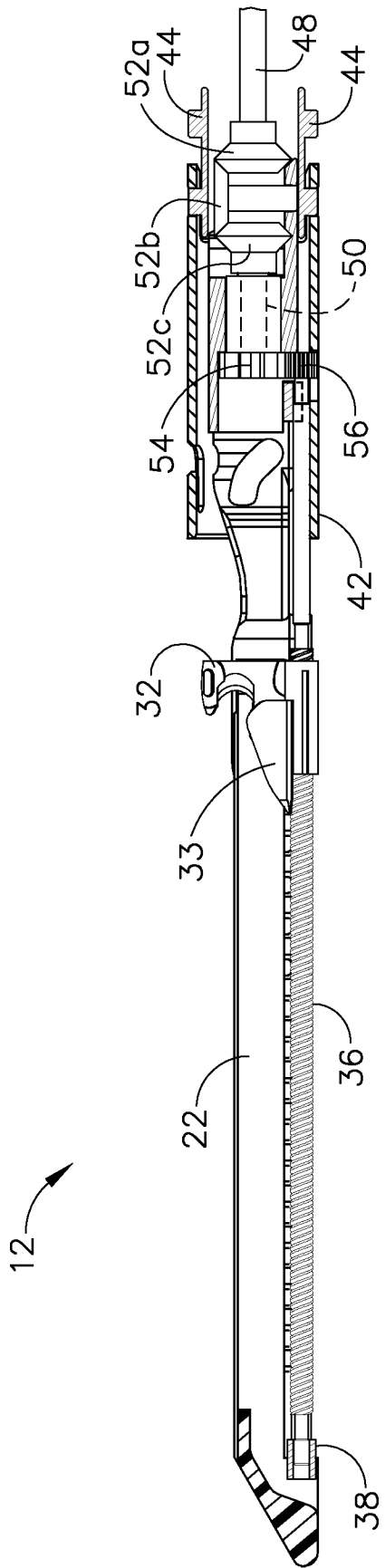


FIG. 6

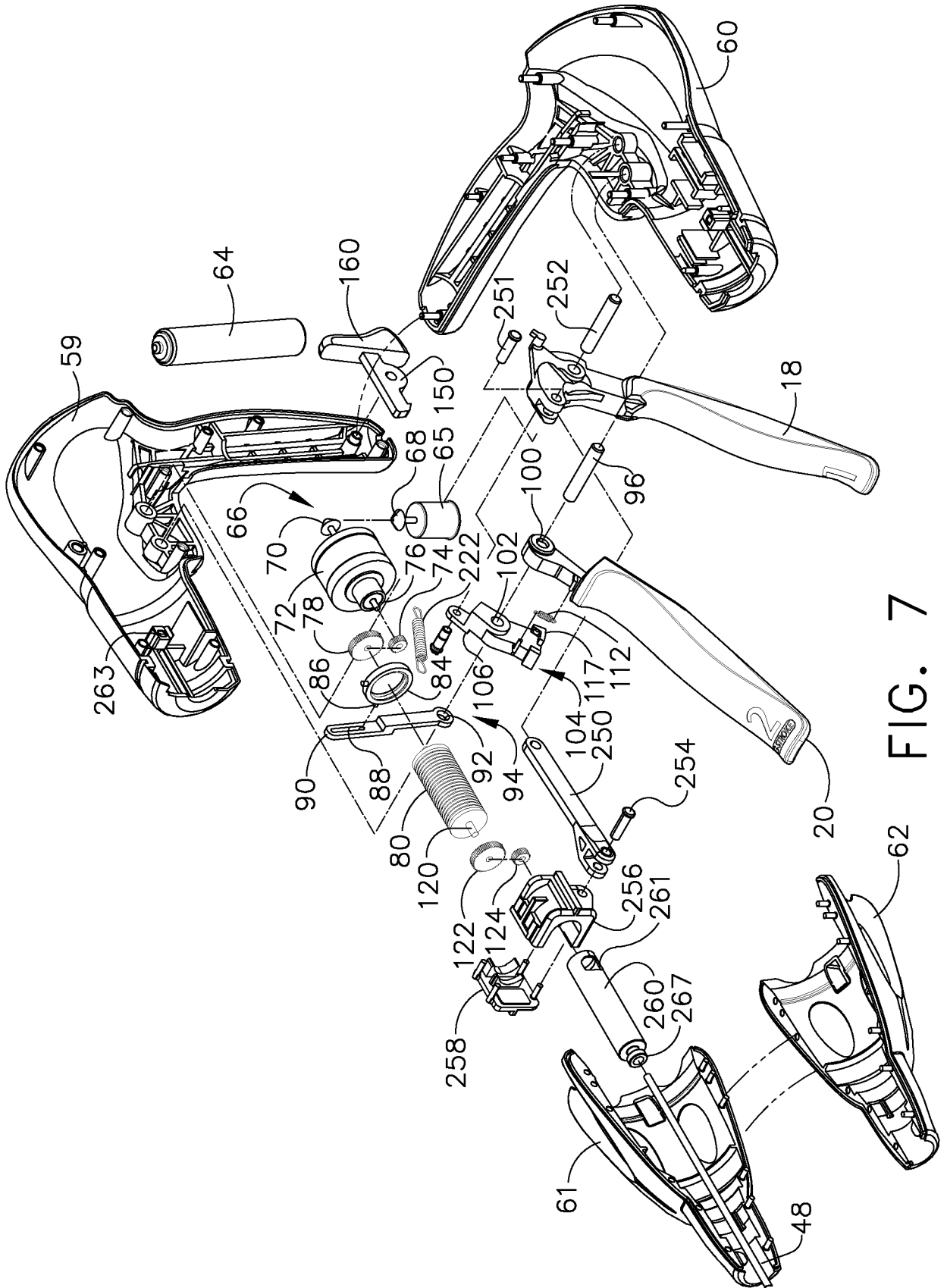


FIG. 7

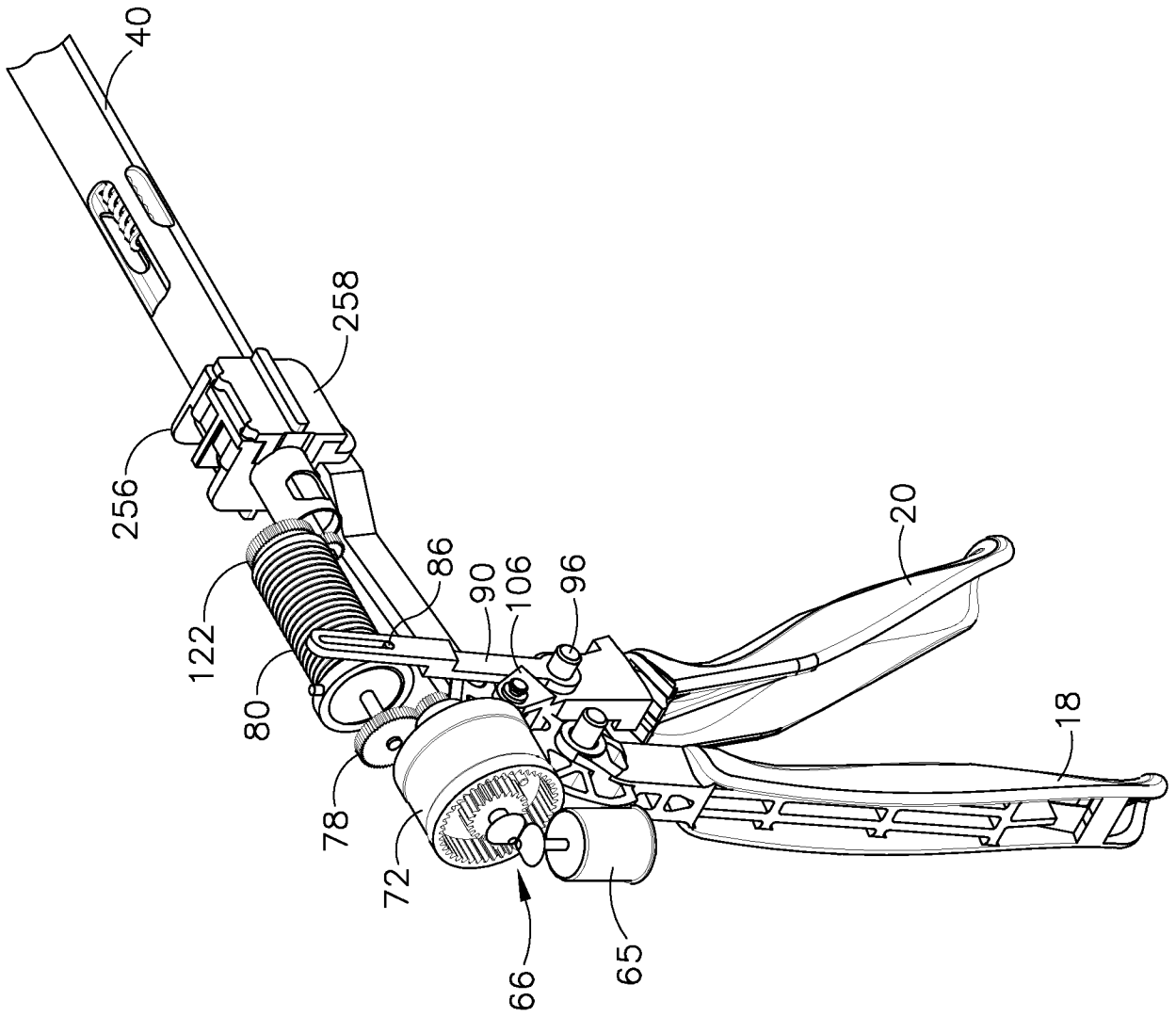


FIG. 8

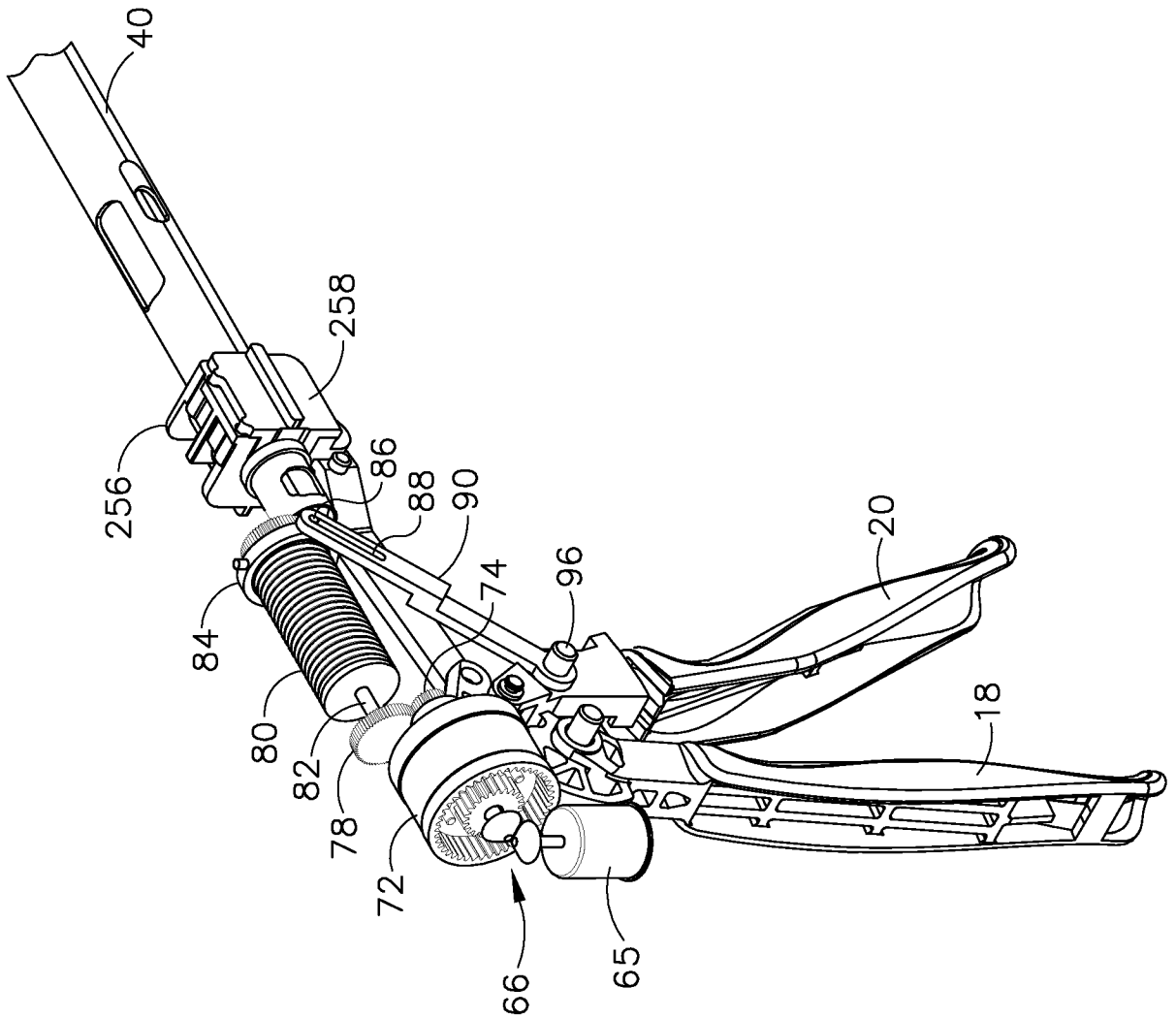


FIG. 9

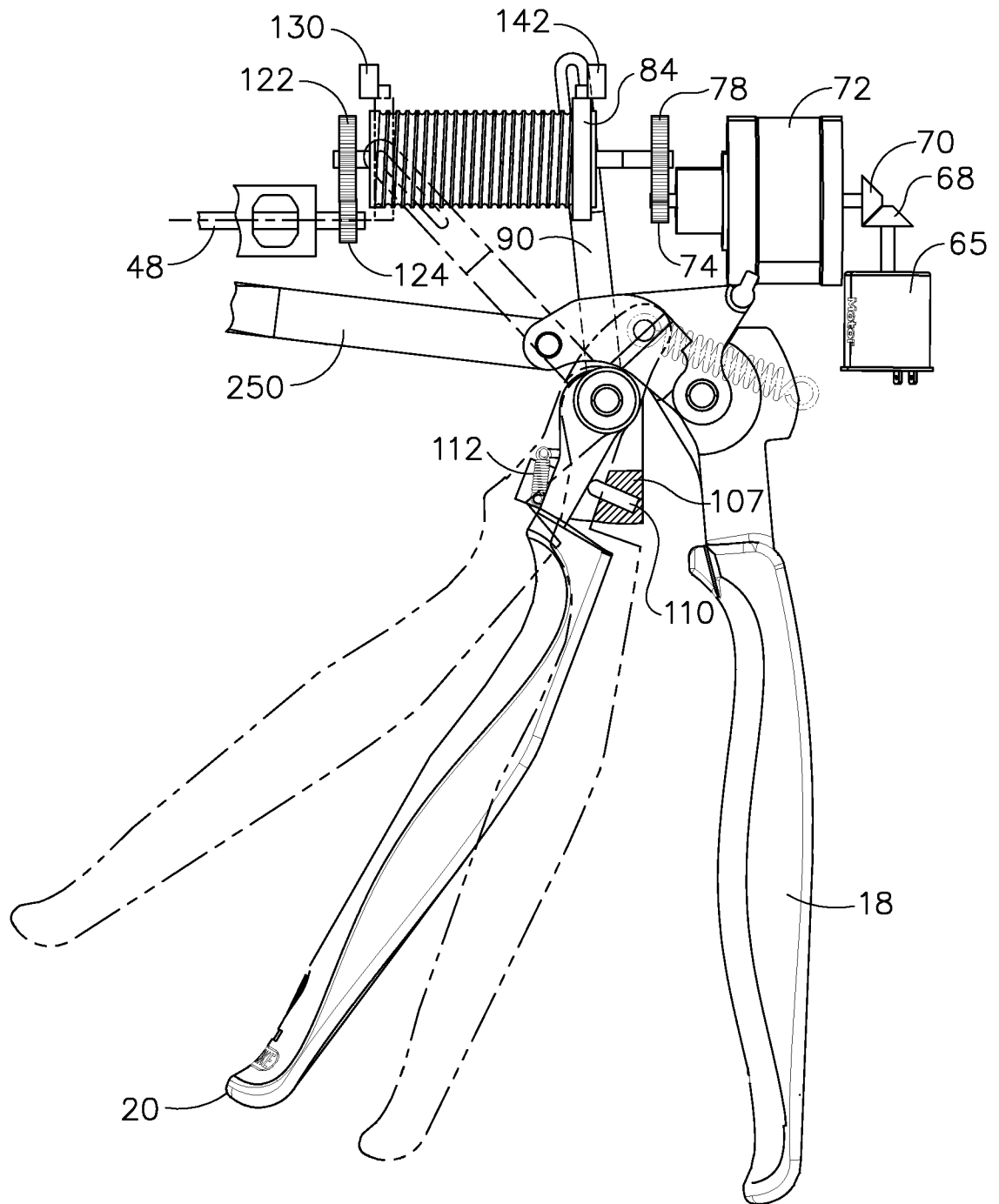


FIG. 10

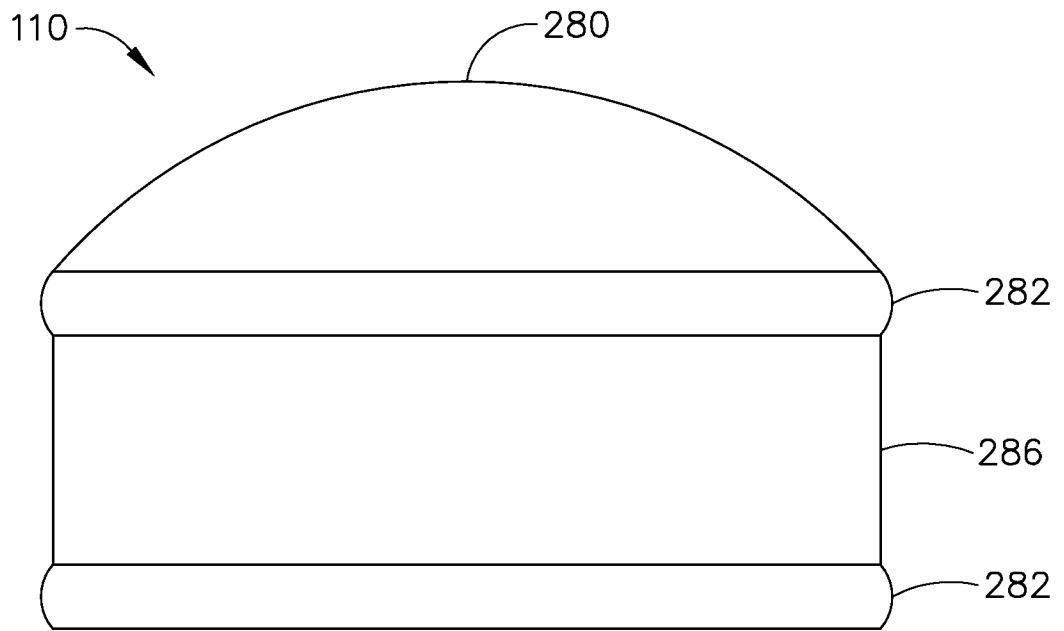


FIG. 10A

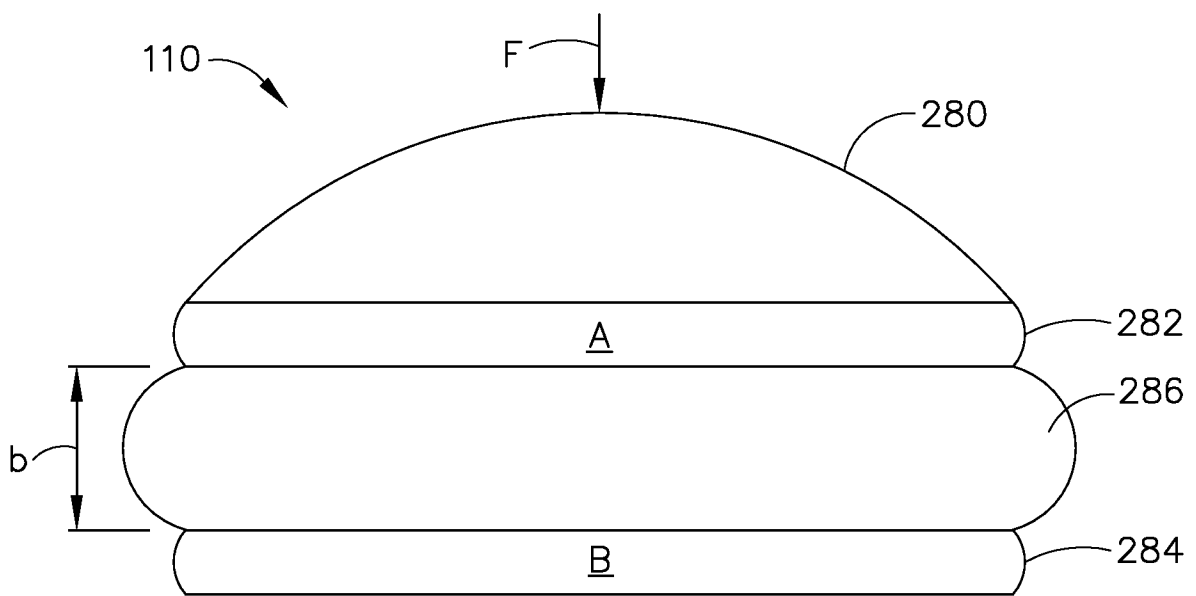


FIG. 10B

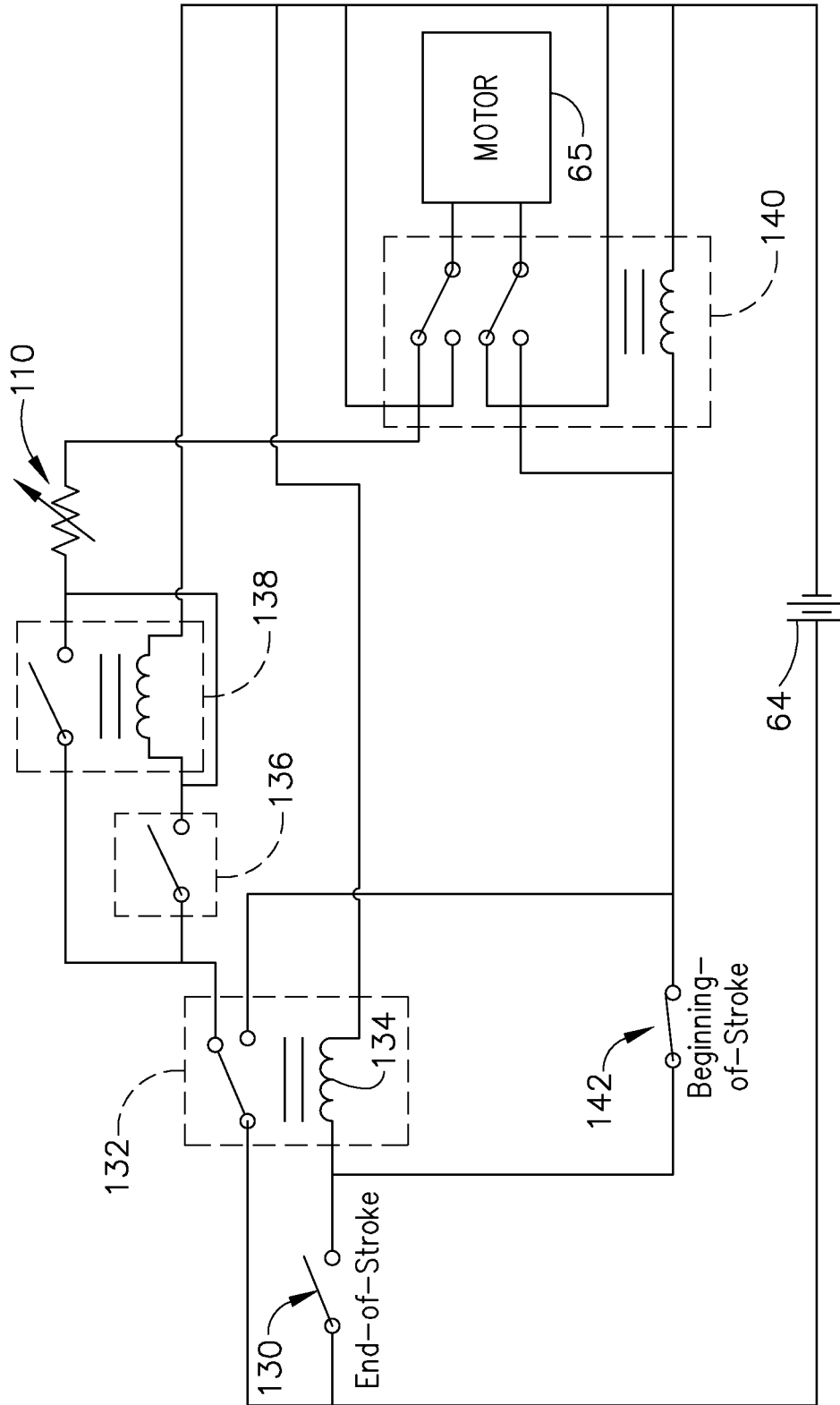


FIG. 11

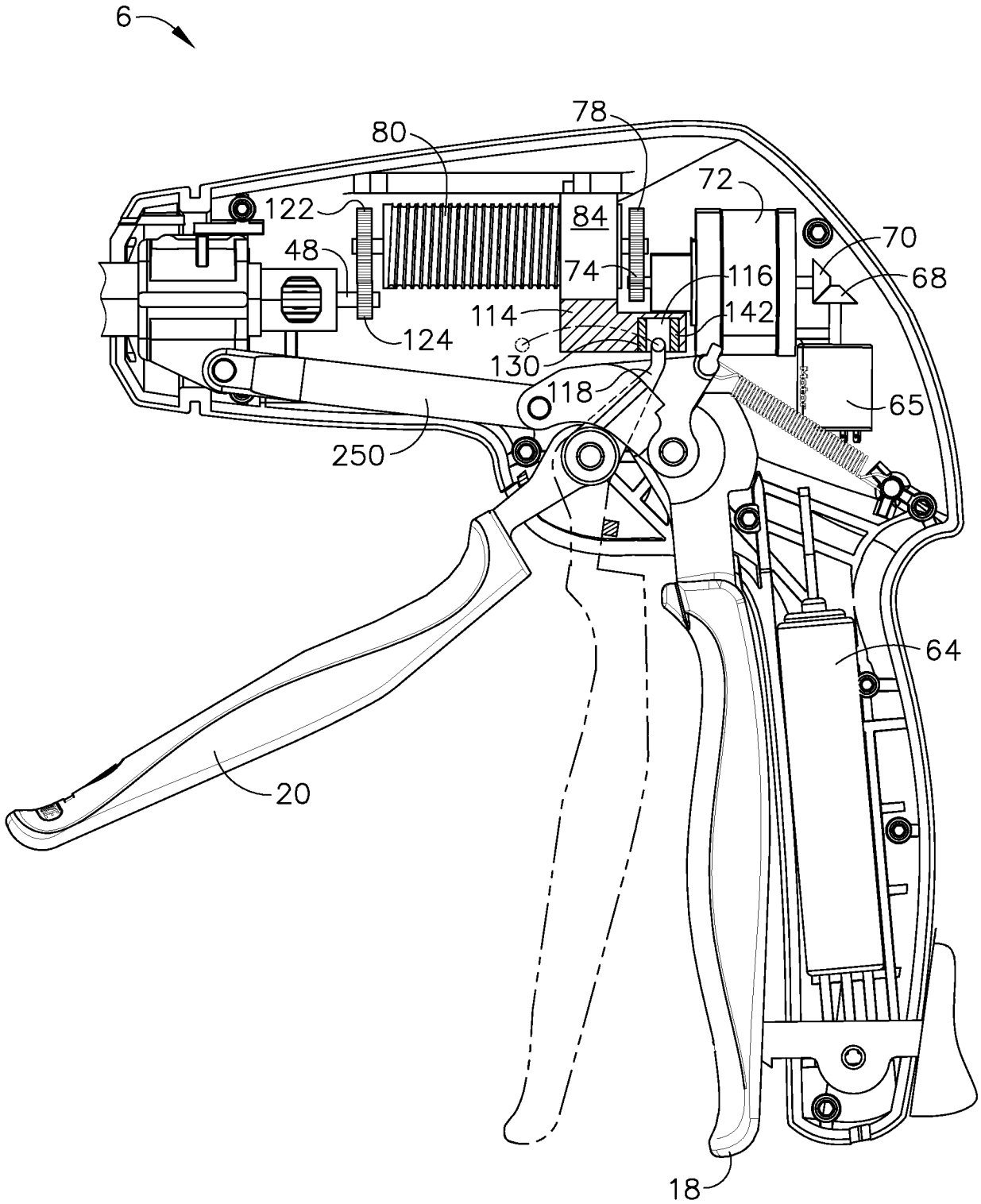


FIG. 12

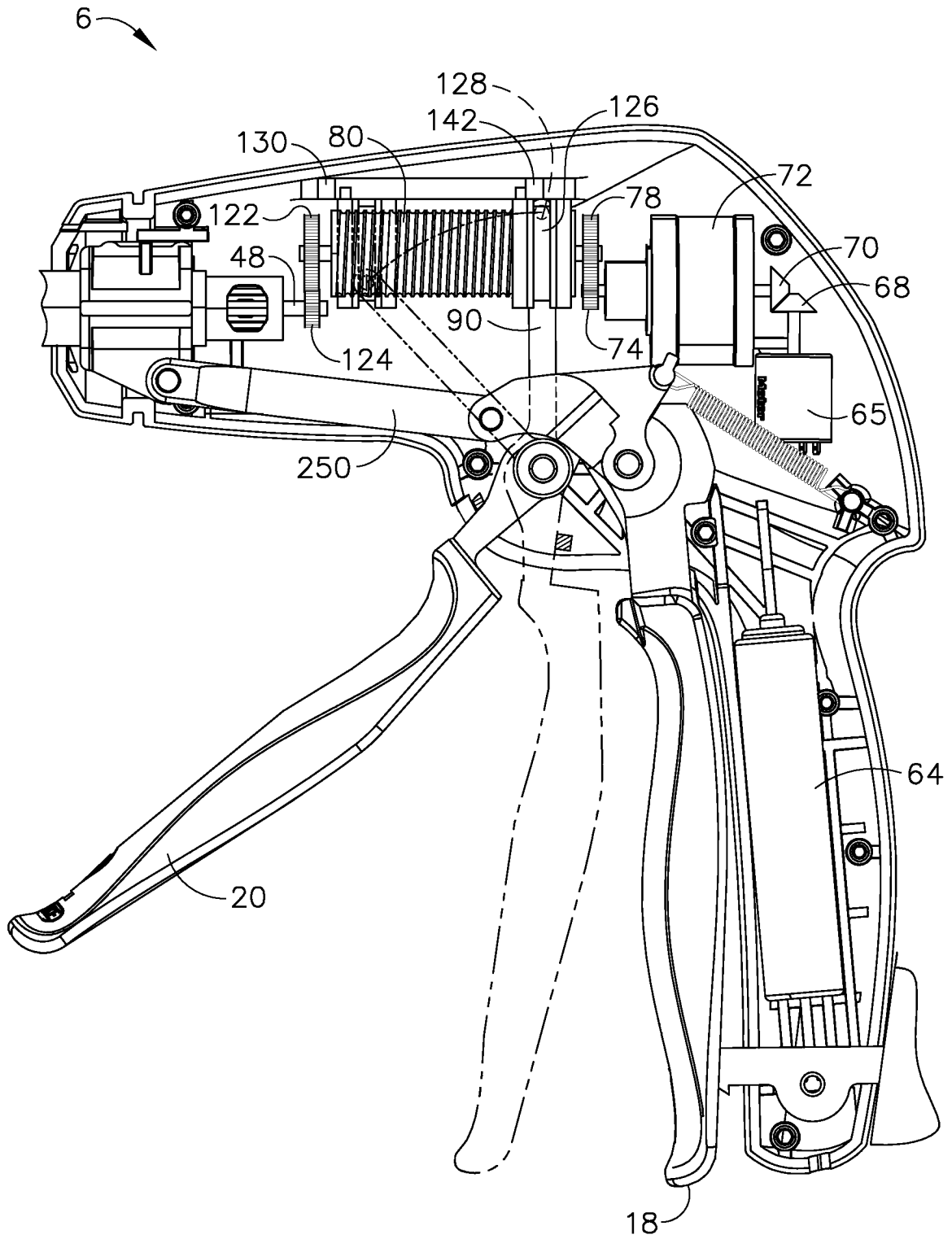


FIG. 13

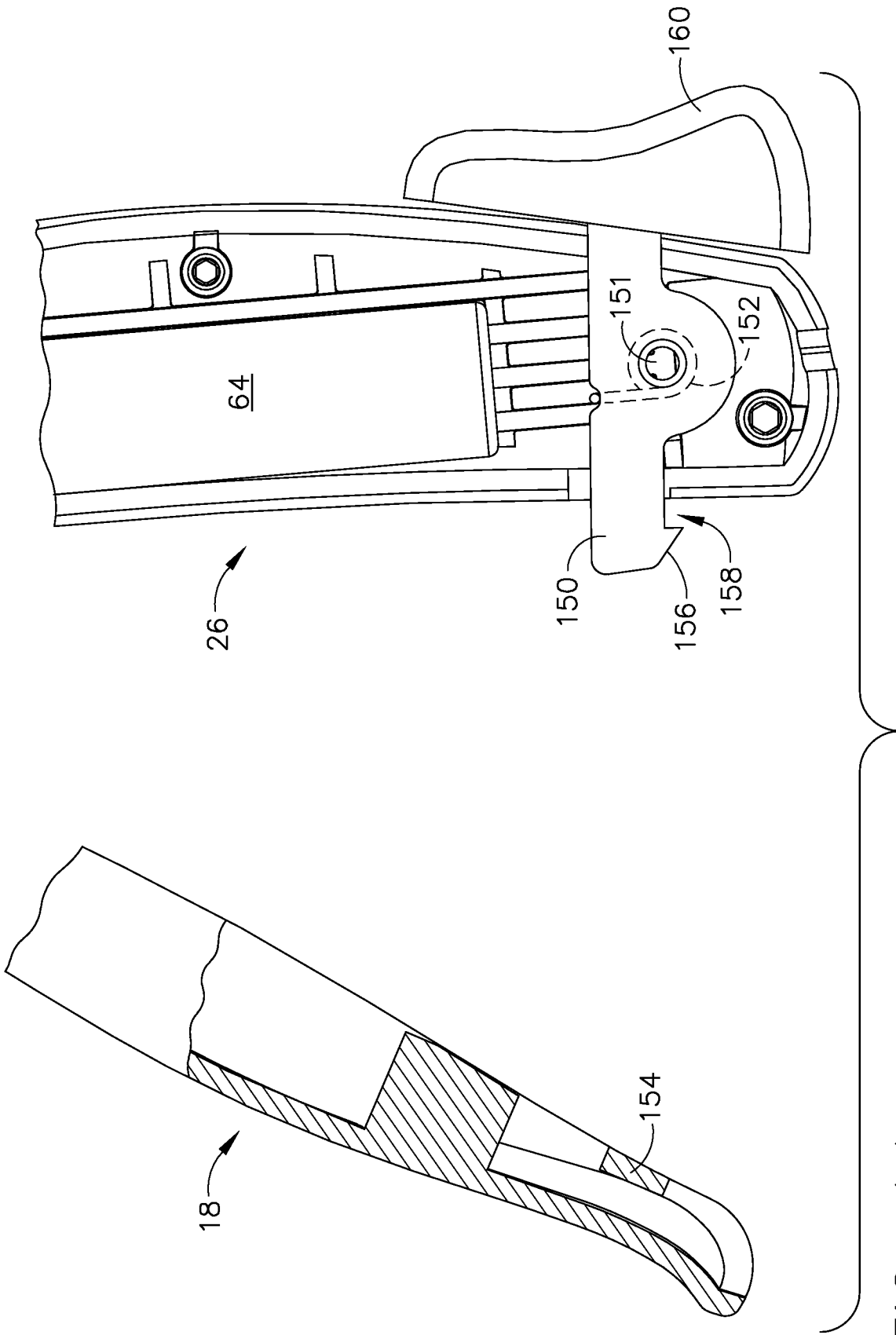


FIG. 14

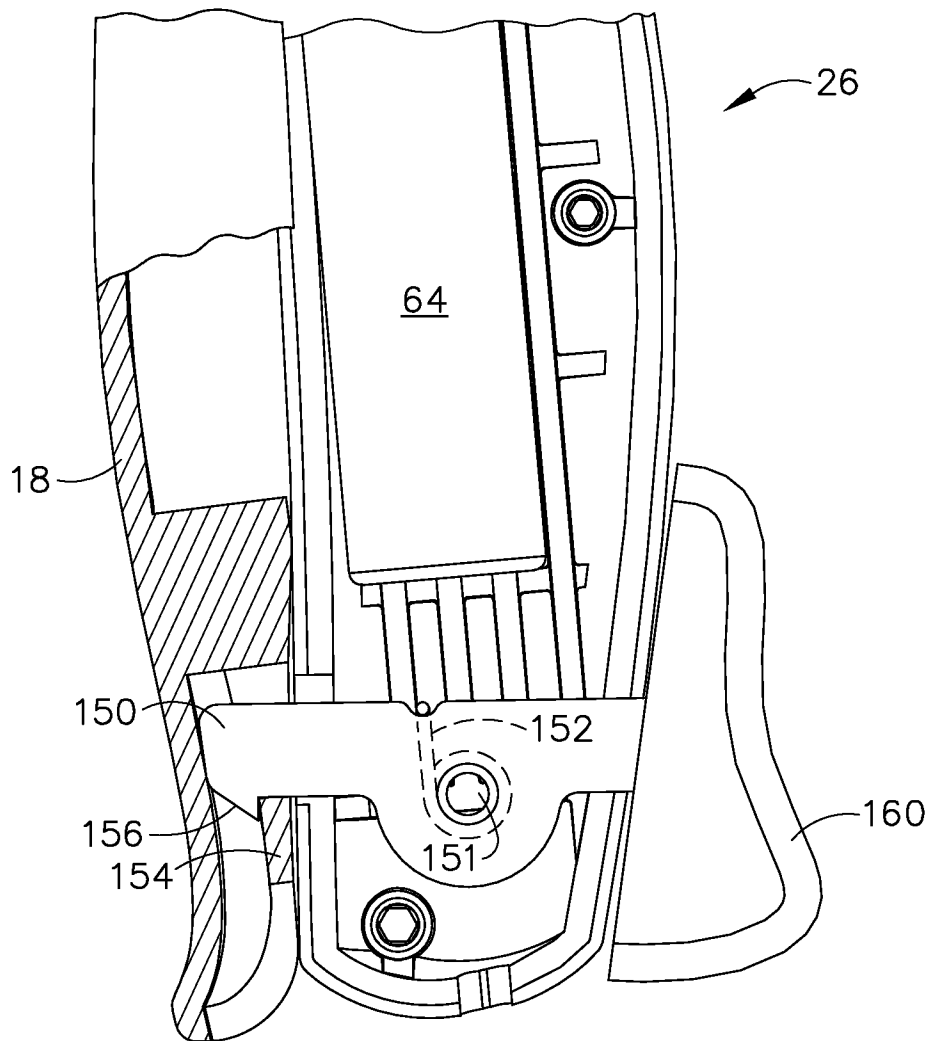


FIG. 15

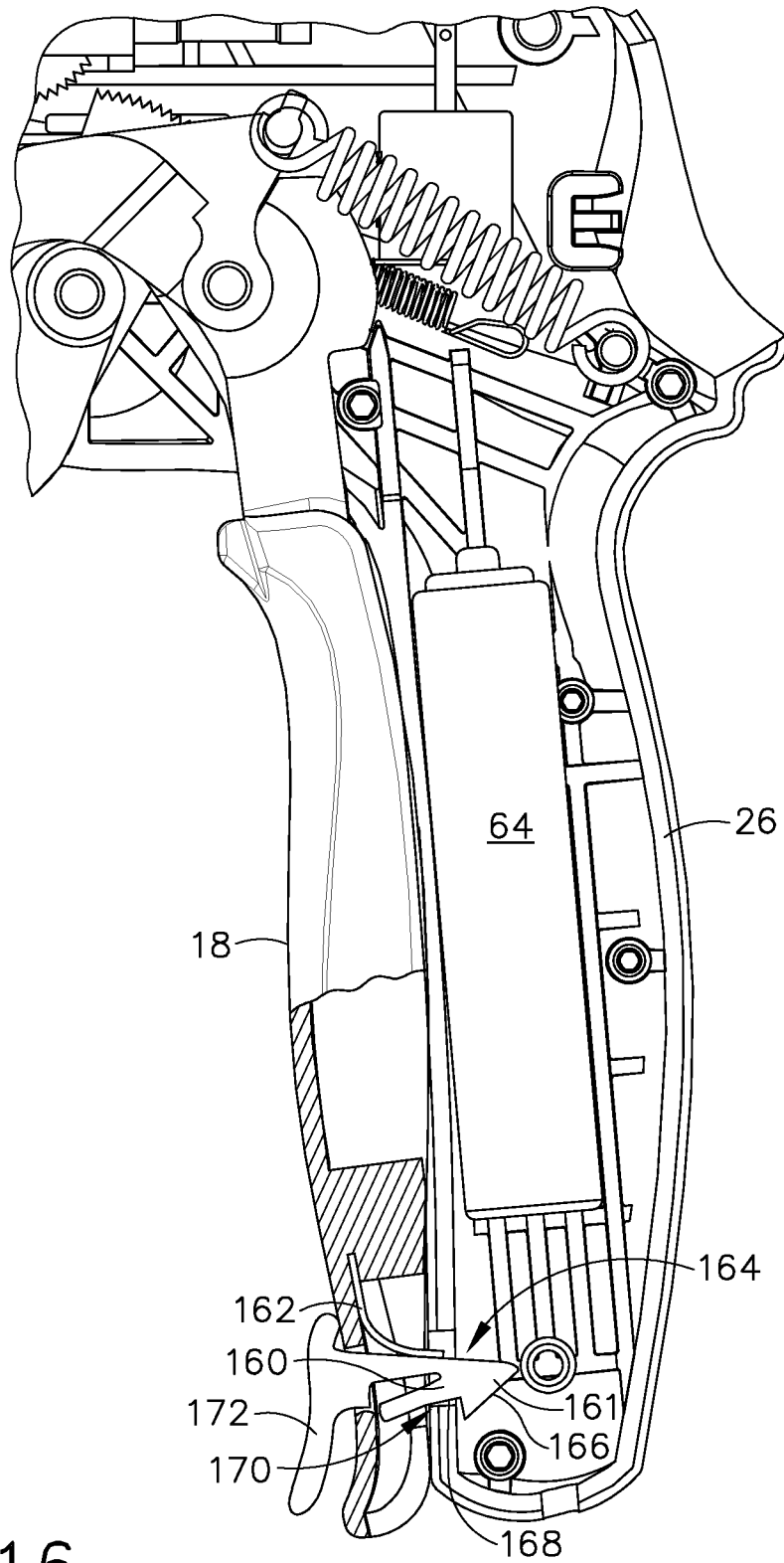


FIG. 16

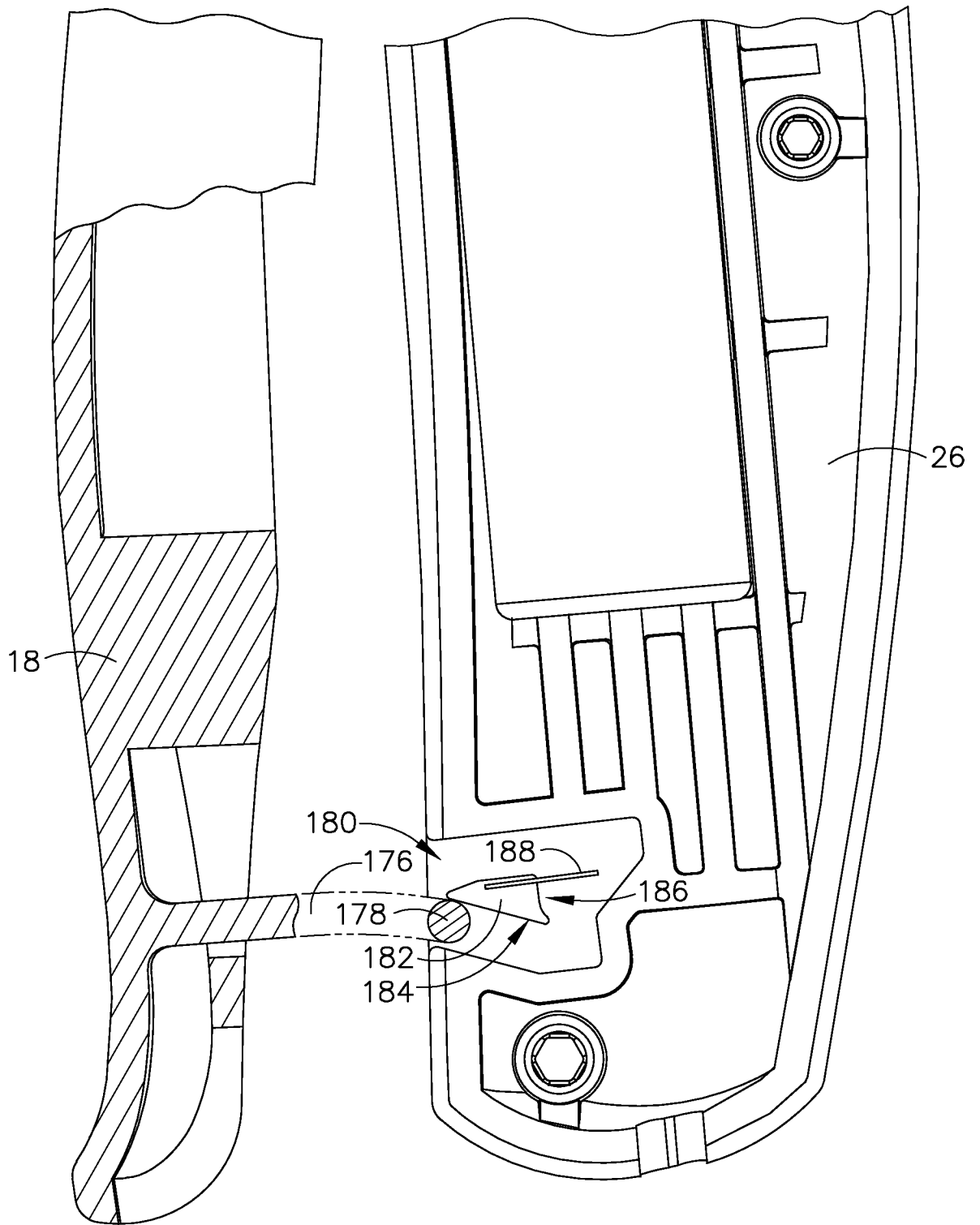


FIG. 17

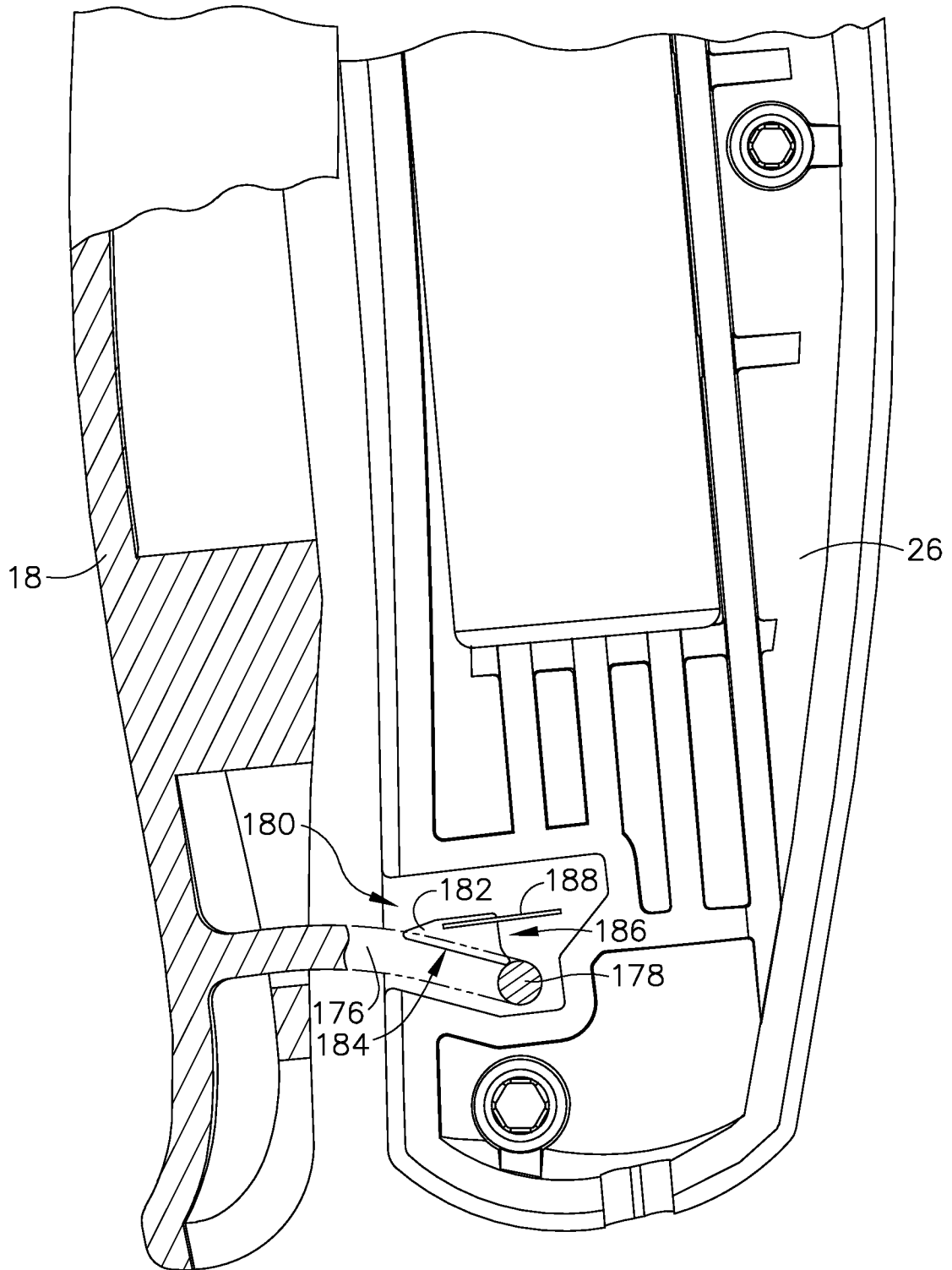


FIG. 18

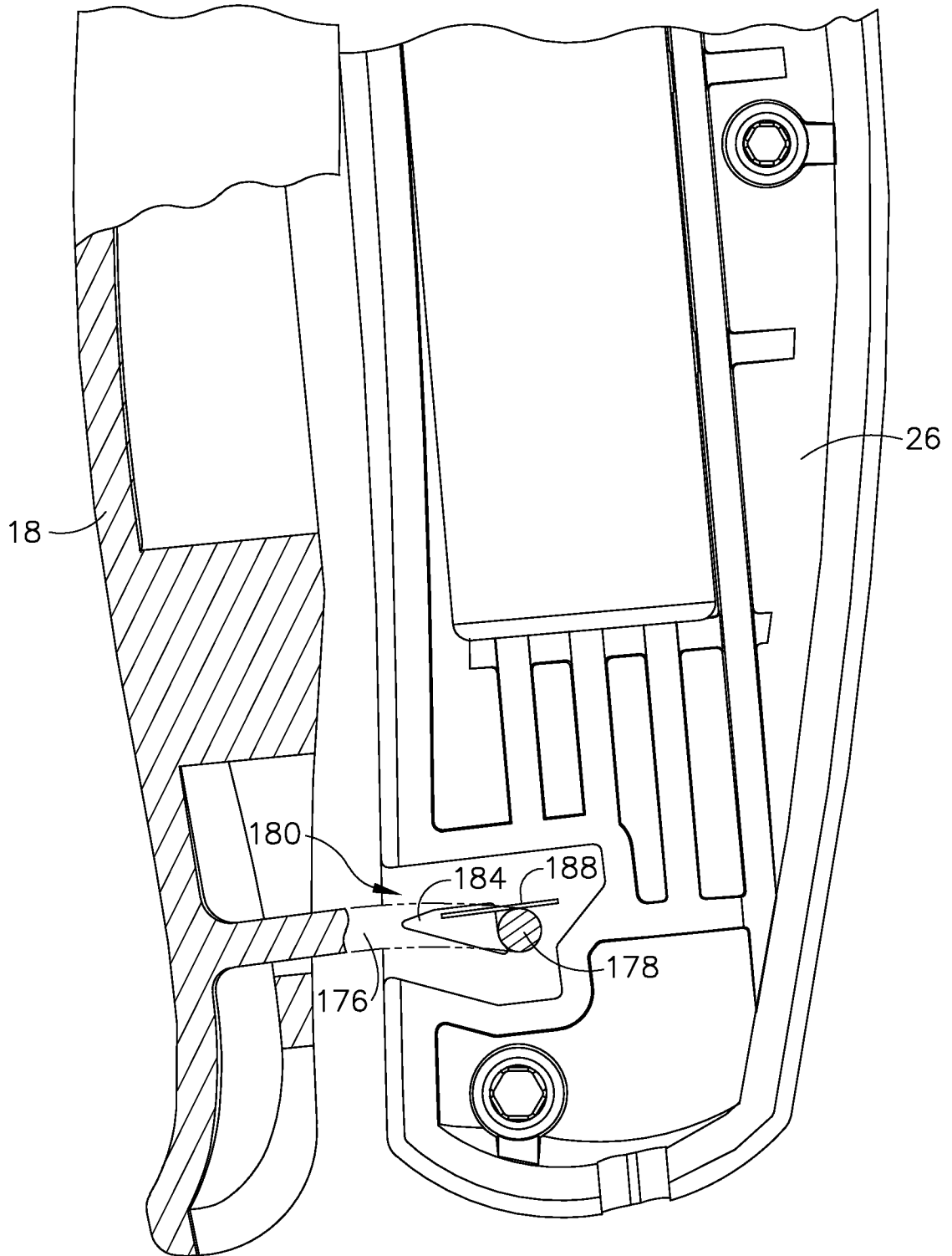


FIG. 19

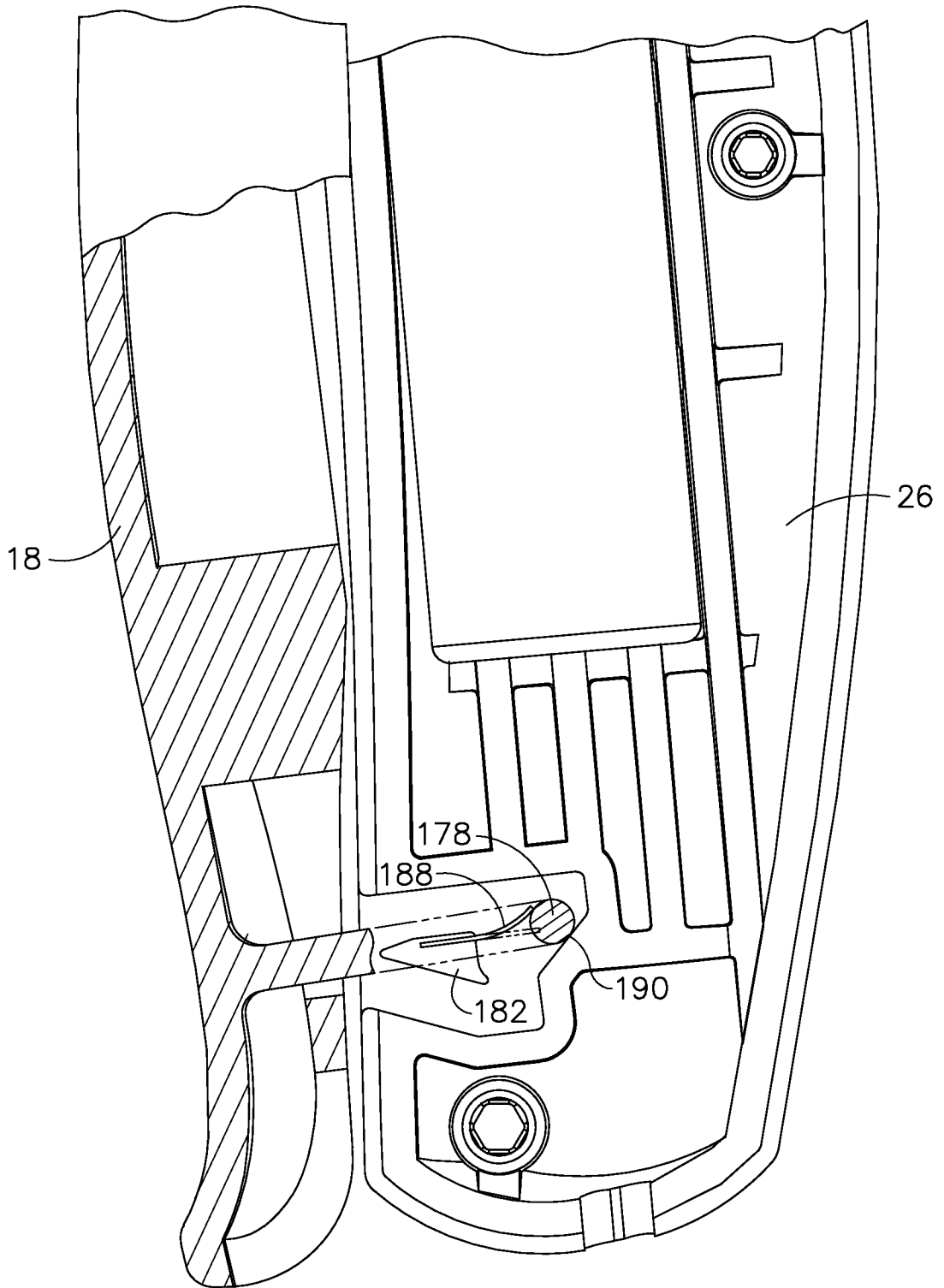


FIG. 20

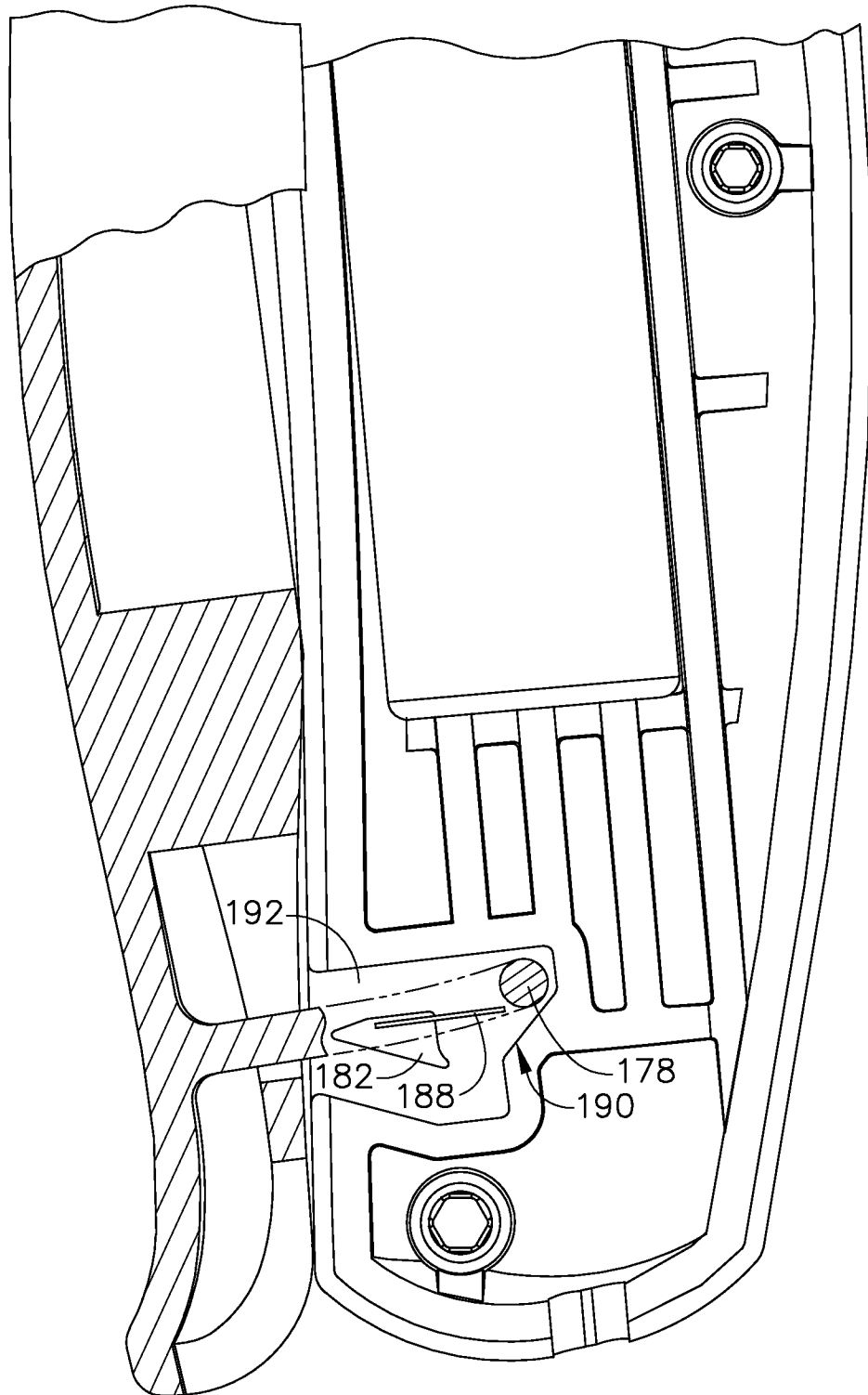


FIG. 21

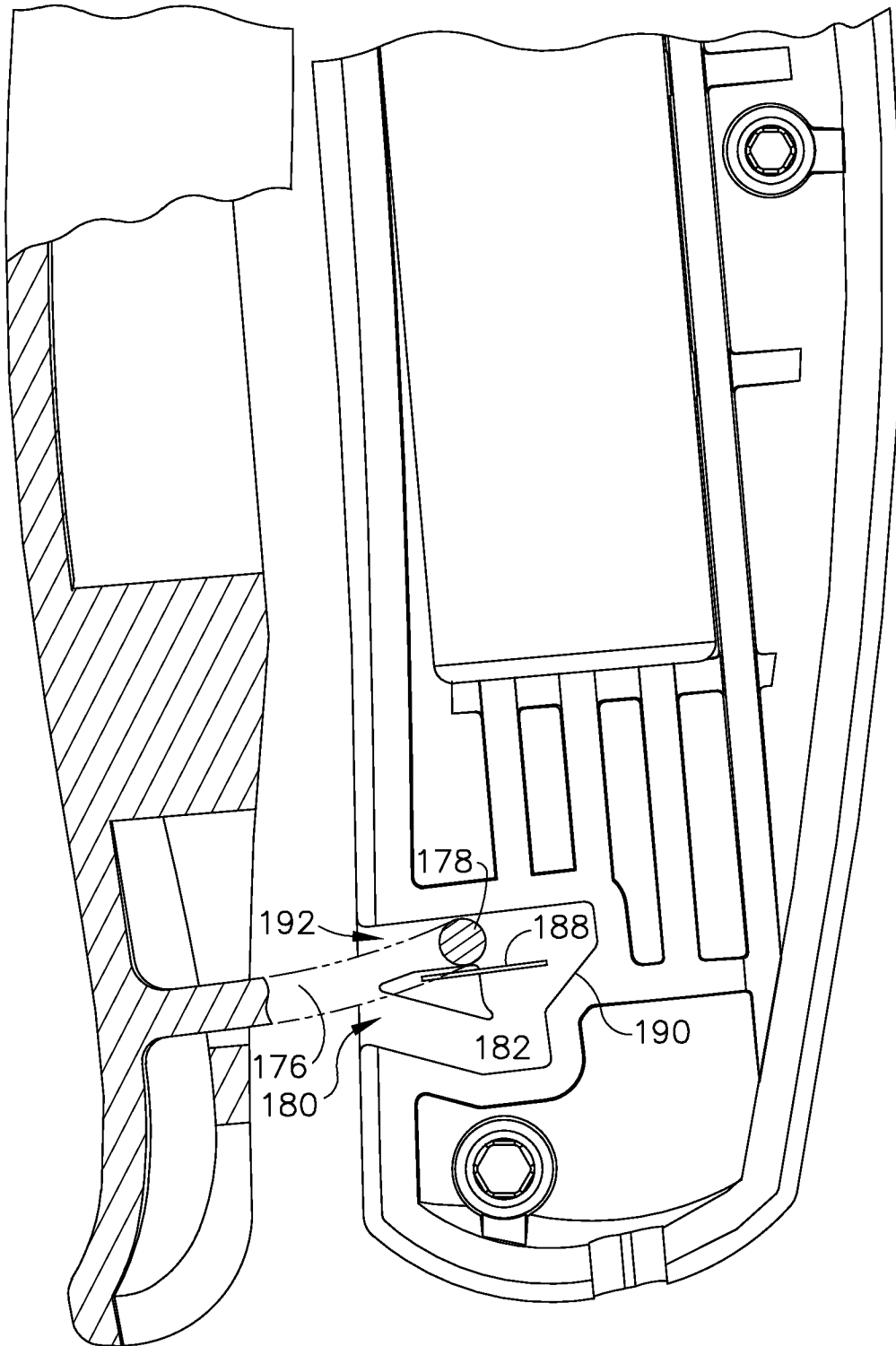


FIG. 22

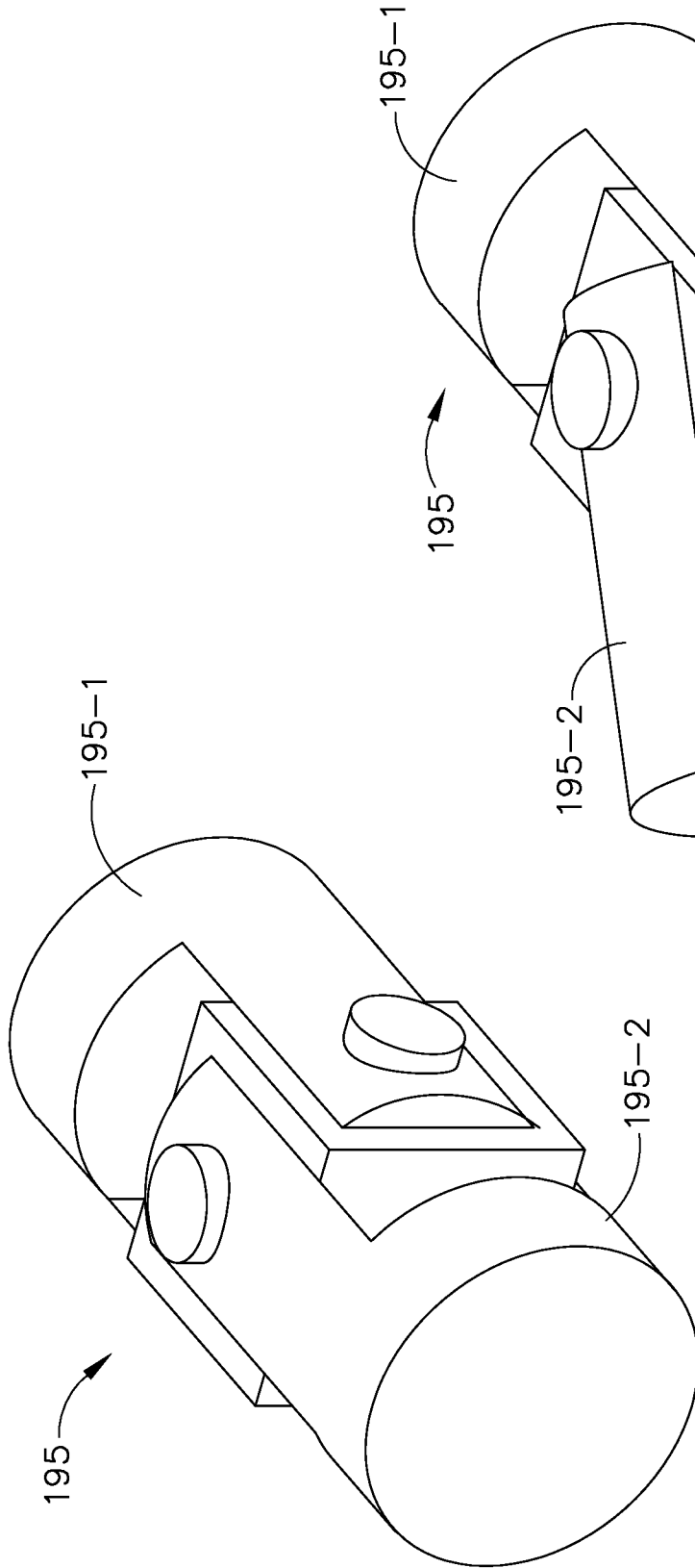


FIG. 23A

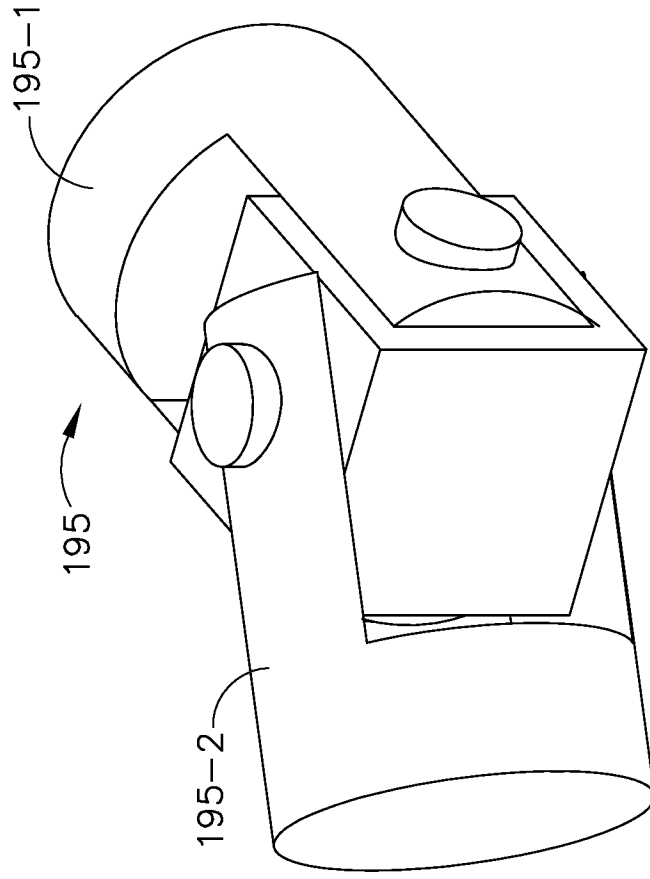


FIG. 23B

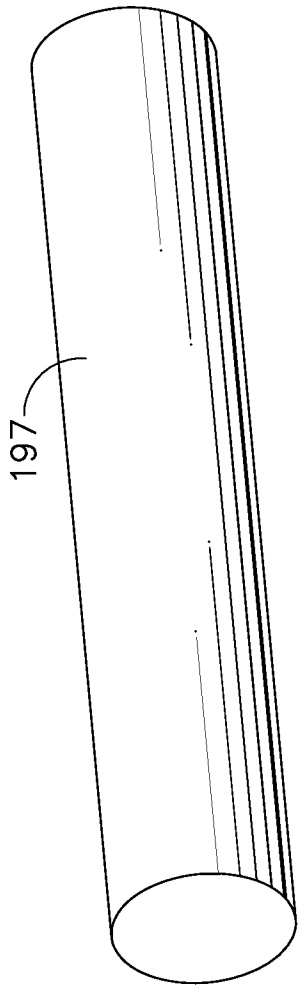


FIG. 24A

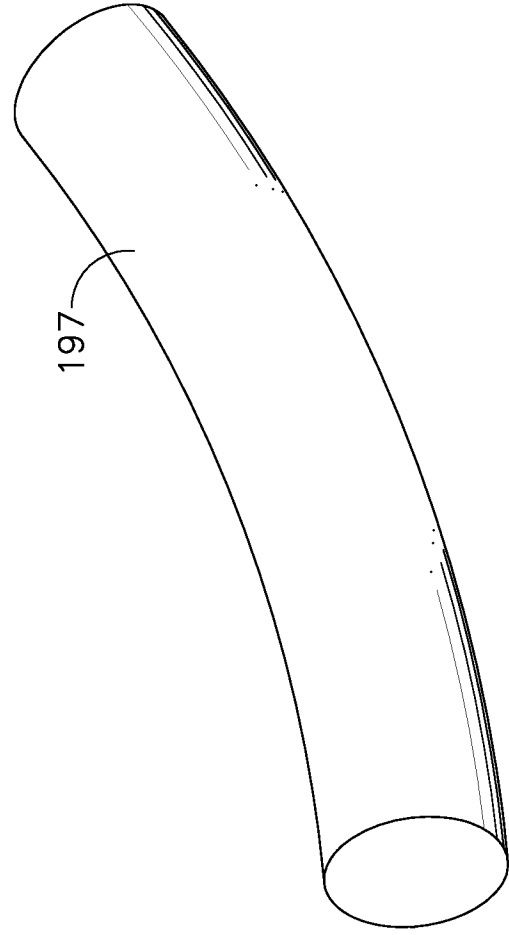


FIG. 24B

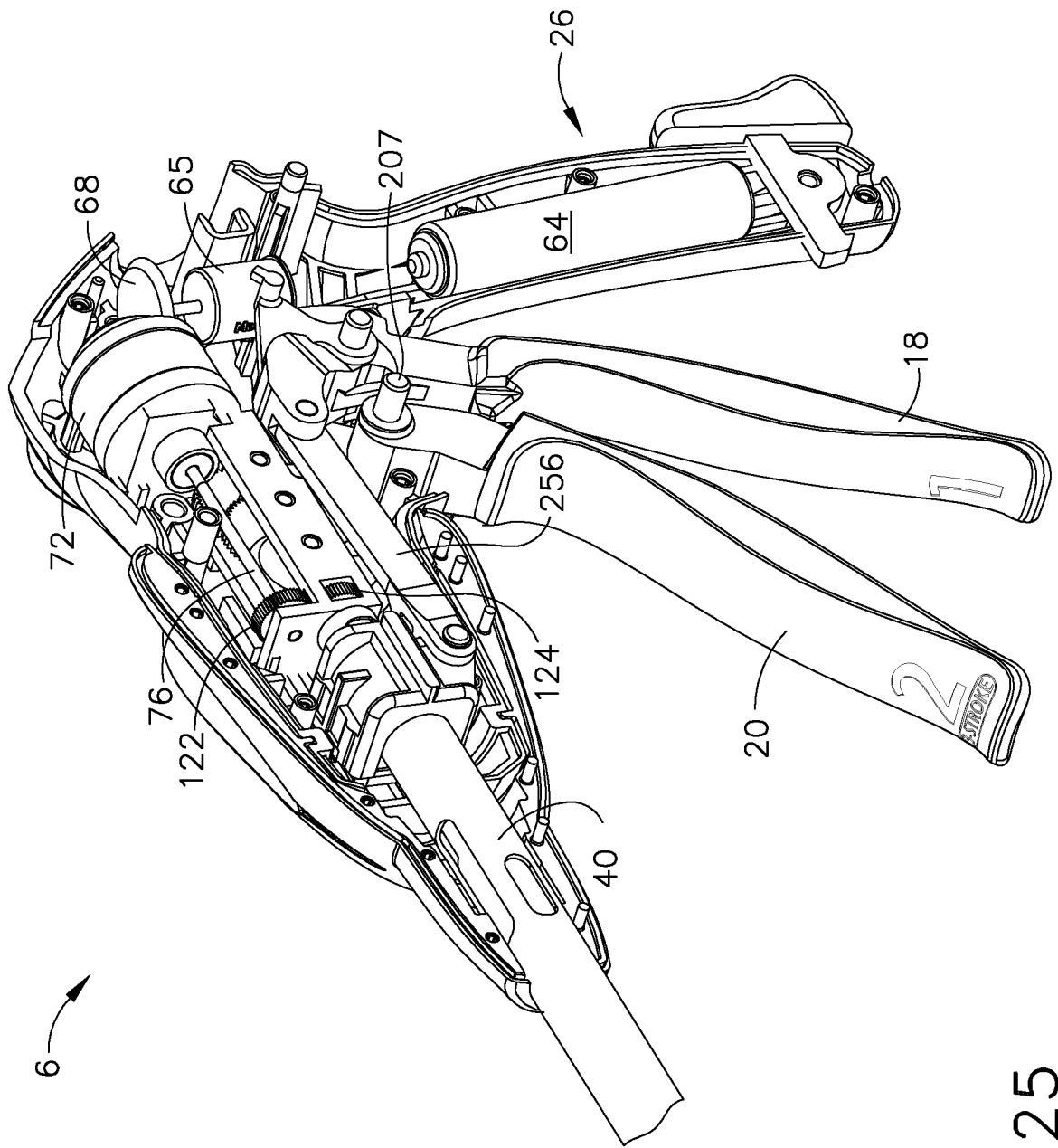


FIG. 25

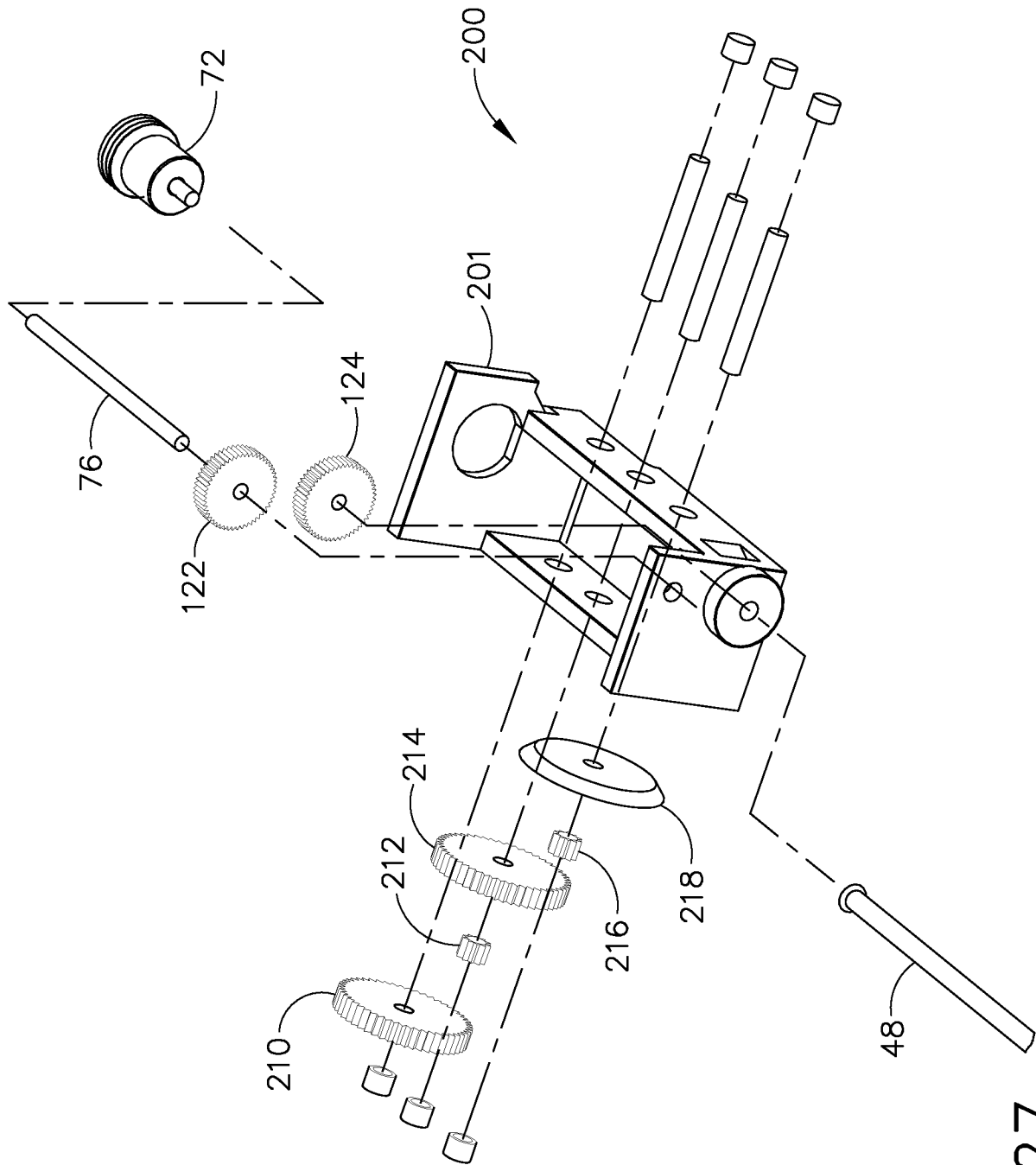


FIG. 27

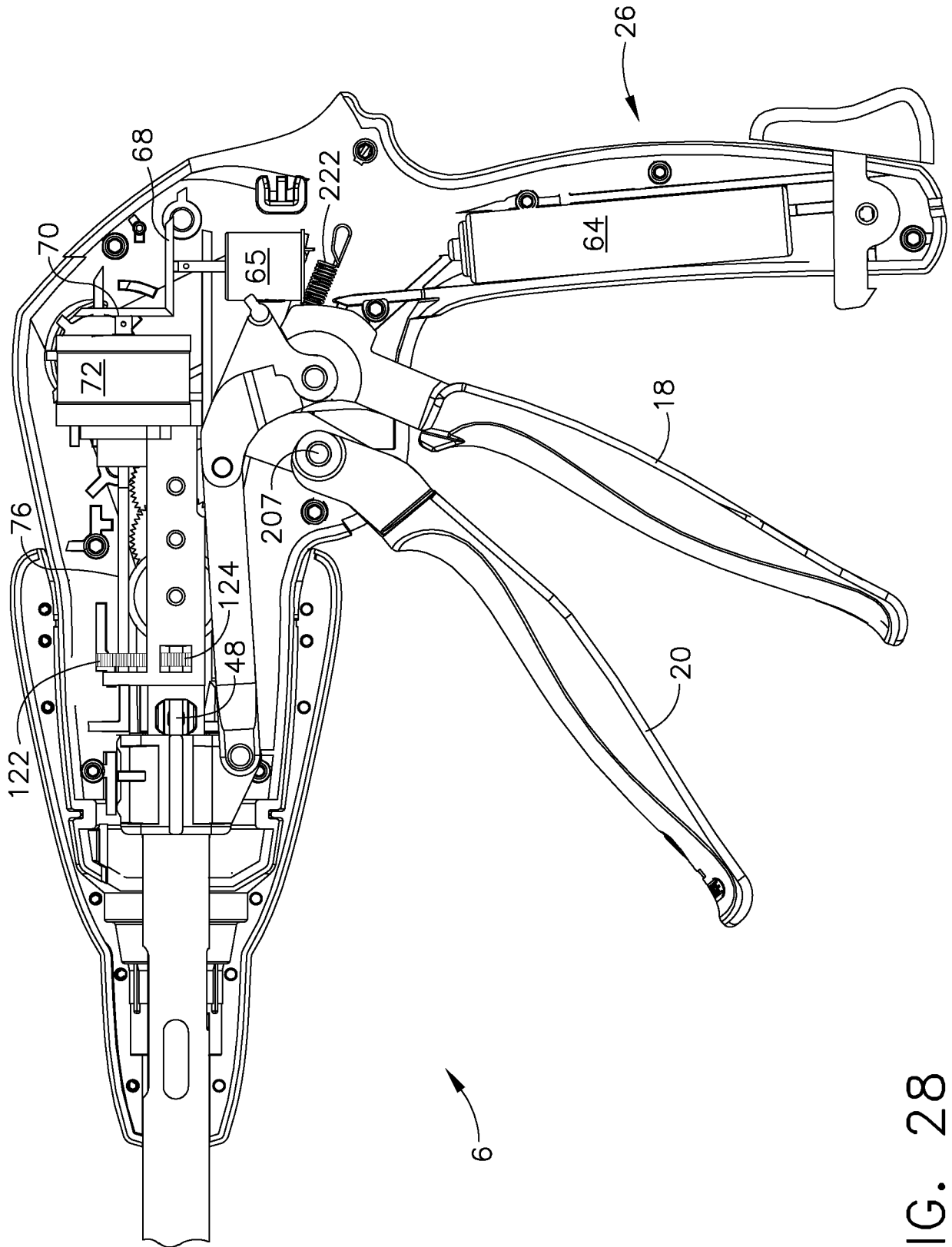


FIG. 28

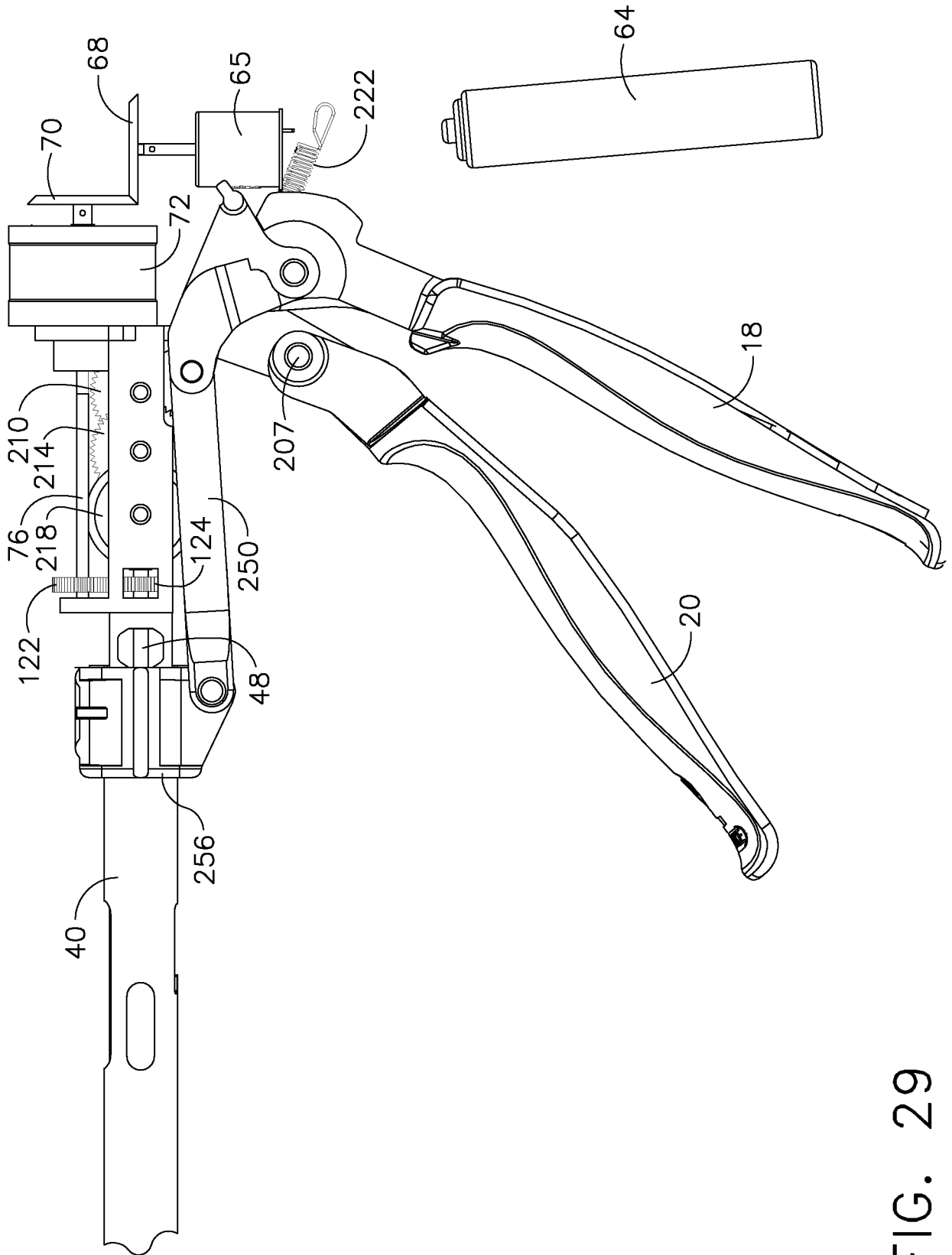


FIG. 29

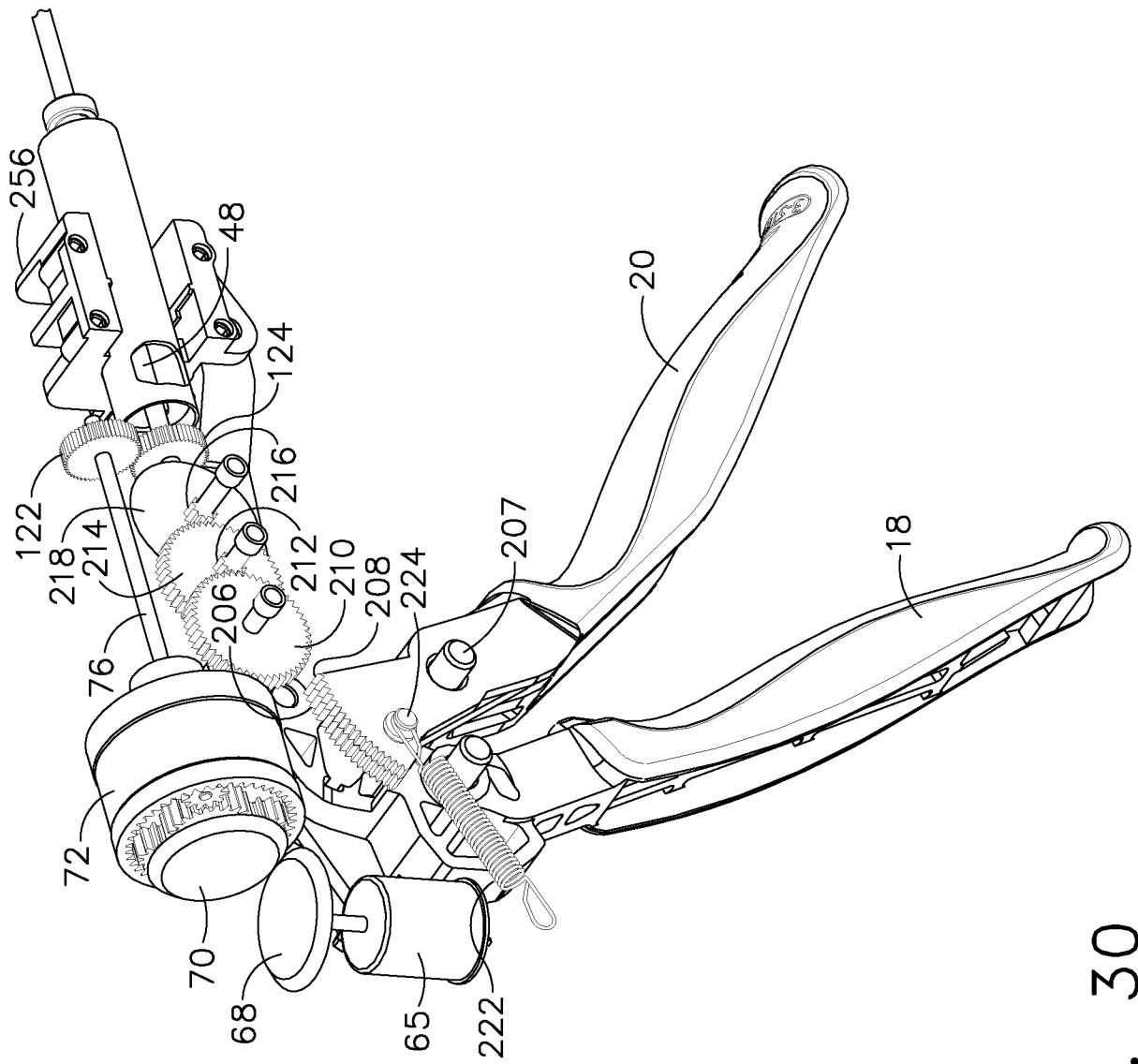


FIG. 30

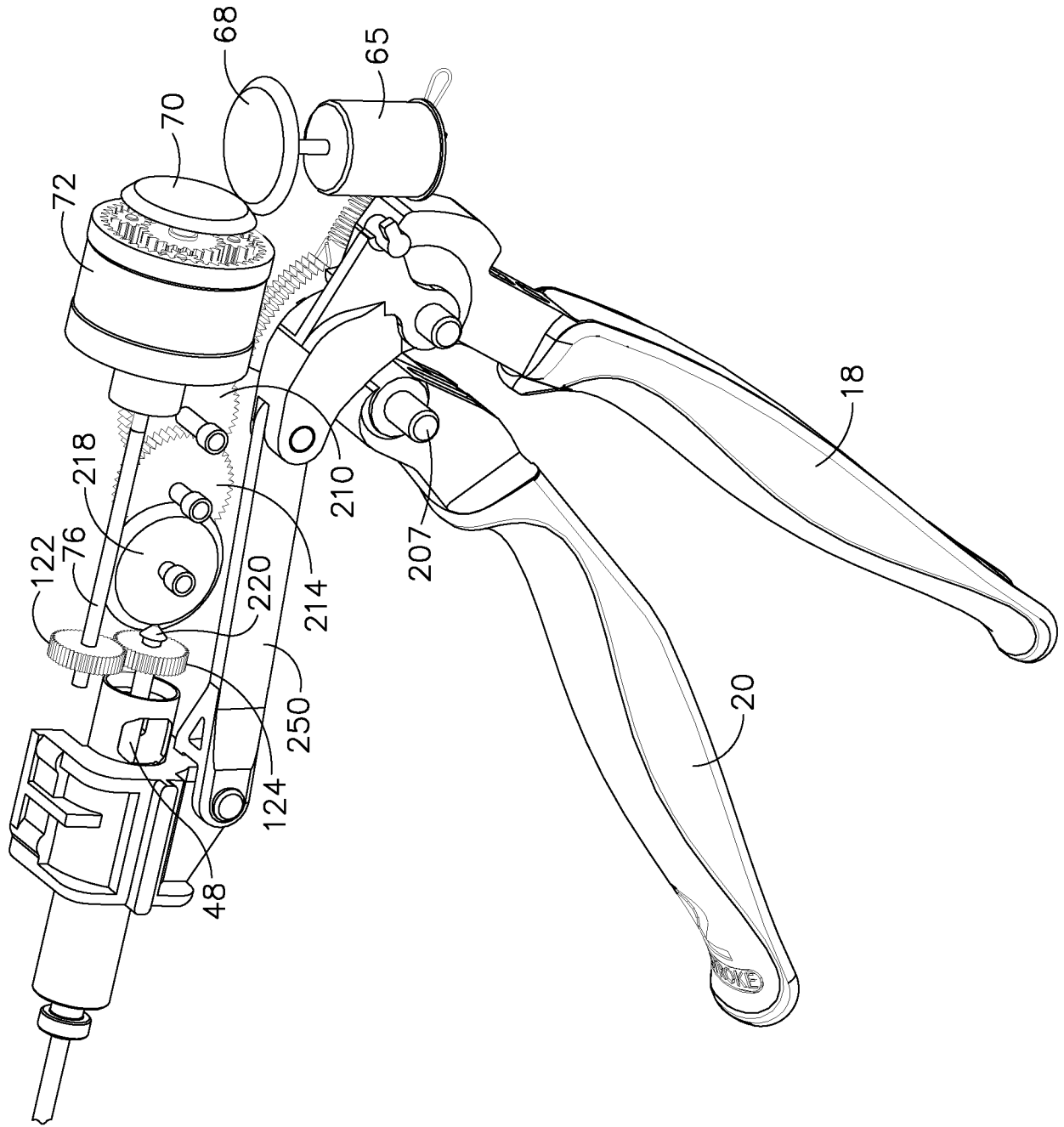


FIG. 31

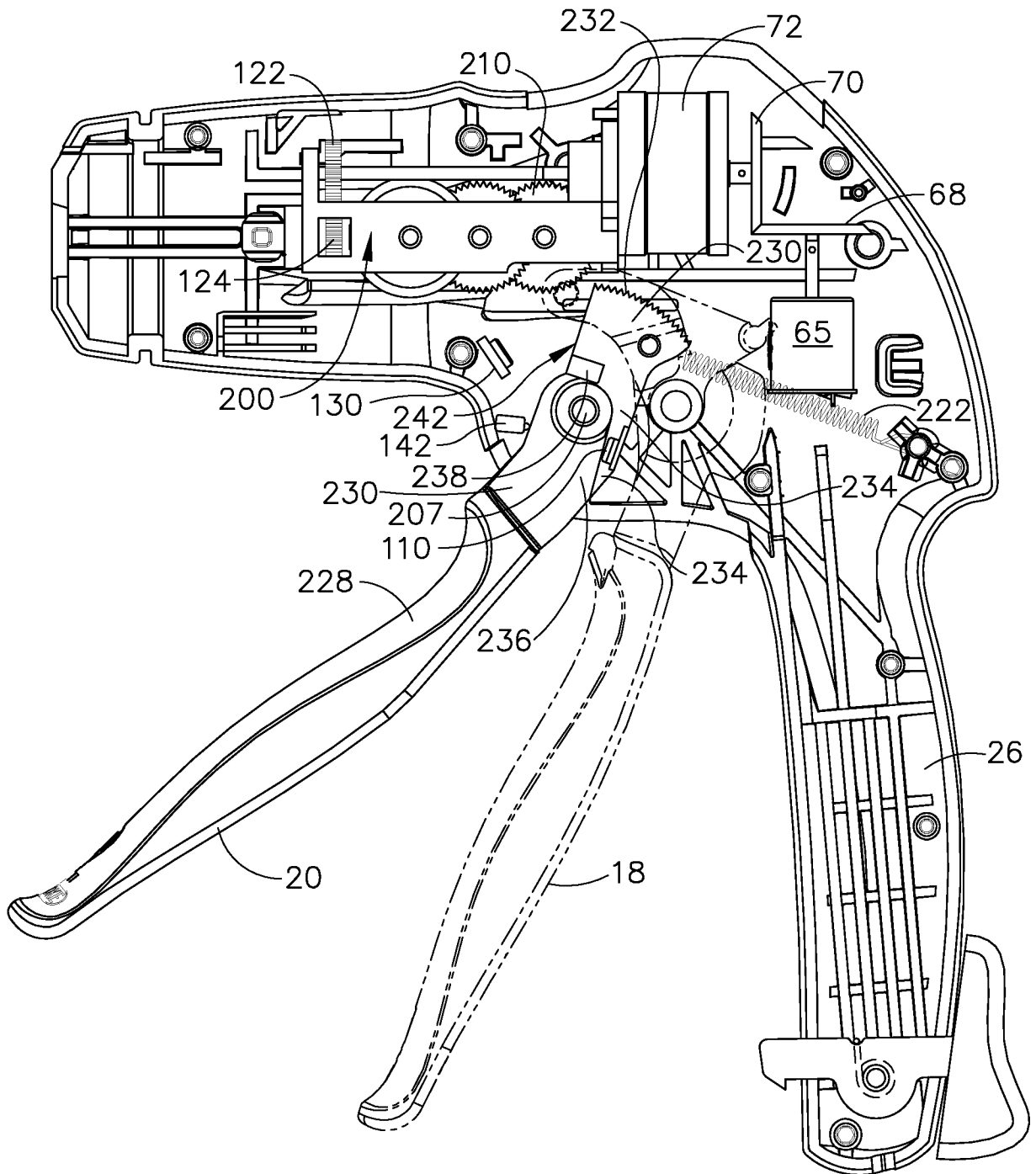


FIG. 32

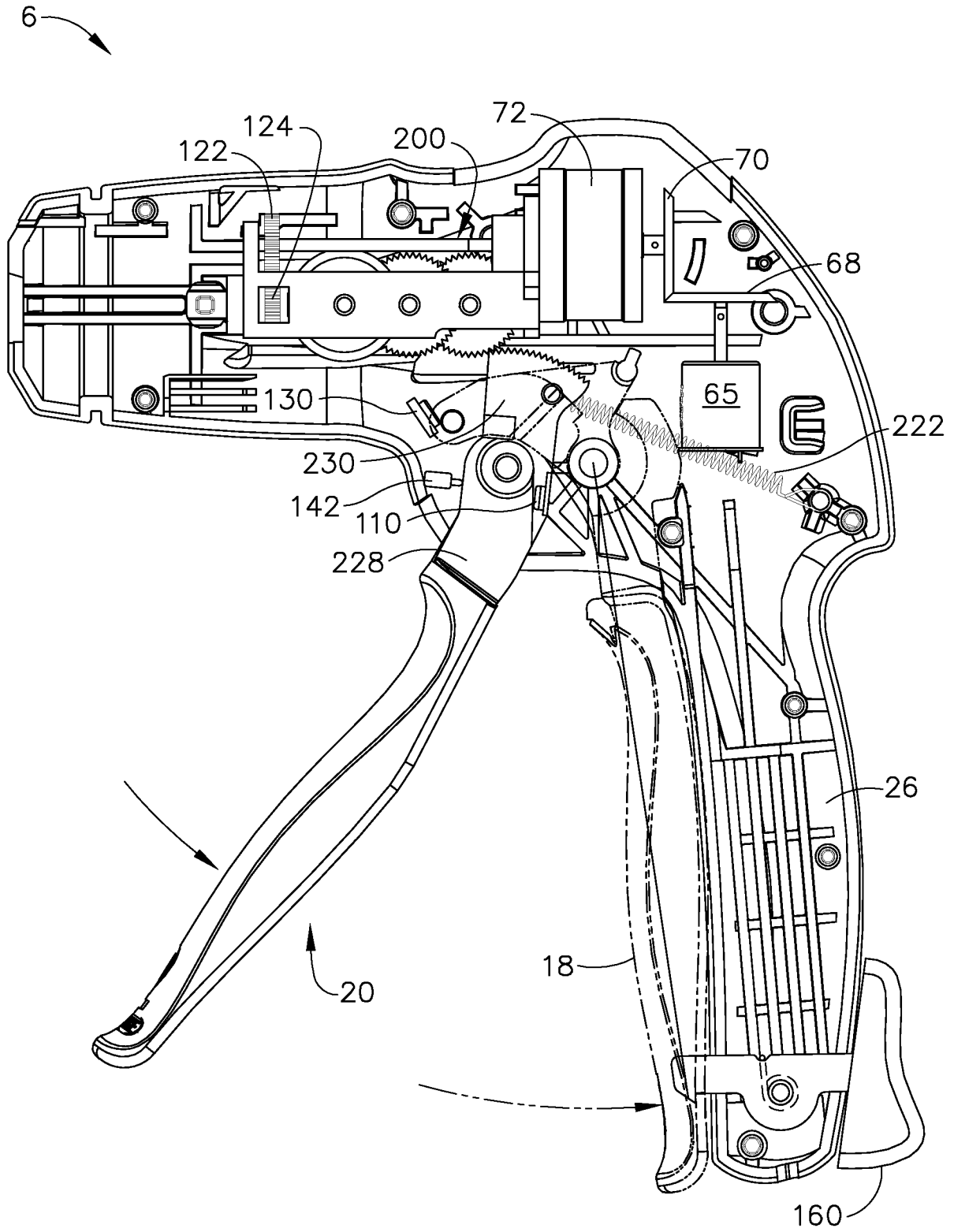


FIG. 33

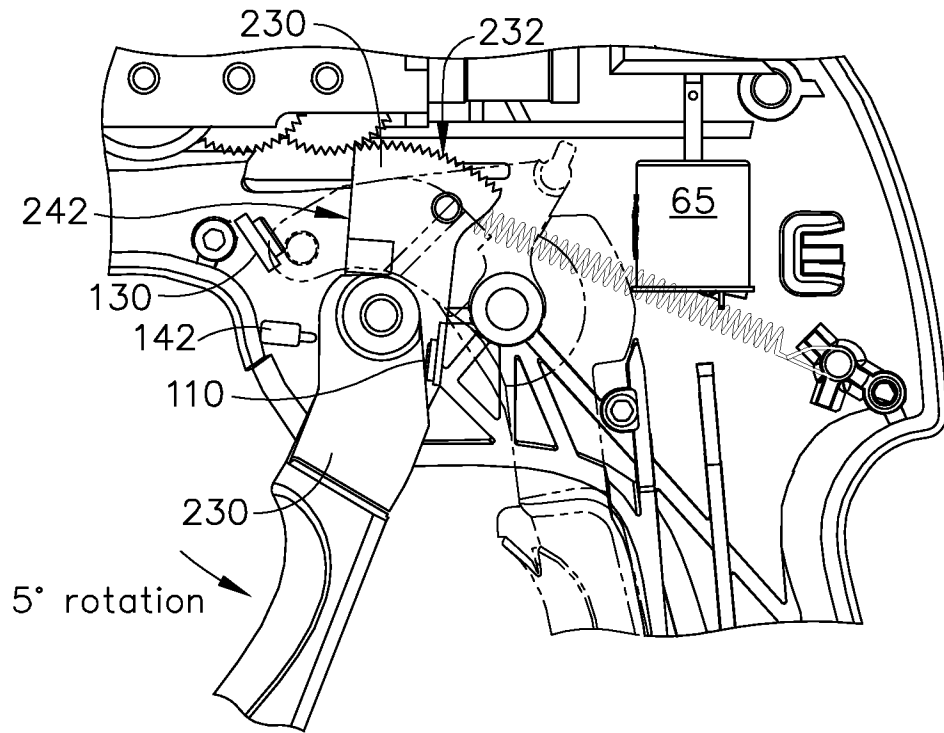


FIG. 34

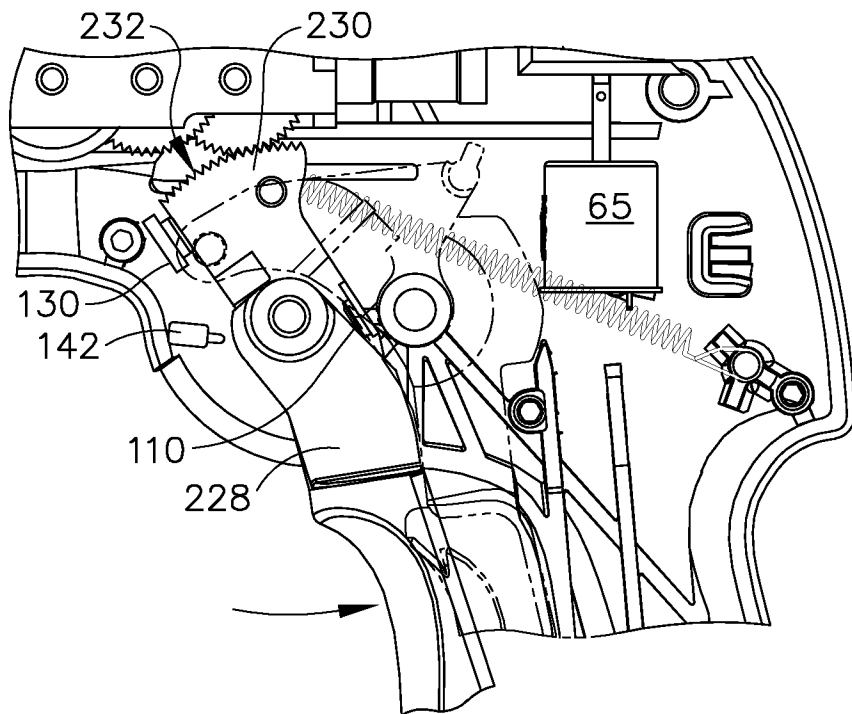


FIG. 35

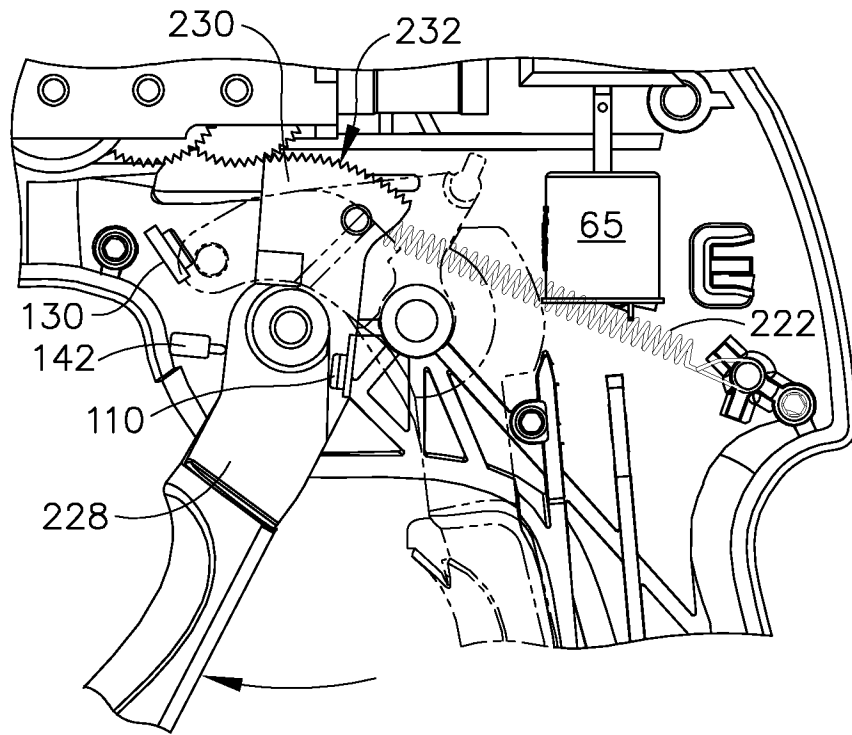


FIG. 36

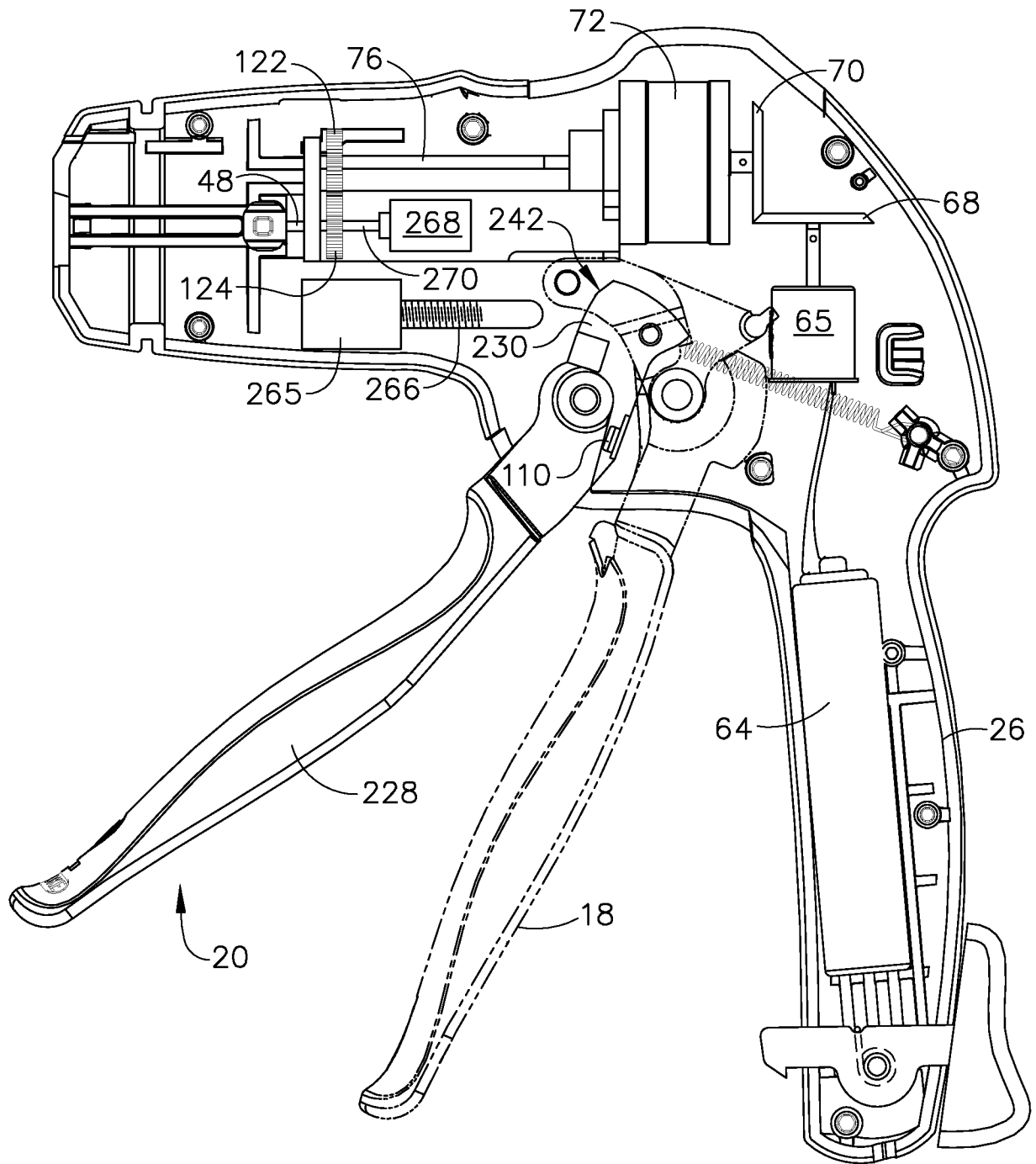


FIG. 37

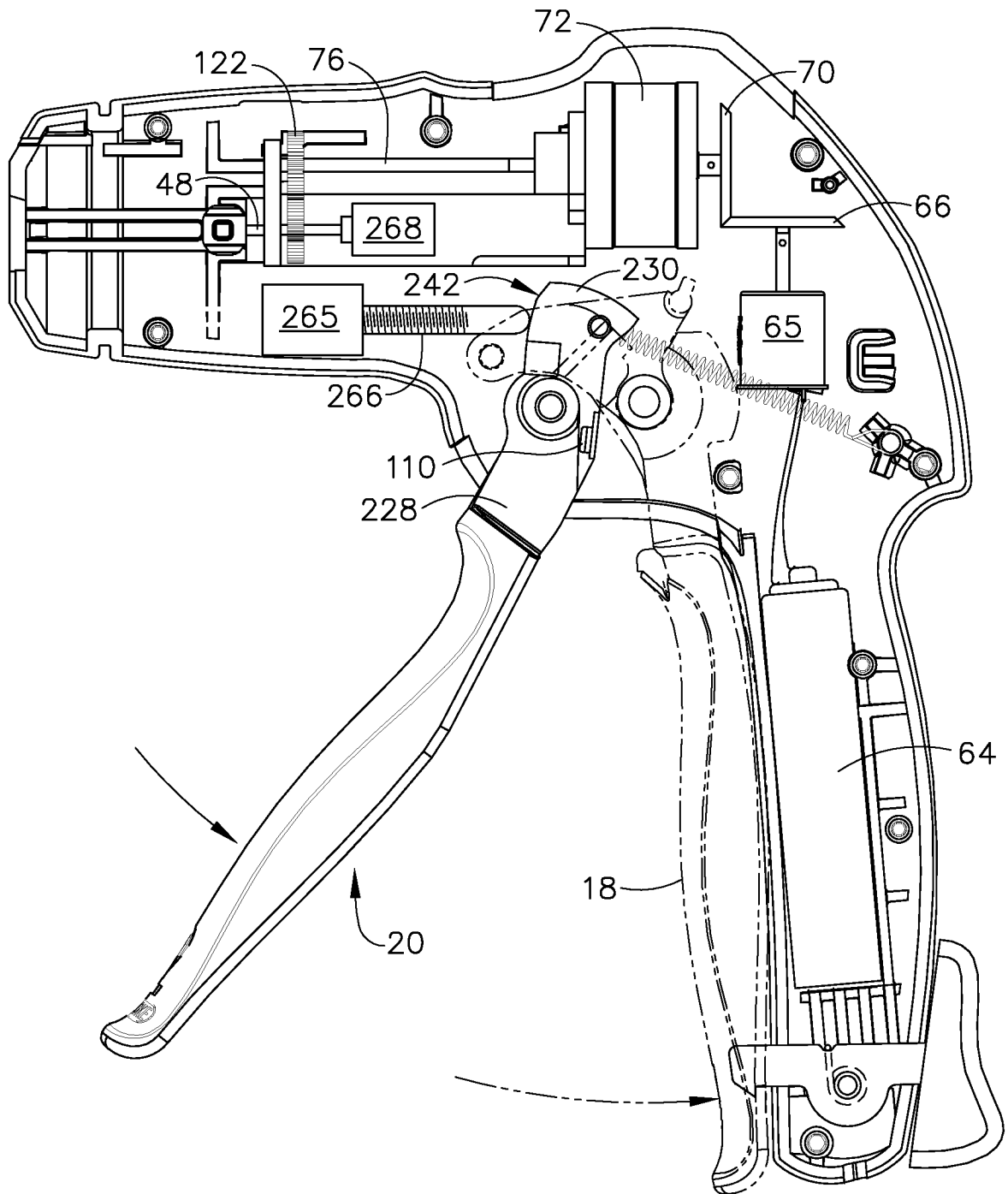


FIG. 38

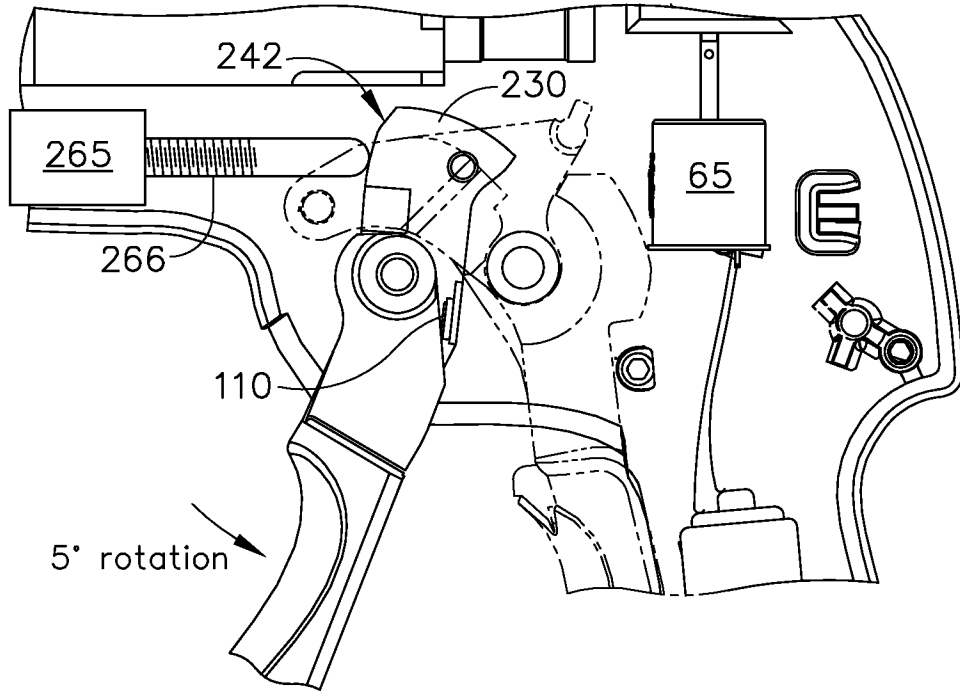


FIG. 39

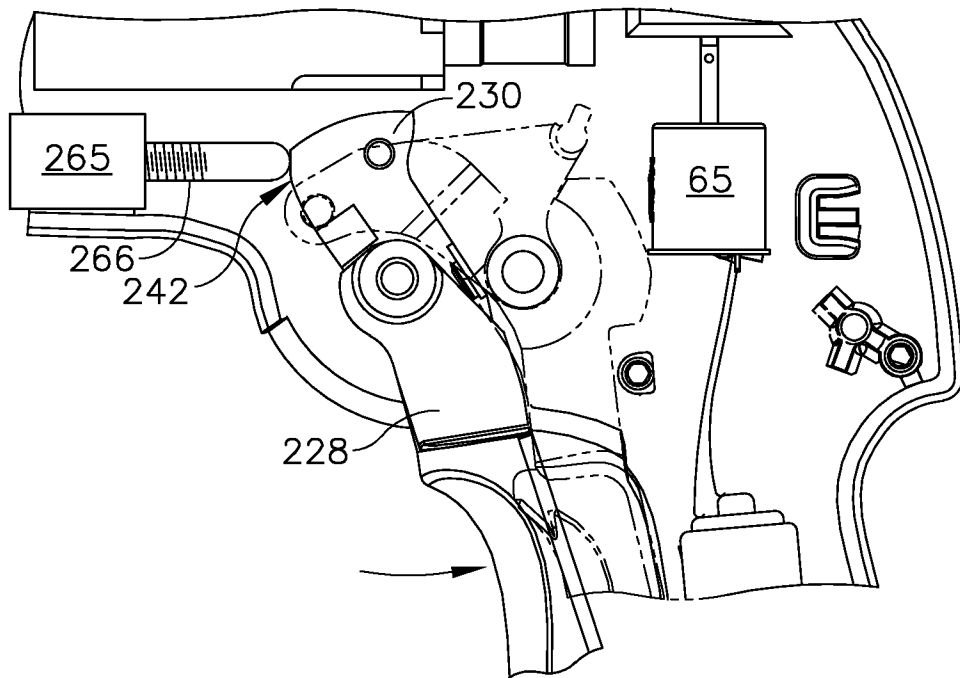


FIG. 40

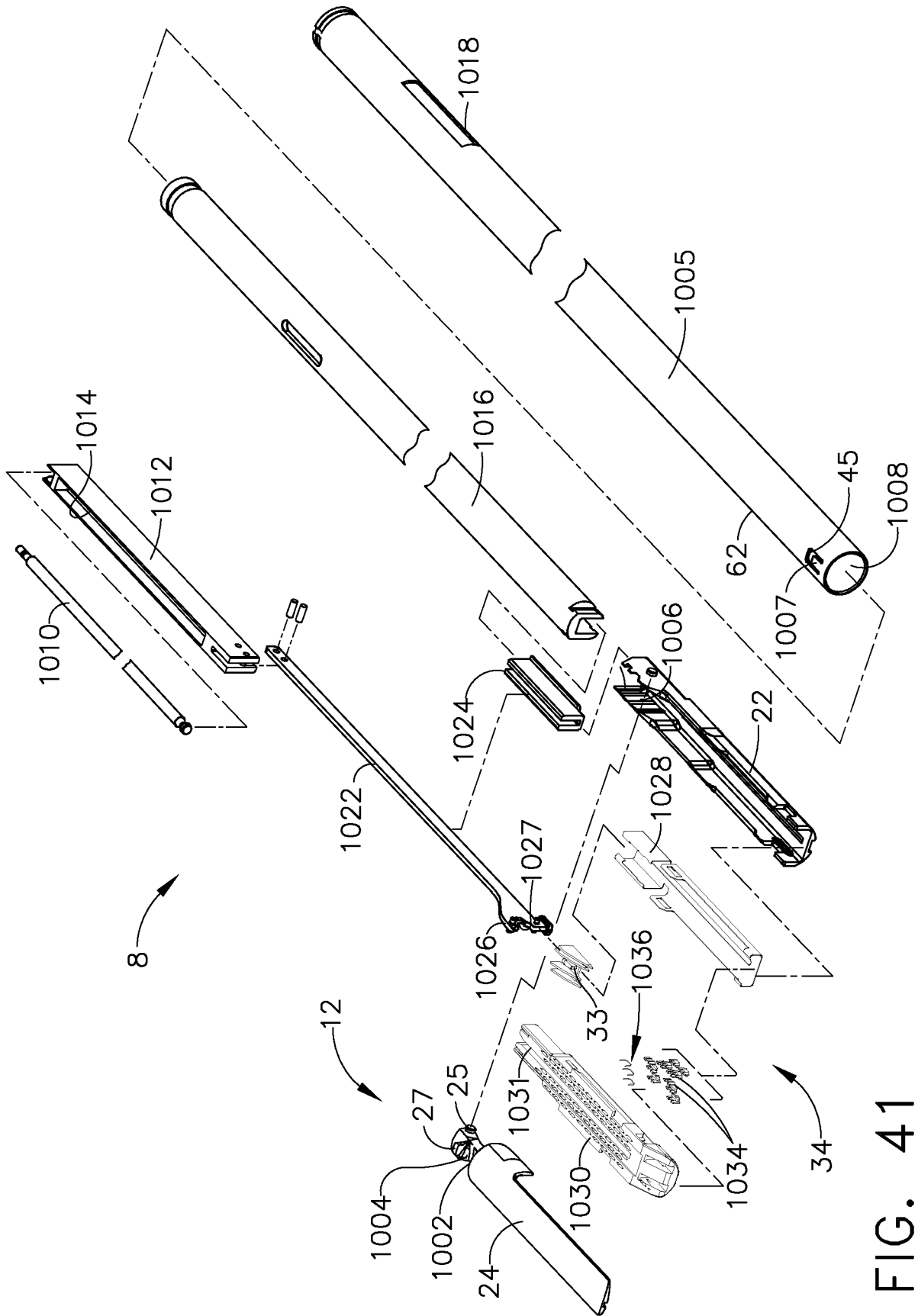


FIG. 41

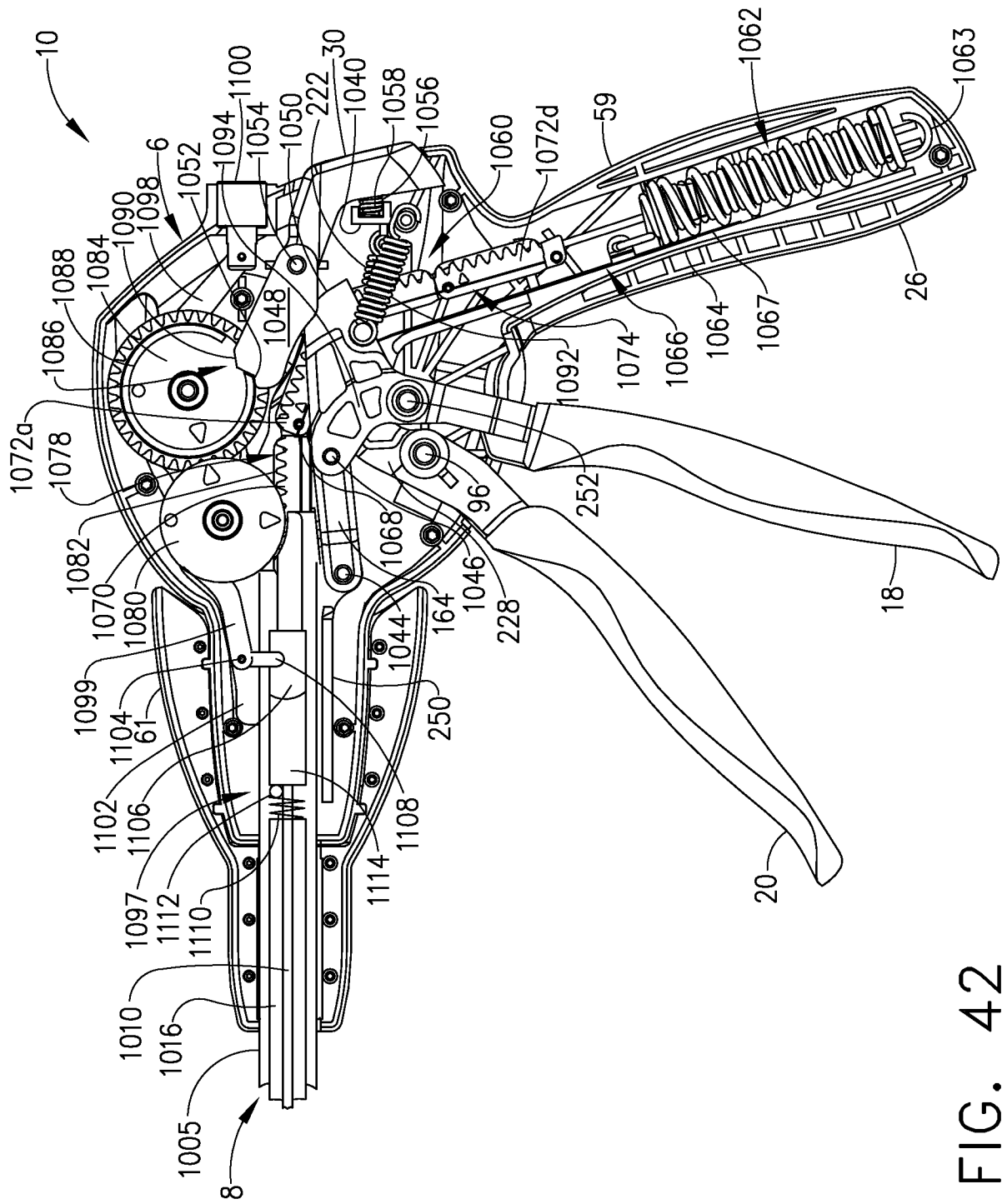


FIG. 42

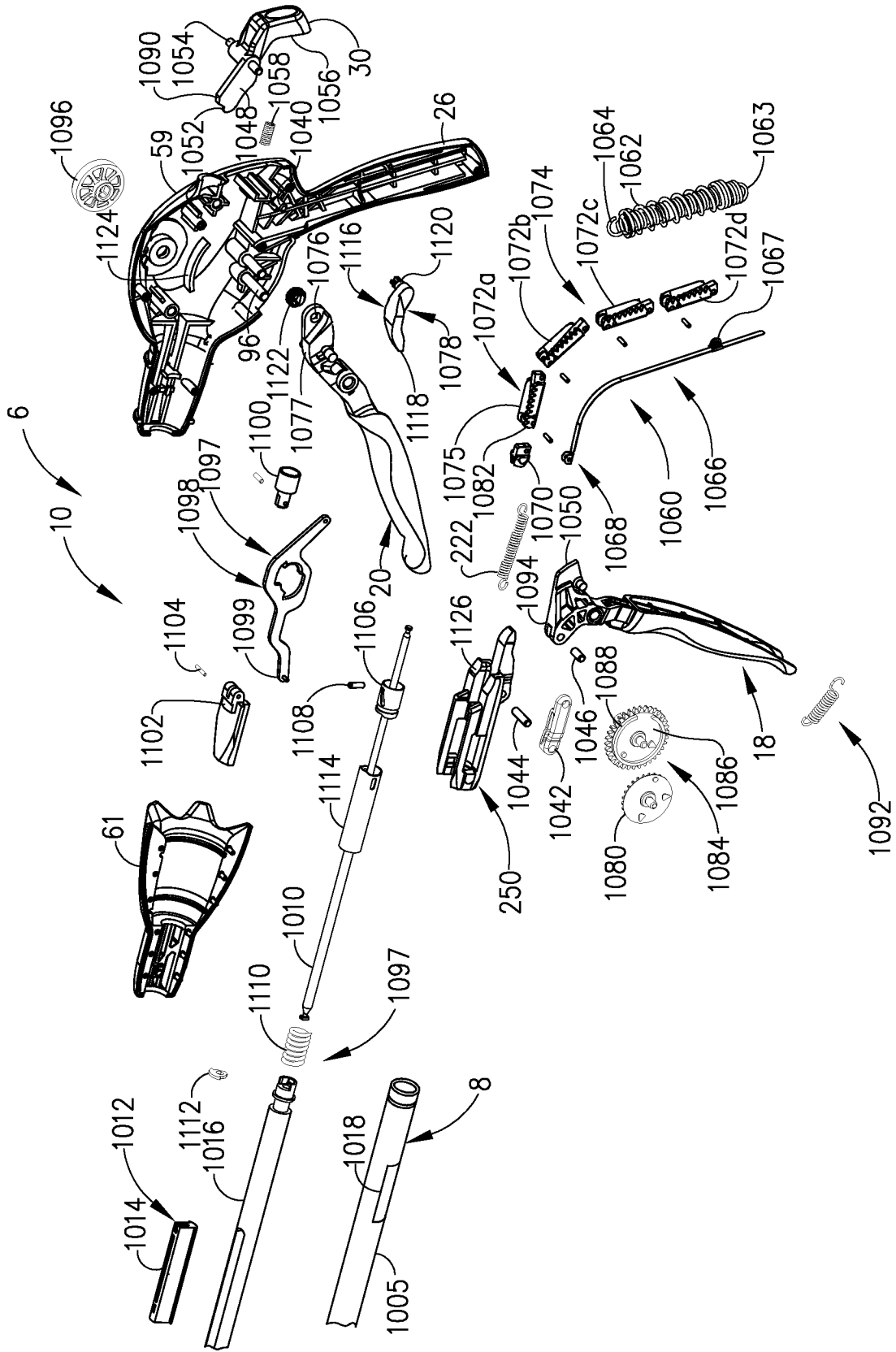


FIG. 43

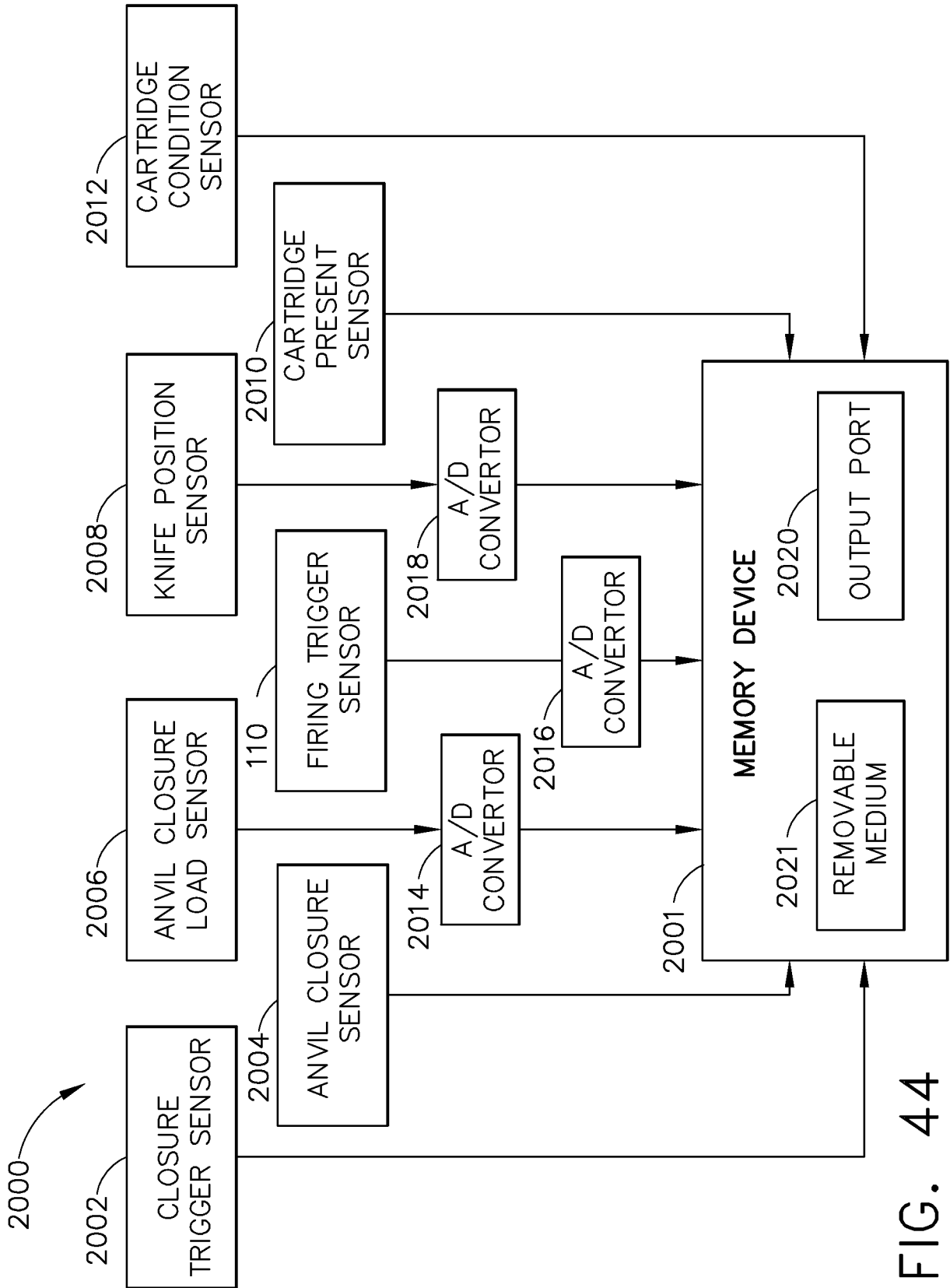


FIG. 44

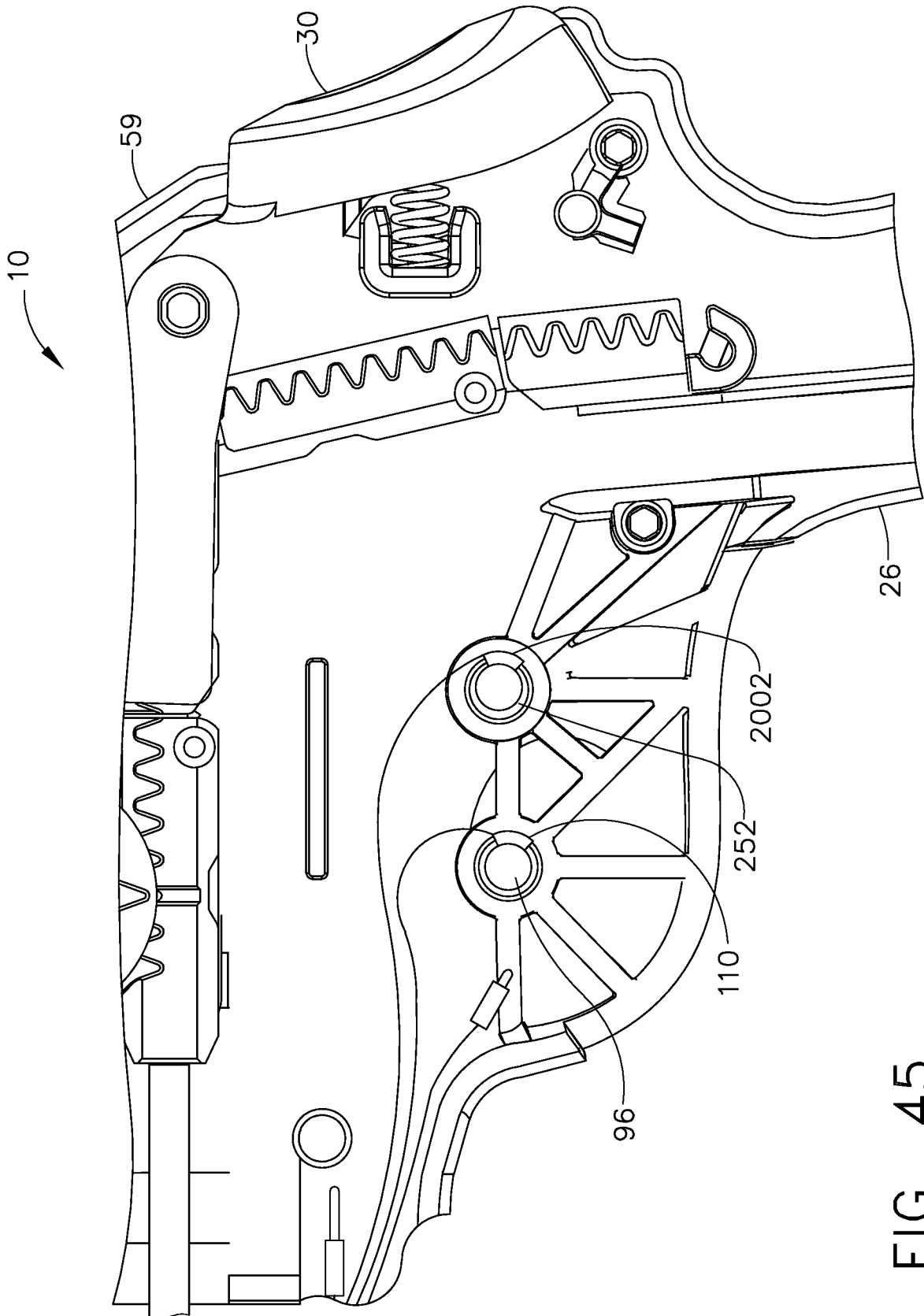


FIG. 45

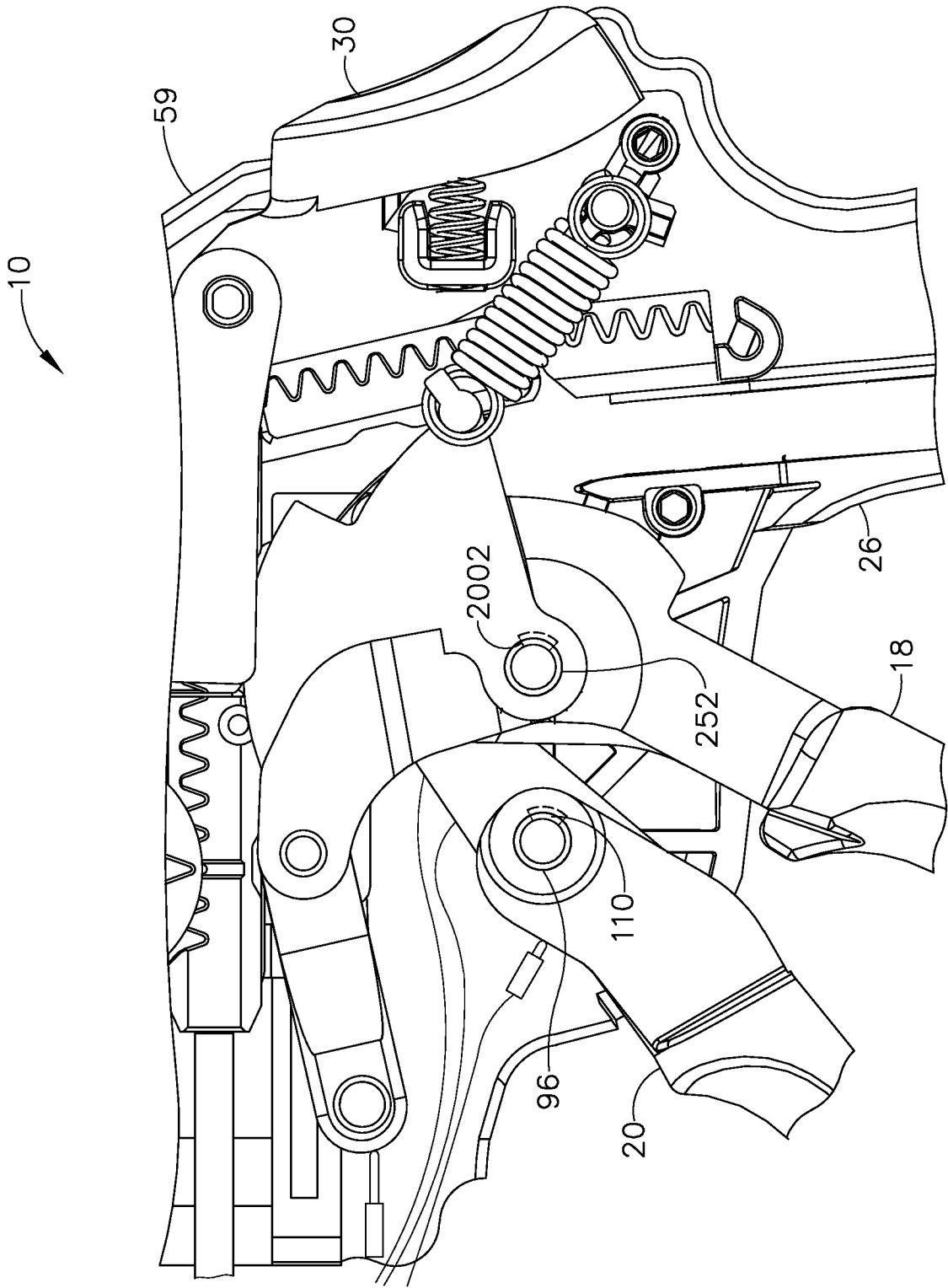


FIG. 46

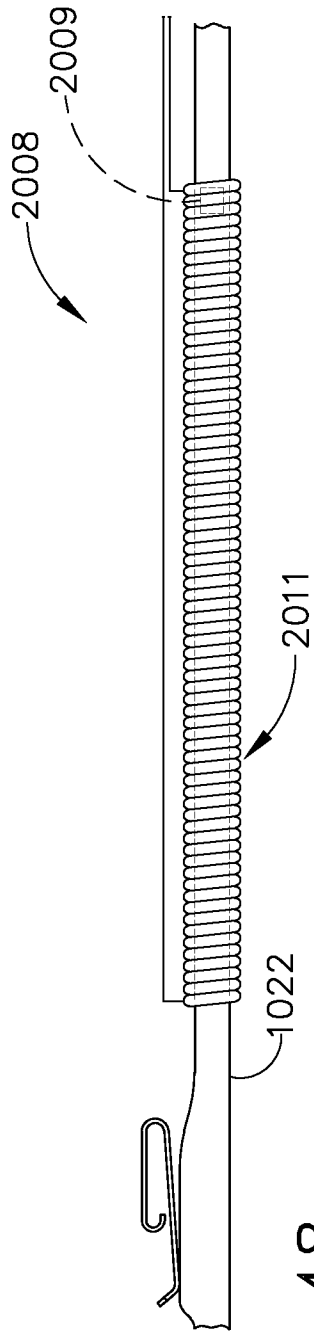


FIG. 48

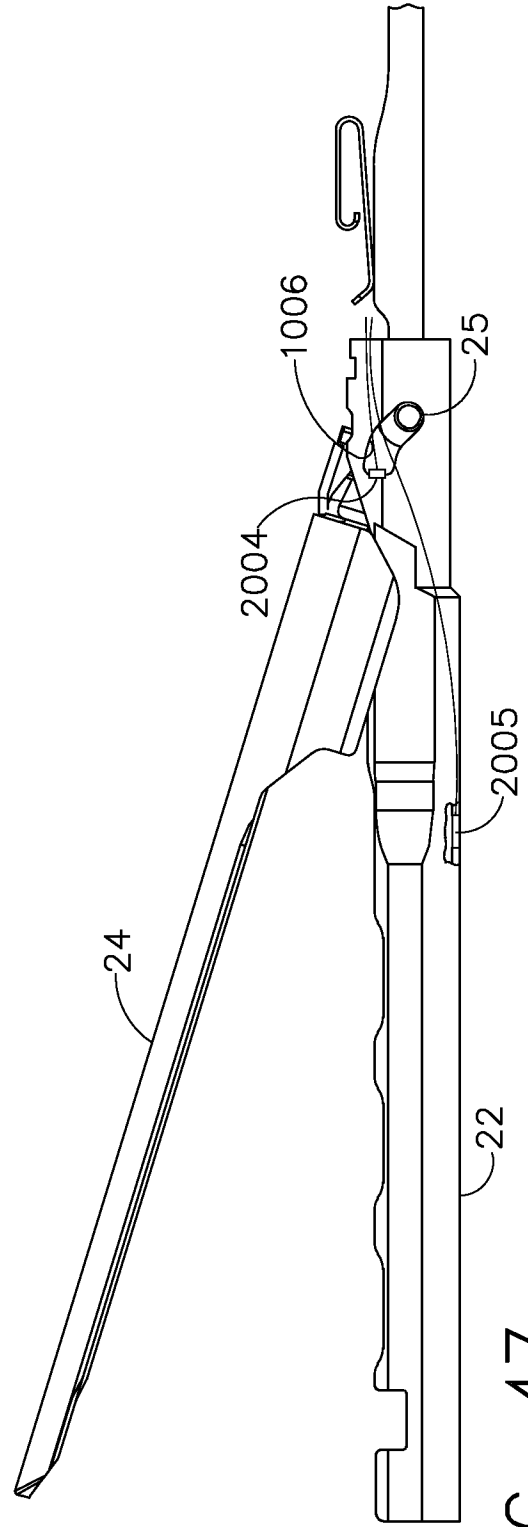
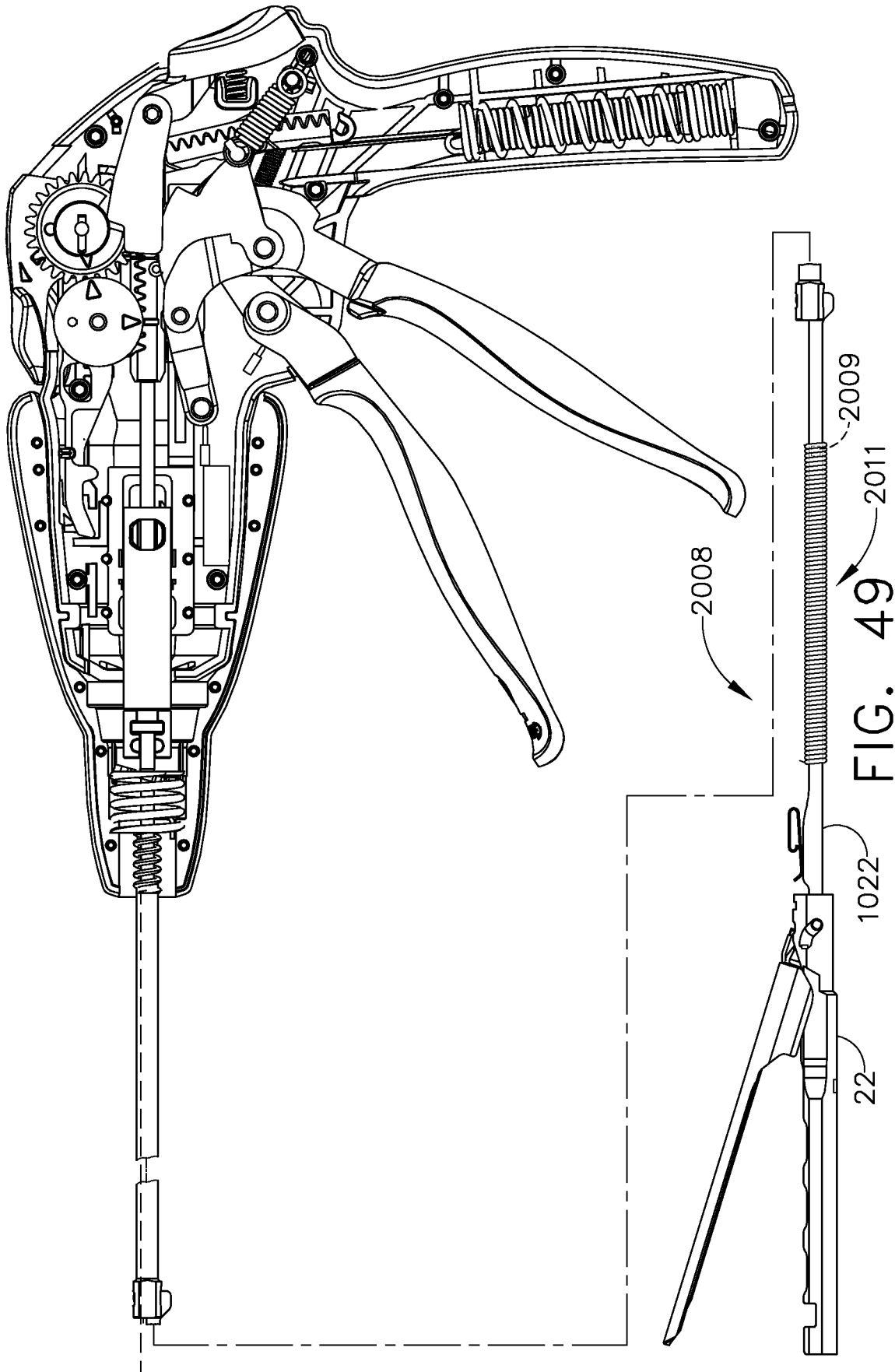


FIG. 47



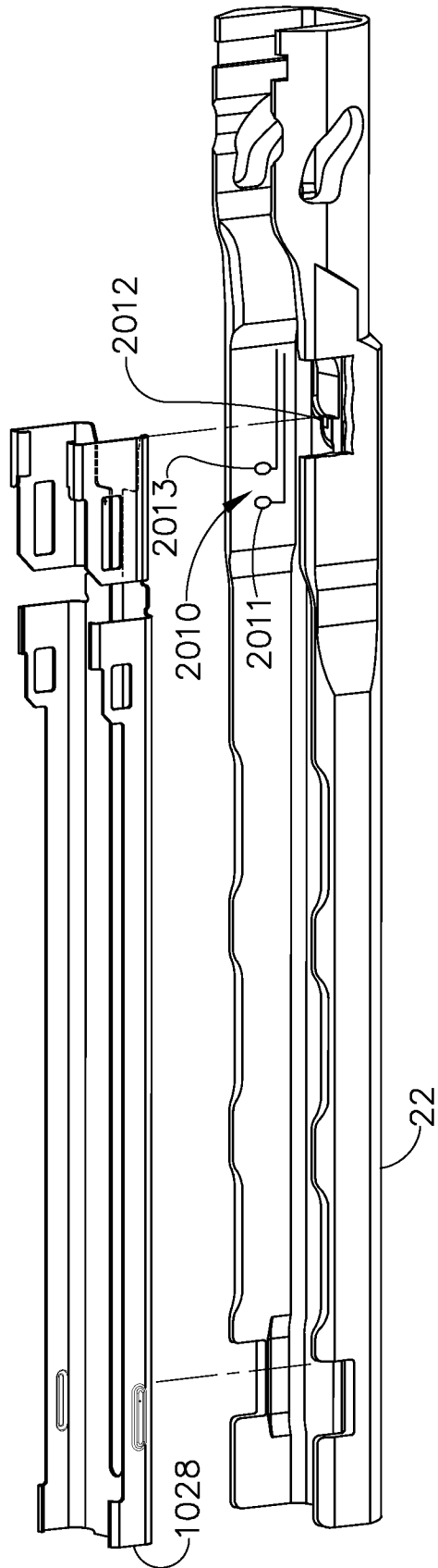


FIG. 50

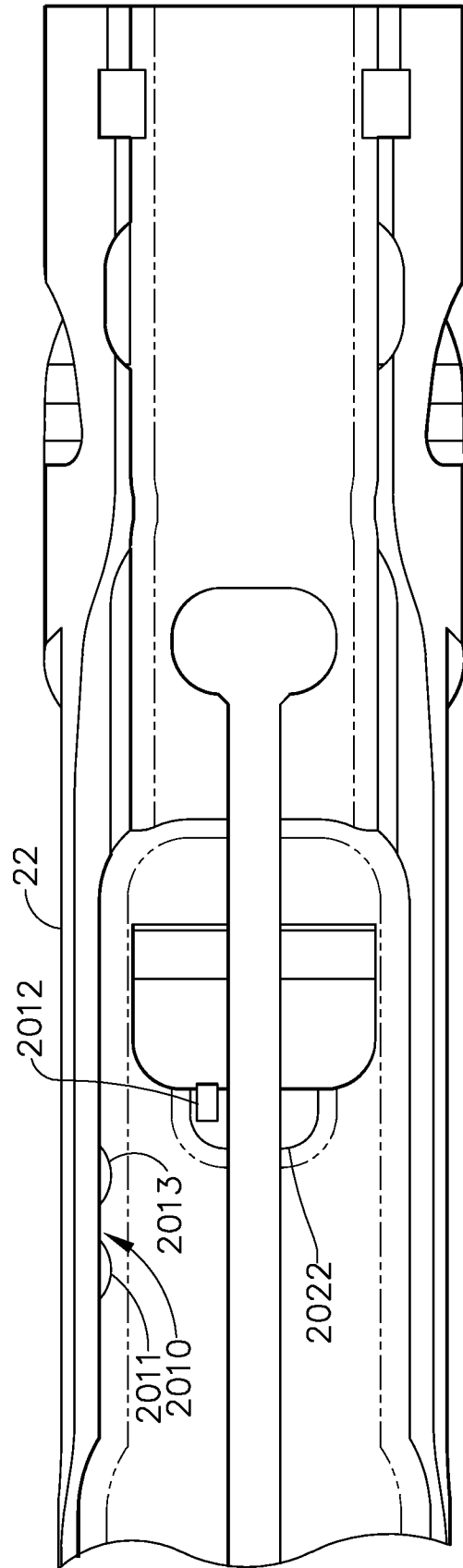


FIG. 51

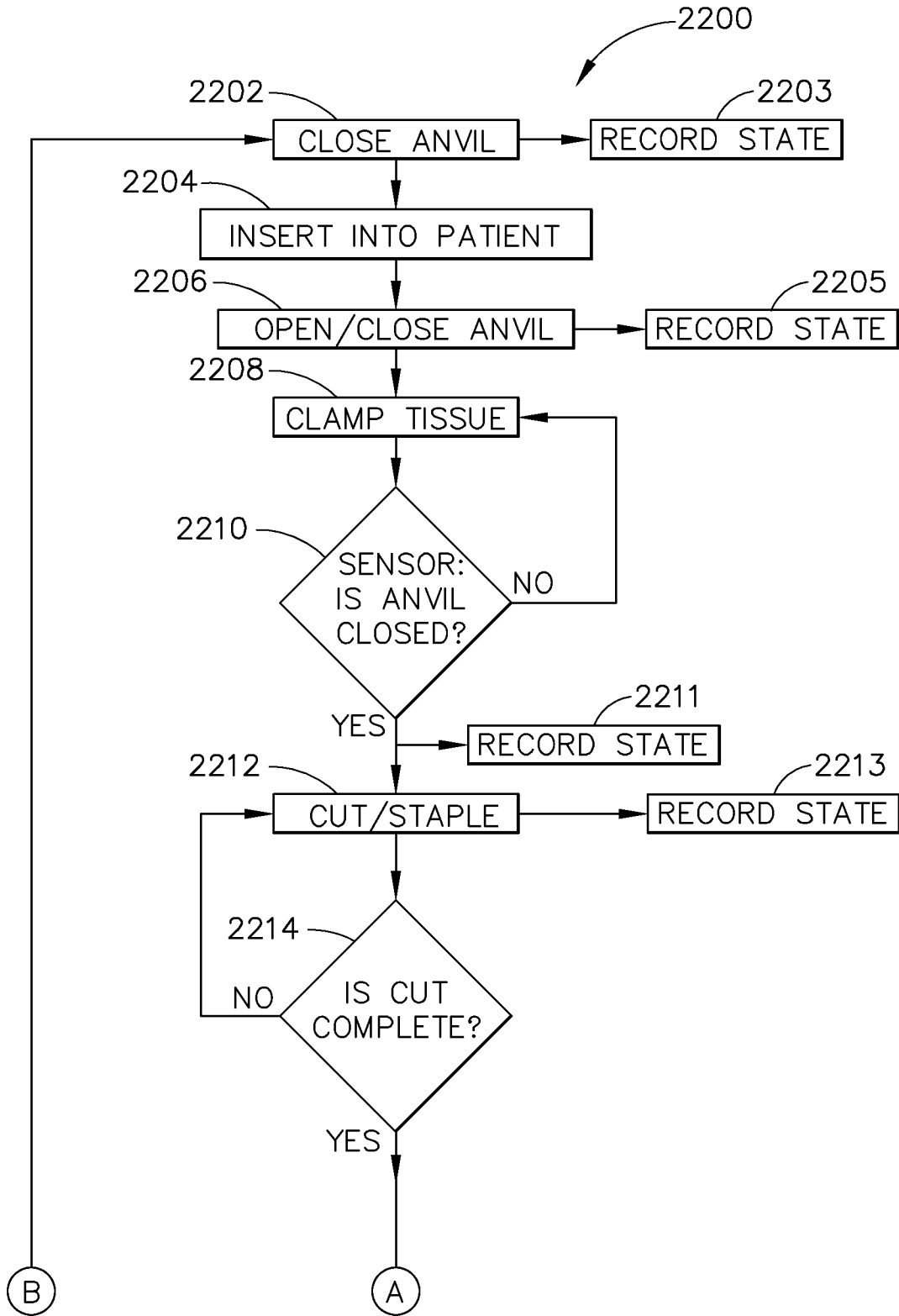


FIG. 52A

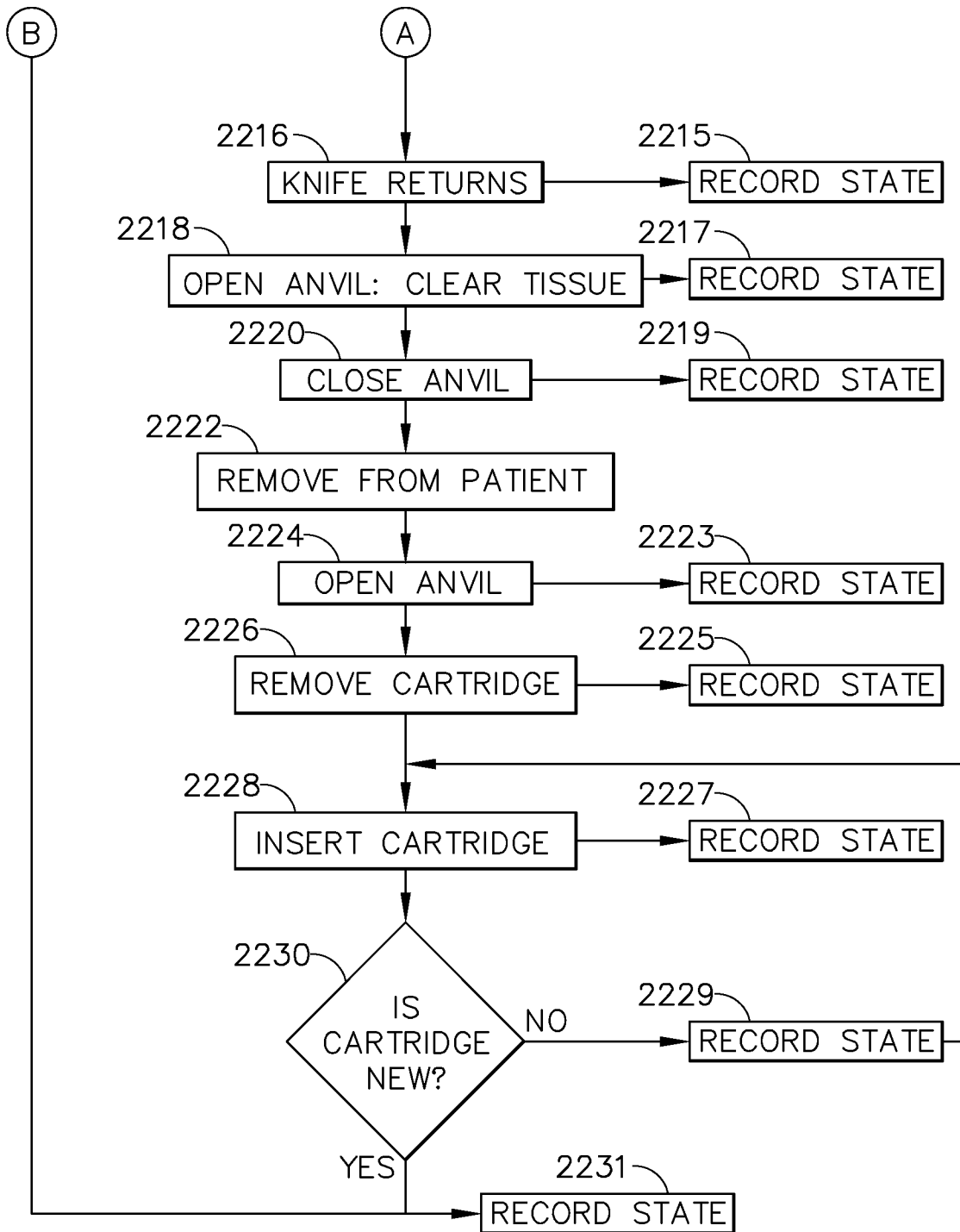


FIG. 52B

| EVENT # | CLOSURE LOAD | FIRING STROKE | FIRING LOAD (MAX) | KNIFE POSITION % | LOCKOUT MEMORY | | | CARTRIDGE PRESENT YES/NO |
|---------|--------------|---------------|-------------------|------------------|-------------------|---------------------|-----------|--------------------------|
| | | | | | ANVIL CLOSED/OPEN | SLED PRESENT YES/NO | IS YES NO | |
| 1 | 10 | | | | 0 | 1 | 1 | ON -1 |
| 2 | 12 | | | | 0 | 1 | 1 | OFF -0 |
| 3 | 15 | | | | 0 | 1 | 1 | |
| 4 | 50 | | | | 1 | 1 | 1 | |
| 25 | 25 | 1 | 250 | .33 | 1 | 0 | 1 | |
| 26 | 100 | 2 | 400 | .66 | 1 | 0 | 1 | |
| 27 | 120 | 3 | 200 | .75 | 1 | 0 | 1 | |
| 55 | 50 | | | | 1 | 0 | 1 | |
| 56 | 50 | | | | 1 | 0 | 1 | |

EXAMPLE:
3 STEP FIRING

FIG. 53

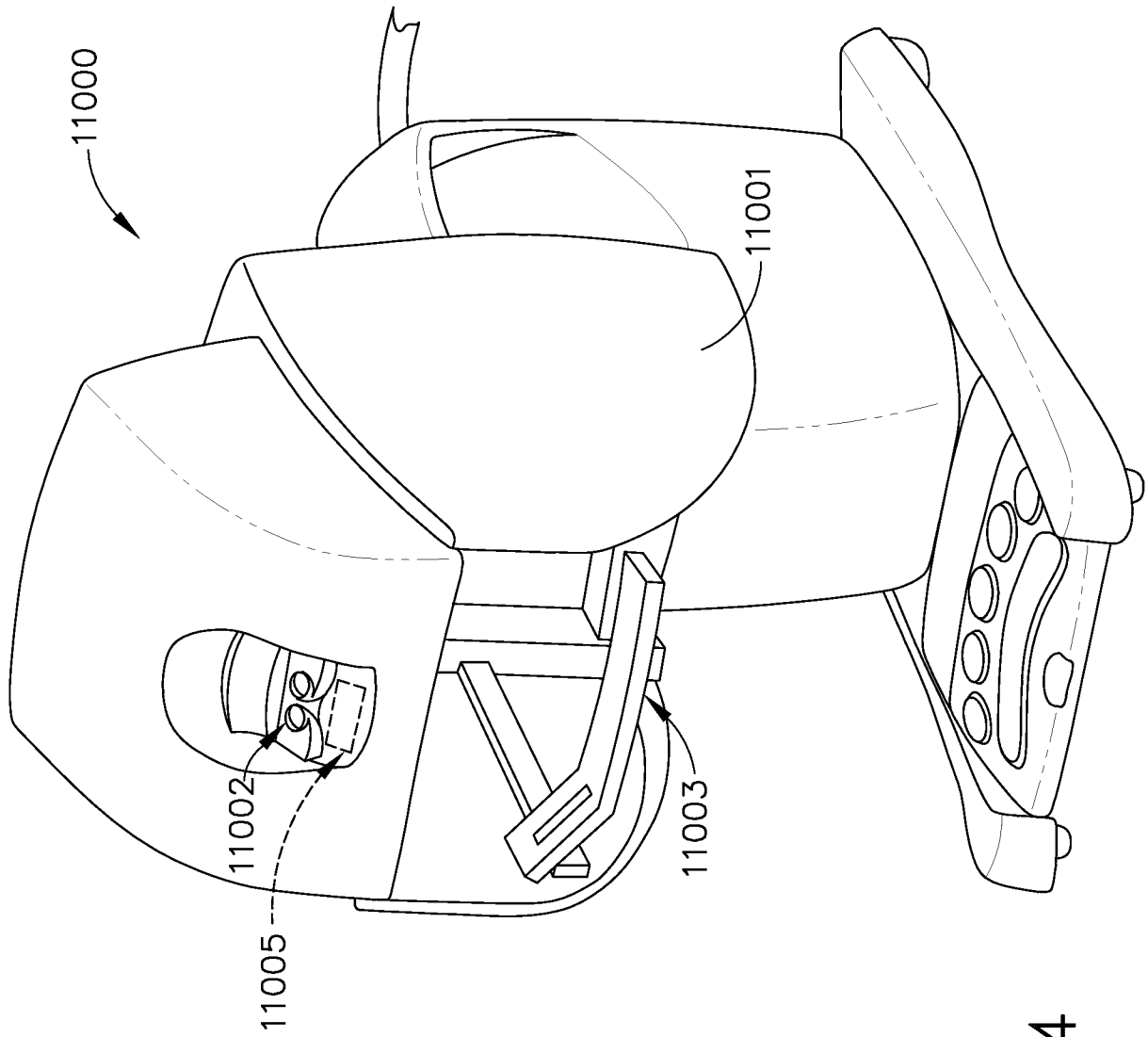


FIG. 54

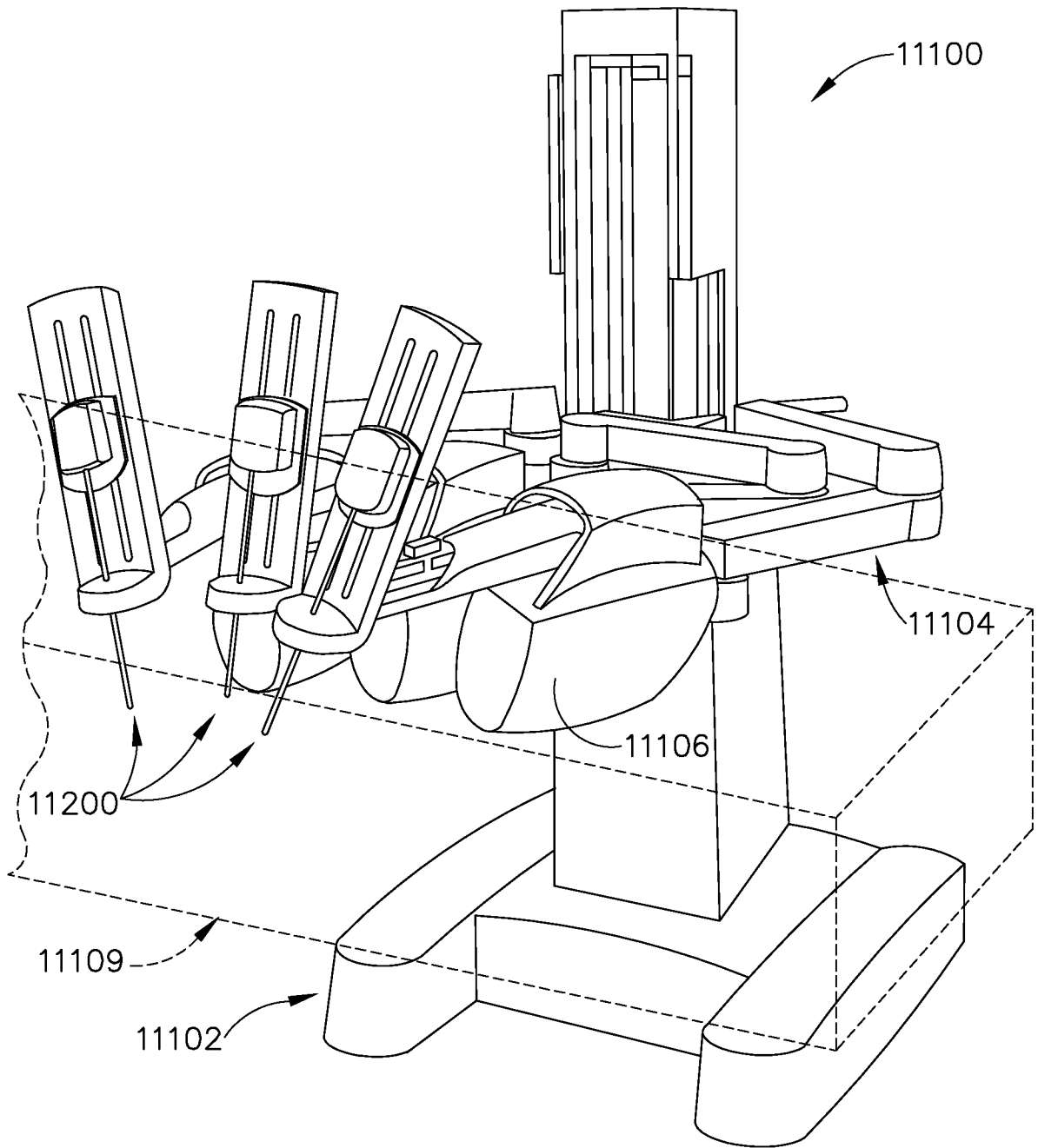


FIG. 55

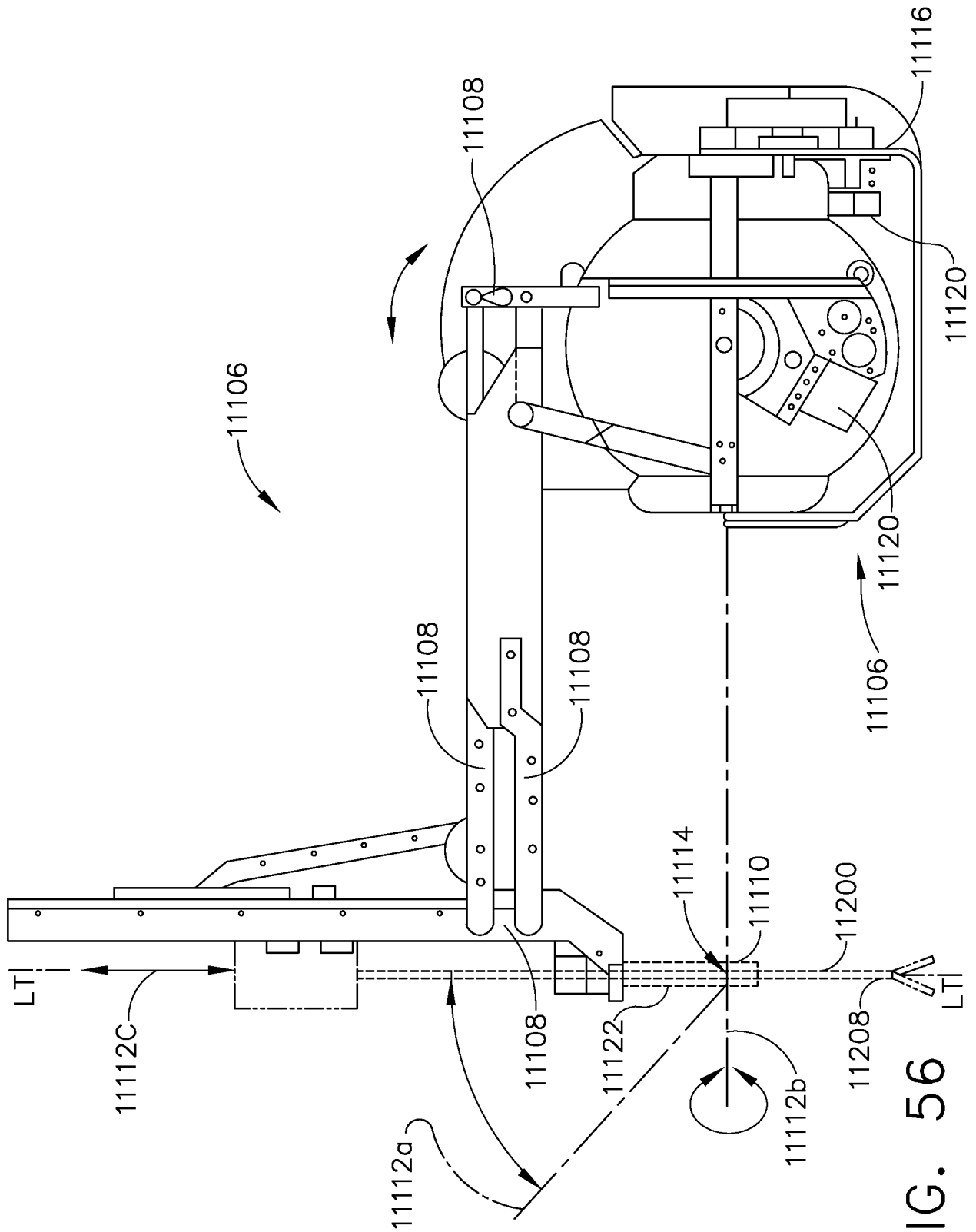


FIG. 56

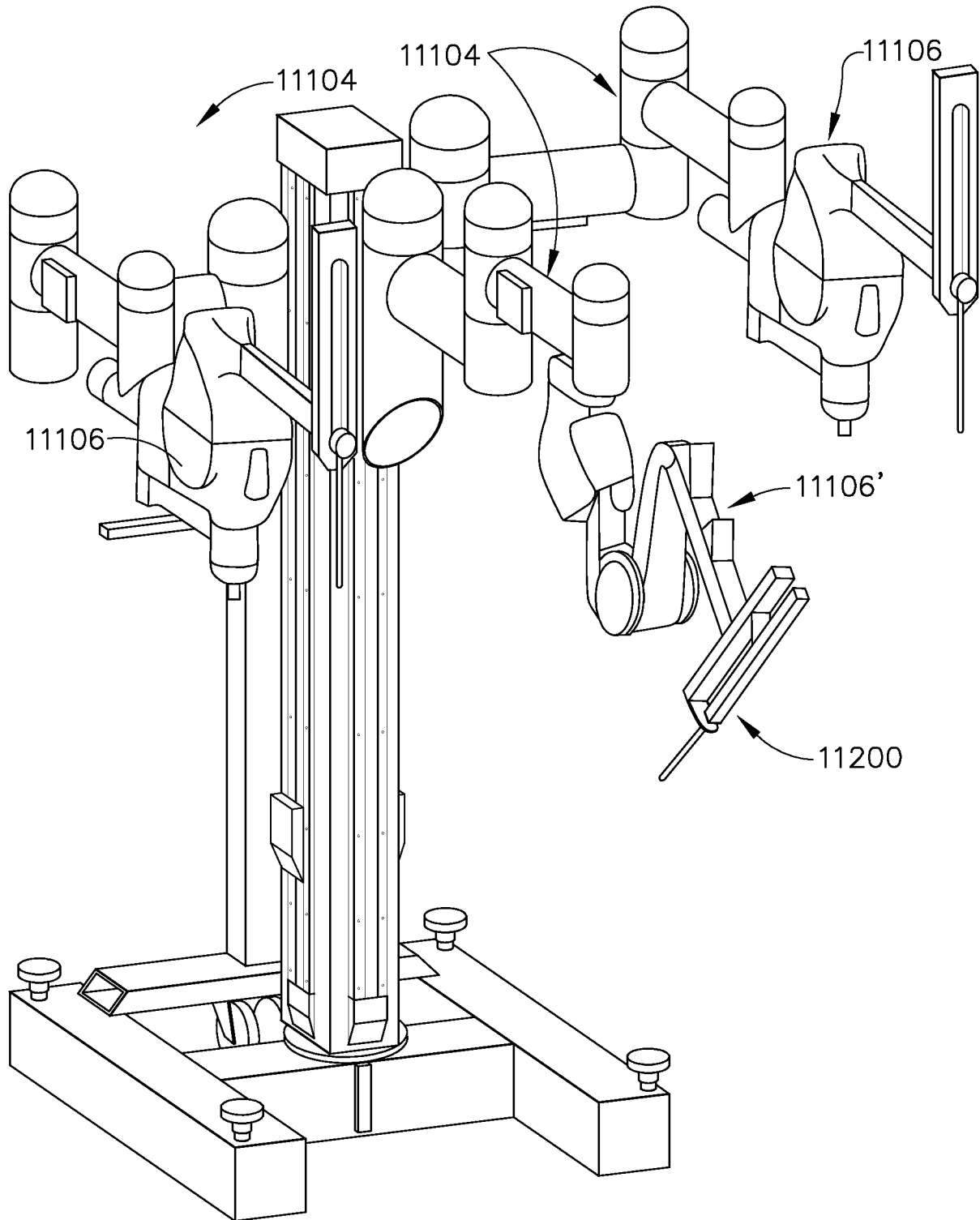


FIG. 57

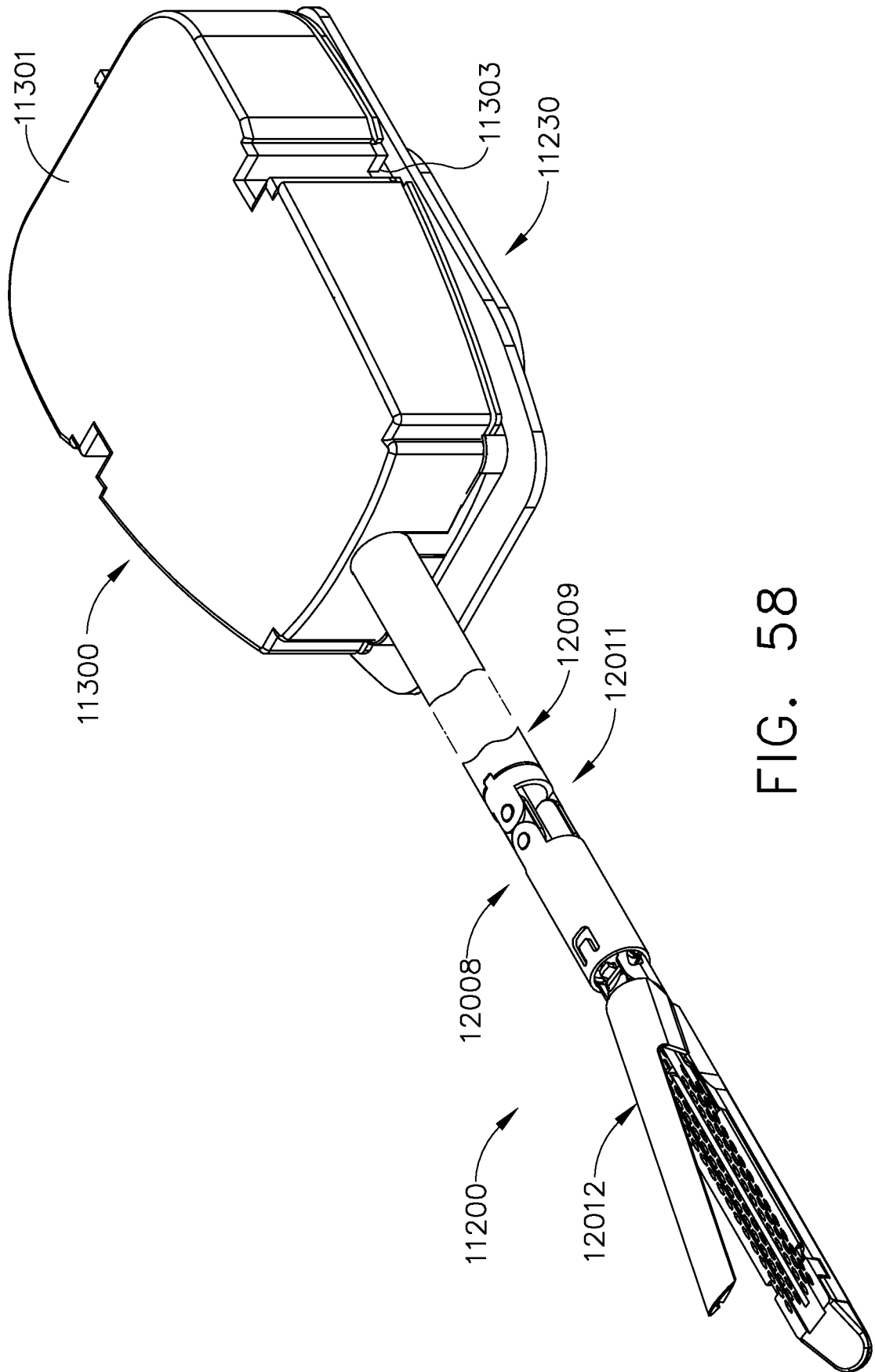


FIG. 58

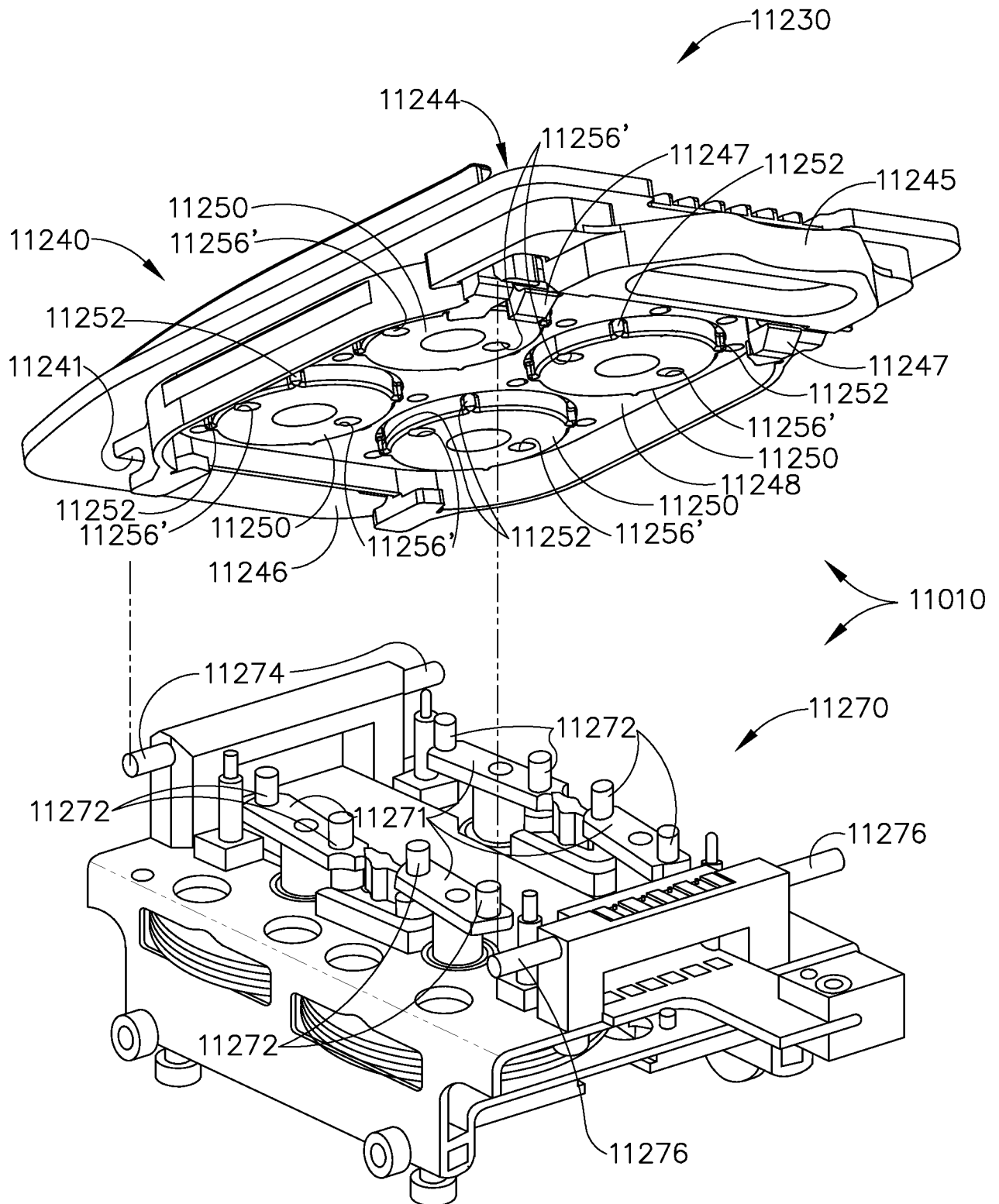


FIG. 59

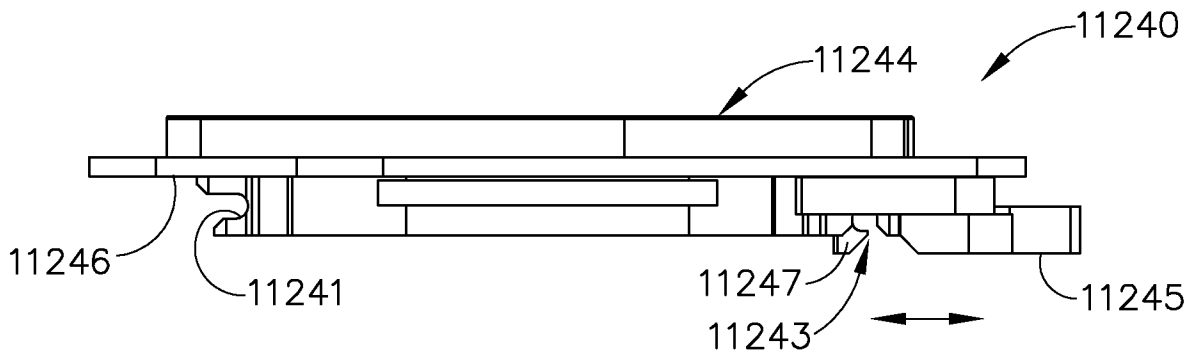


FIG. 60

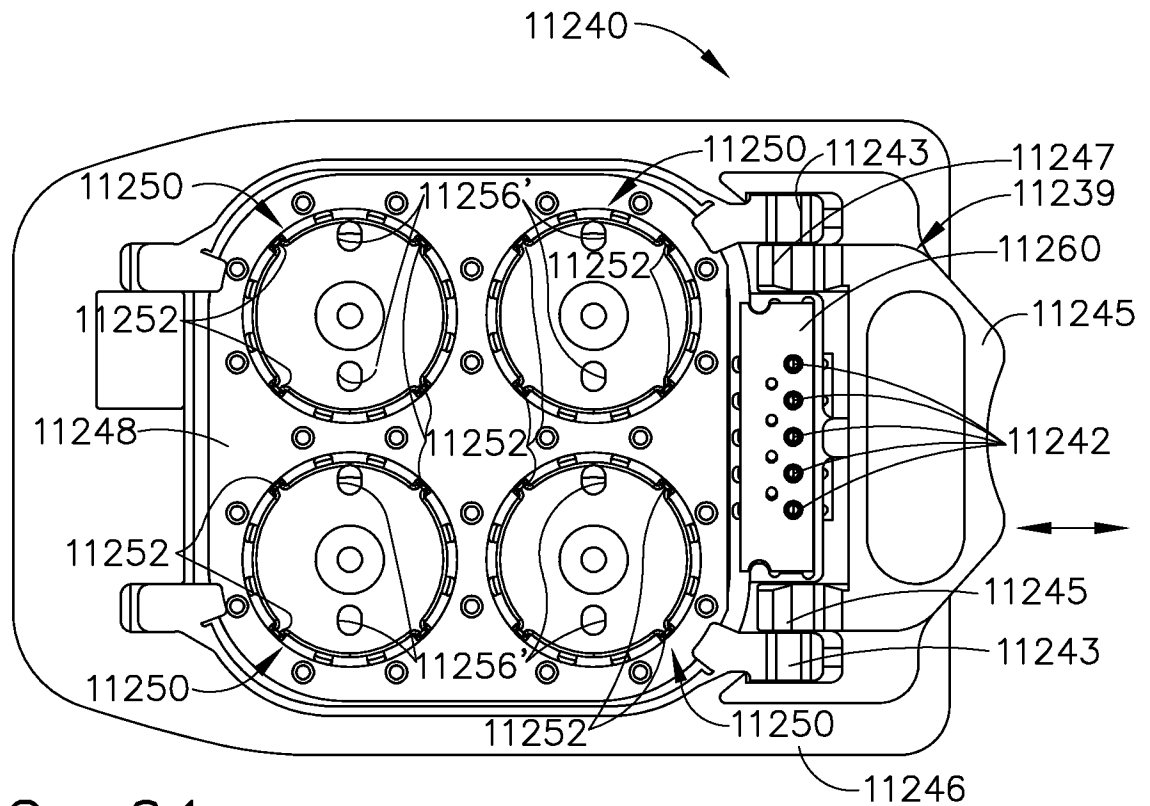


FIG. 61

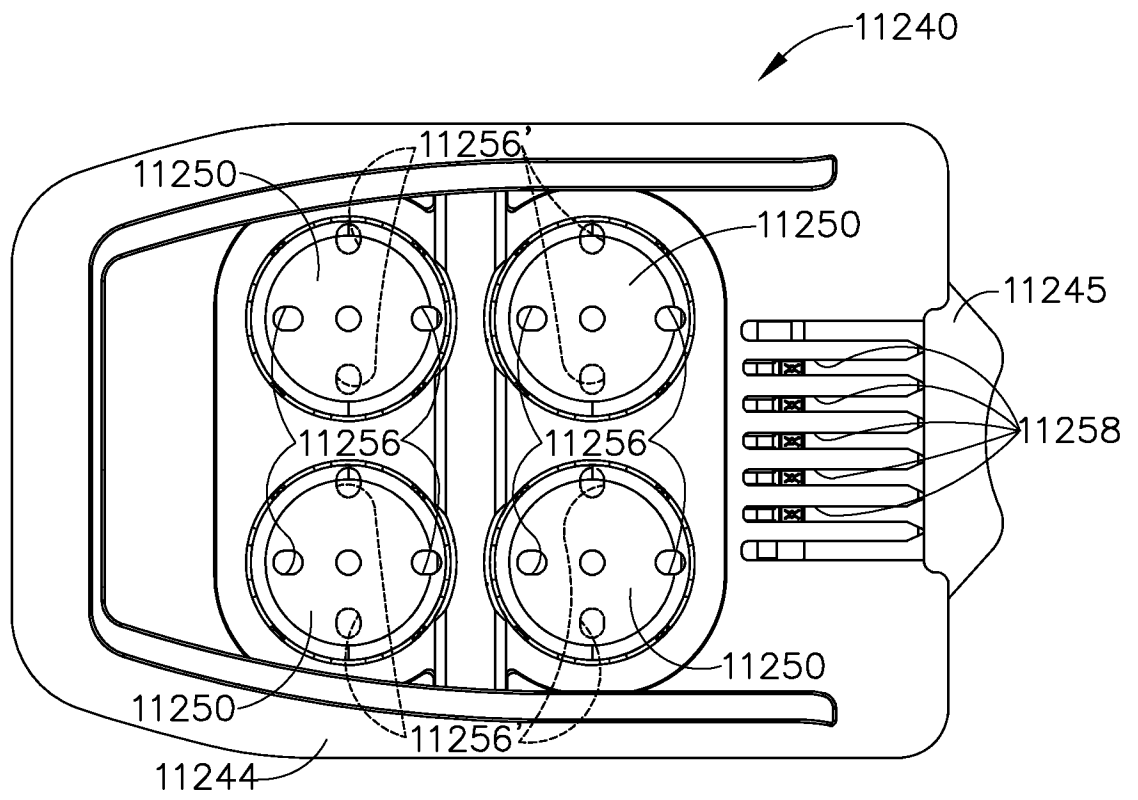


FIG. 62

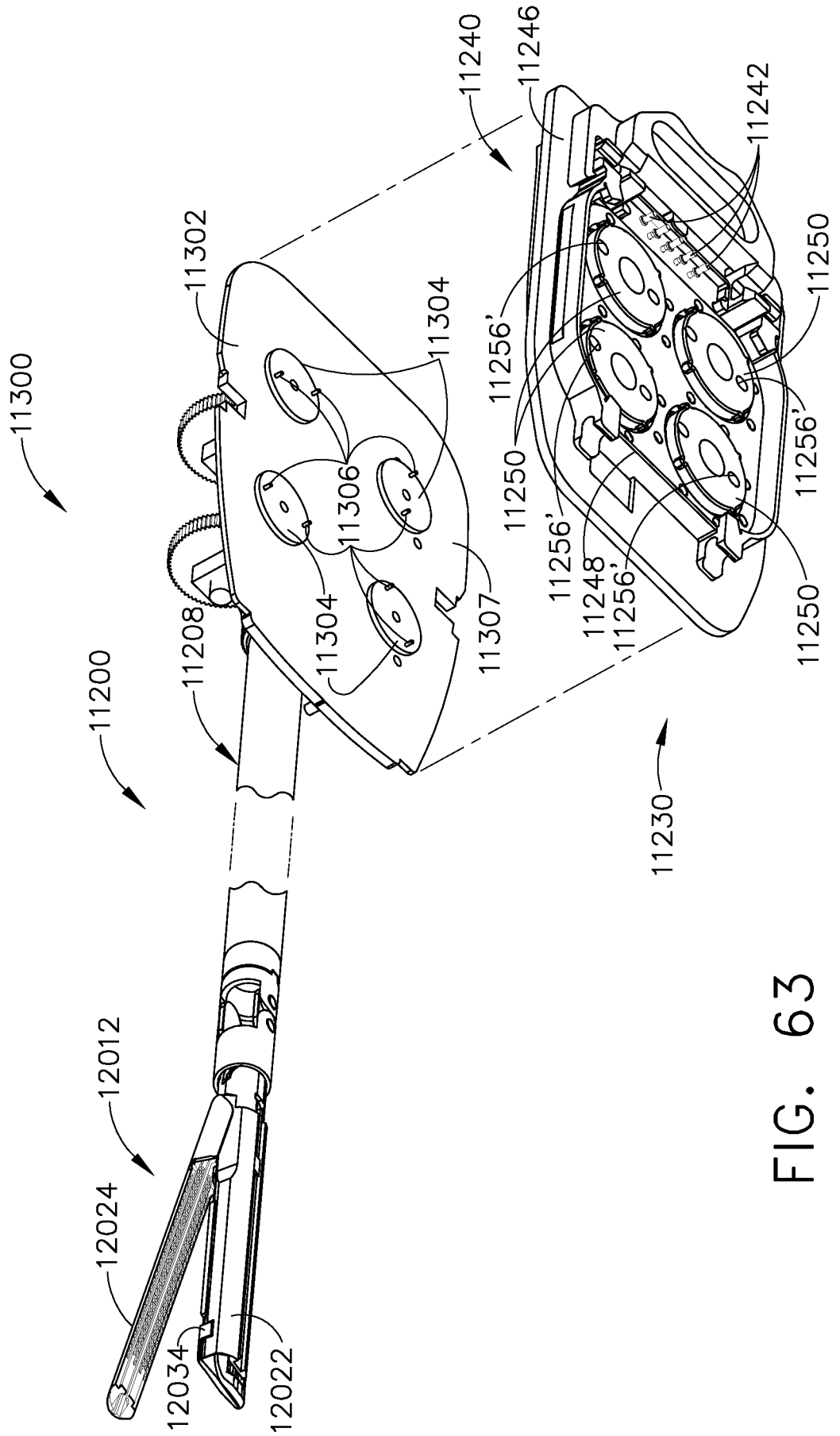


FIG. 63

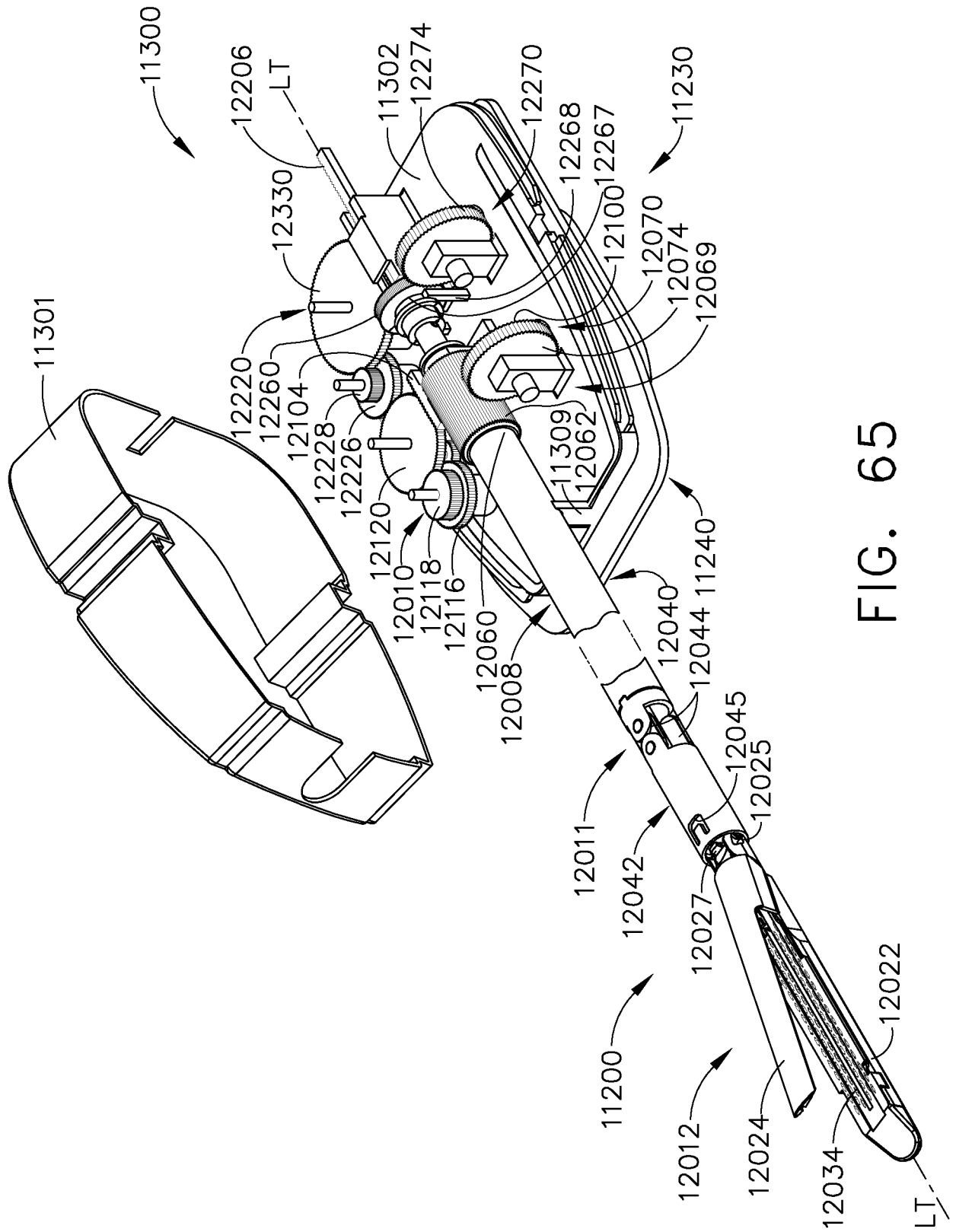


FIG. 65

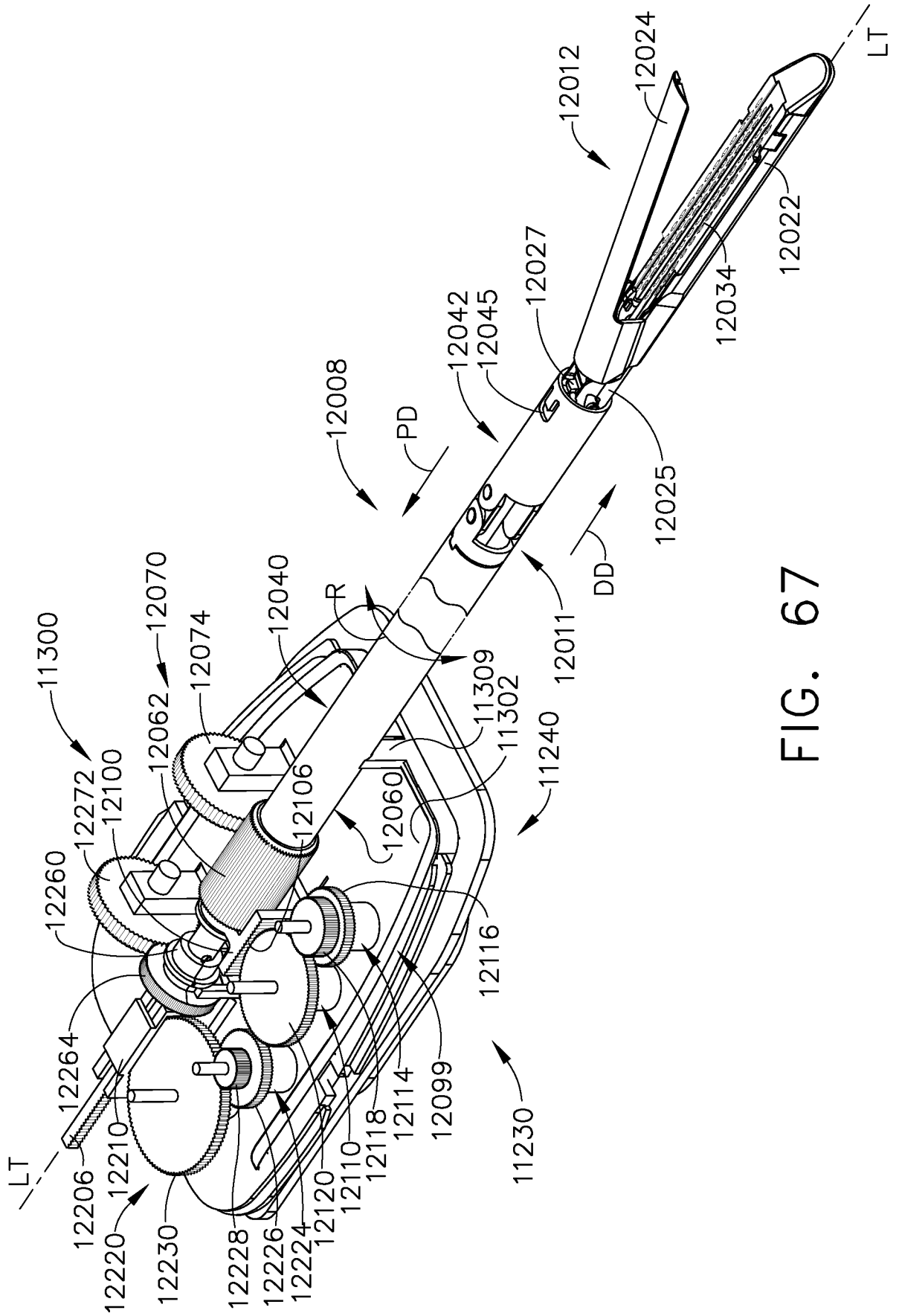


FIG. 67

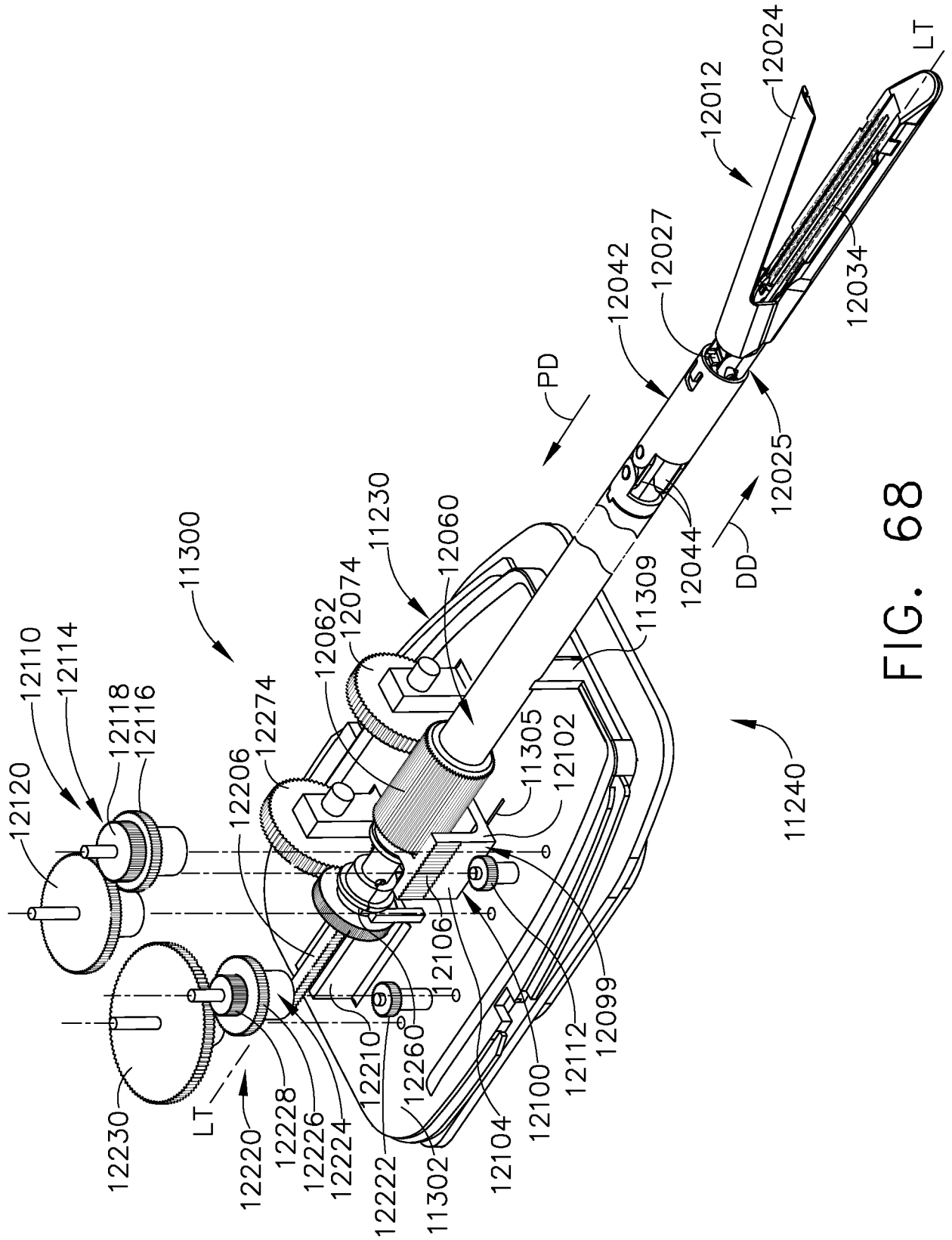


FIG. 68

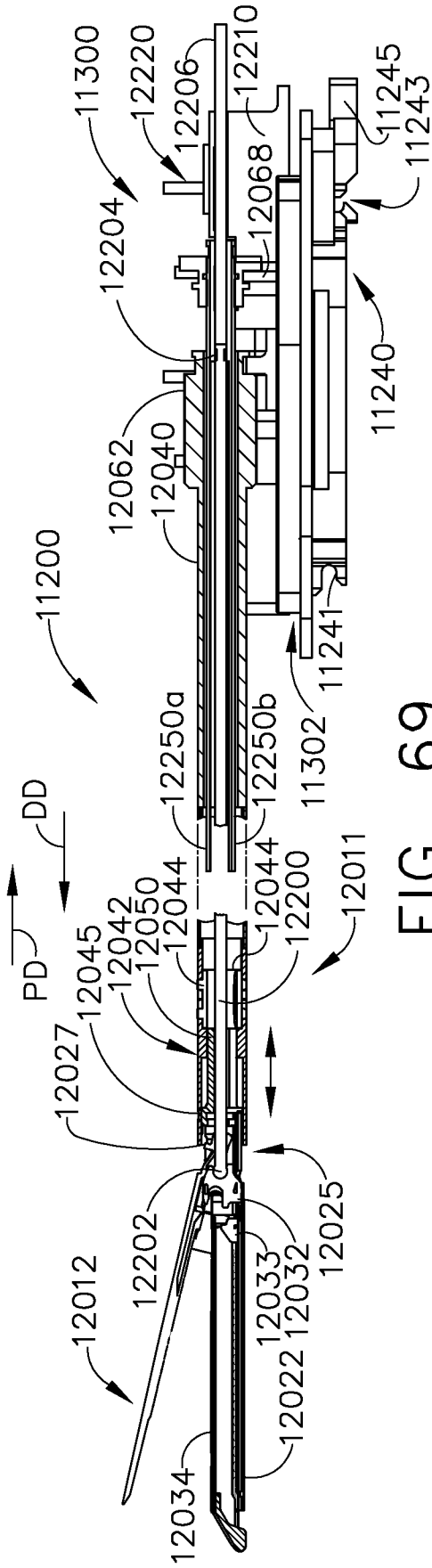


FIG. 69

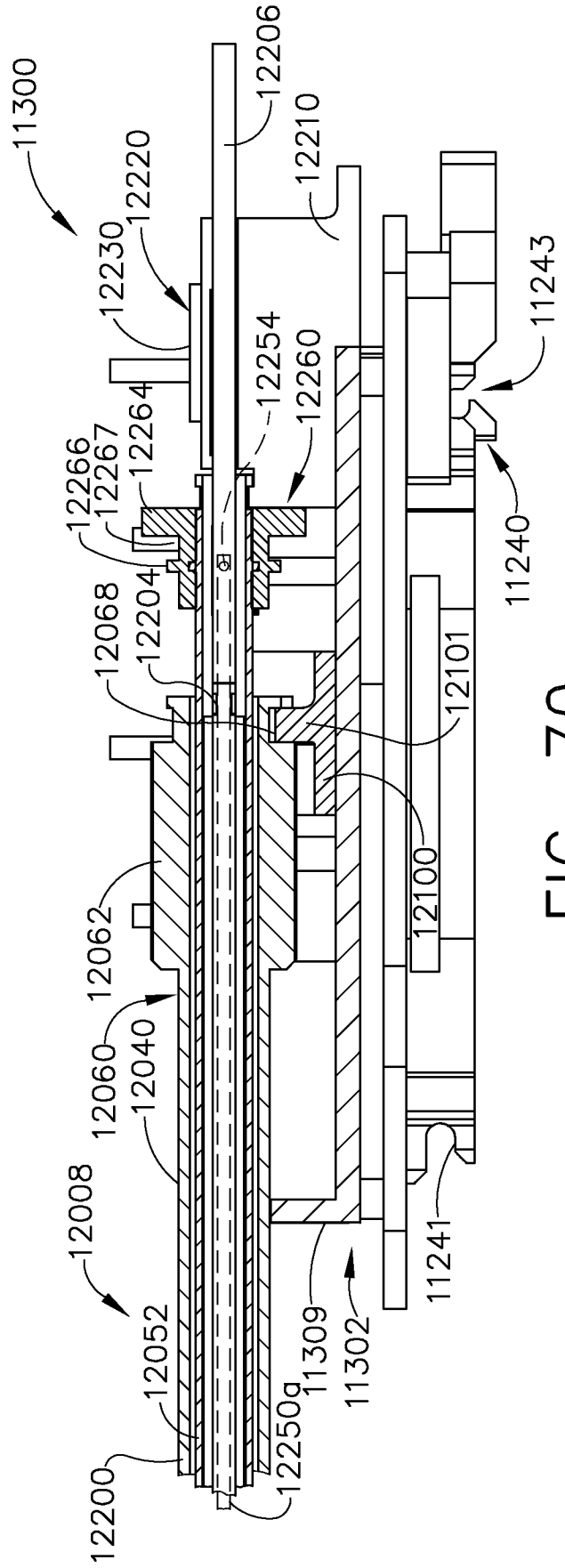


FIG. 70

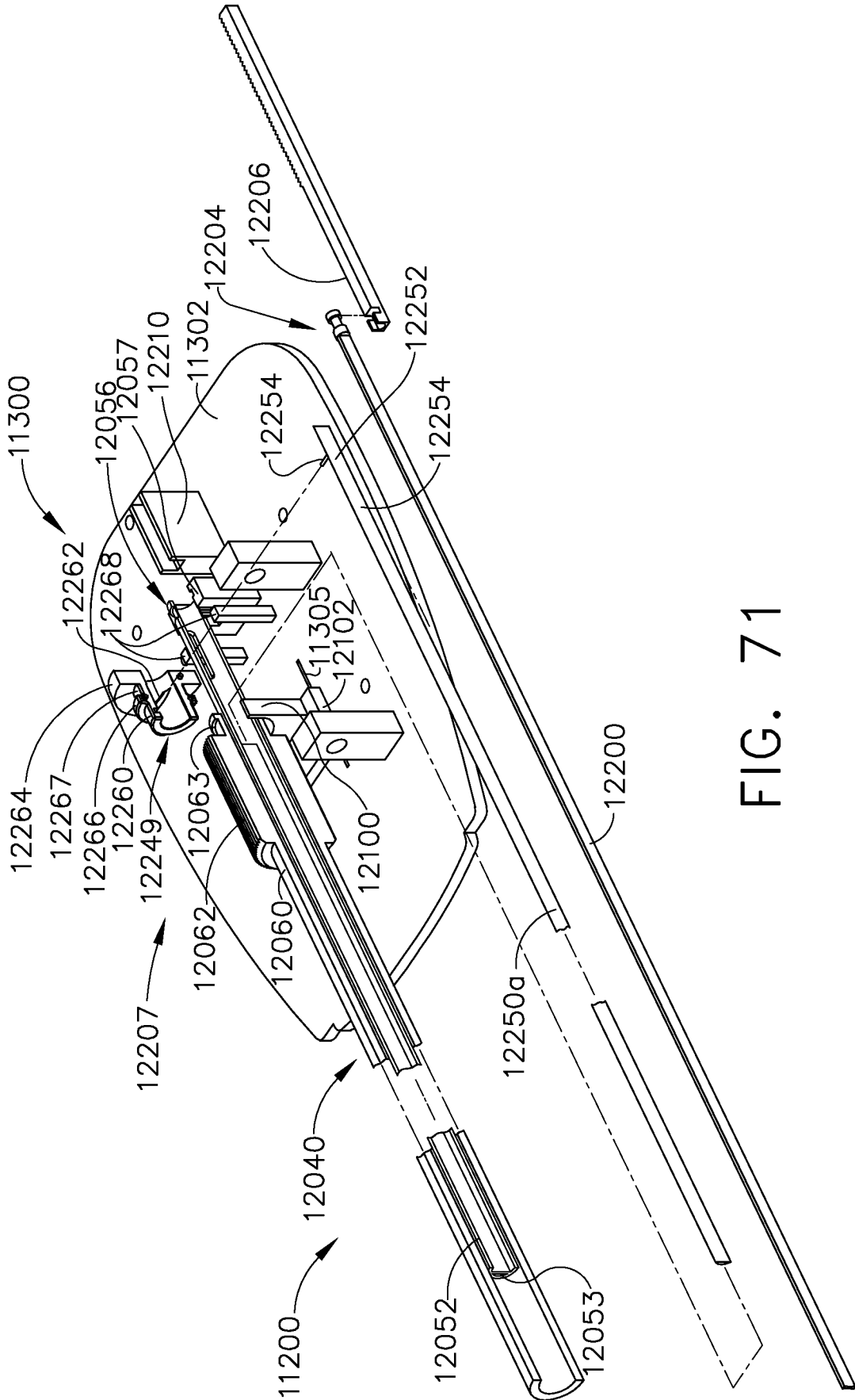


FIG. 71

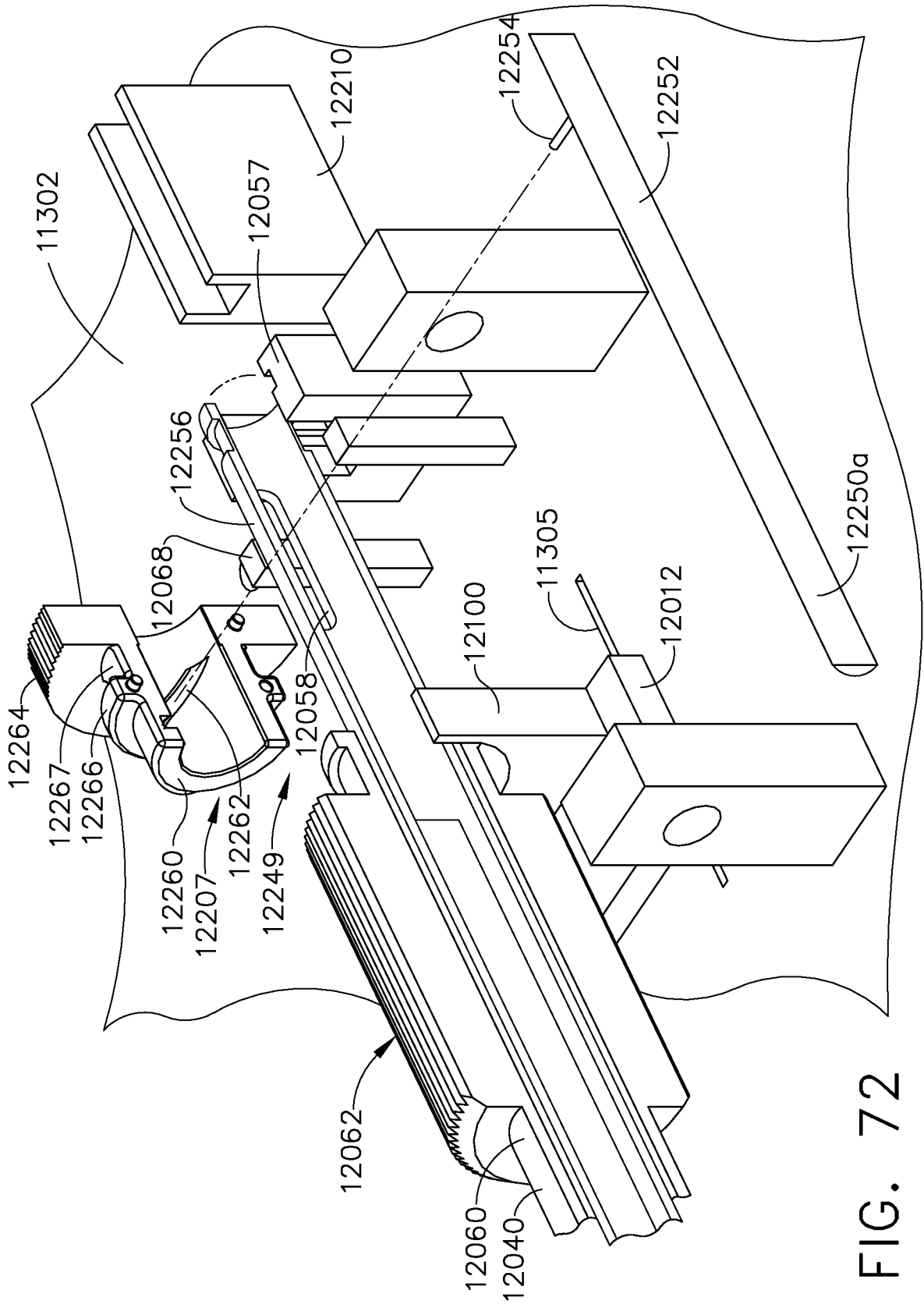


FIG. 72

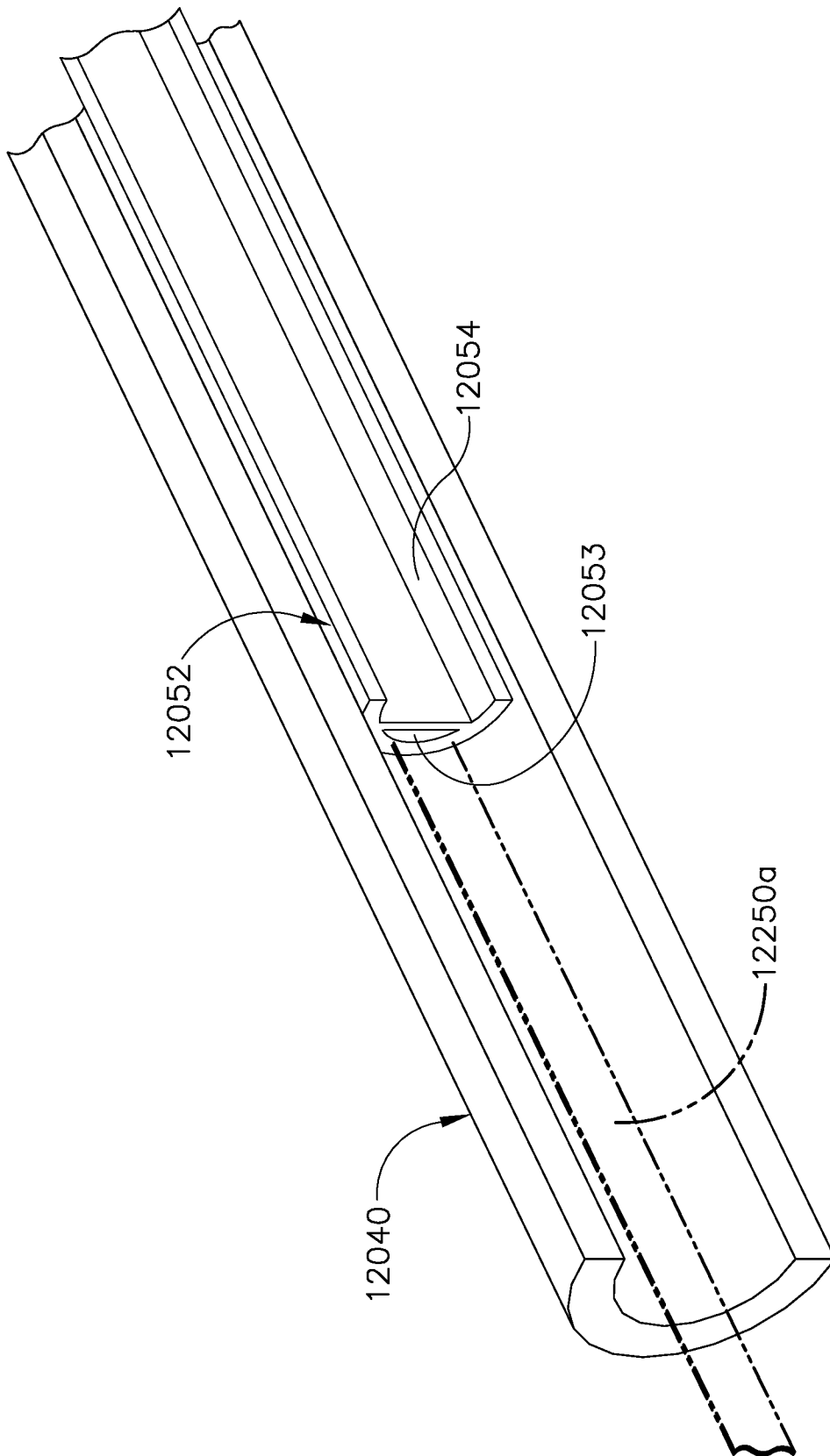


FIG. 73

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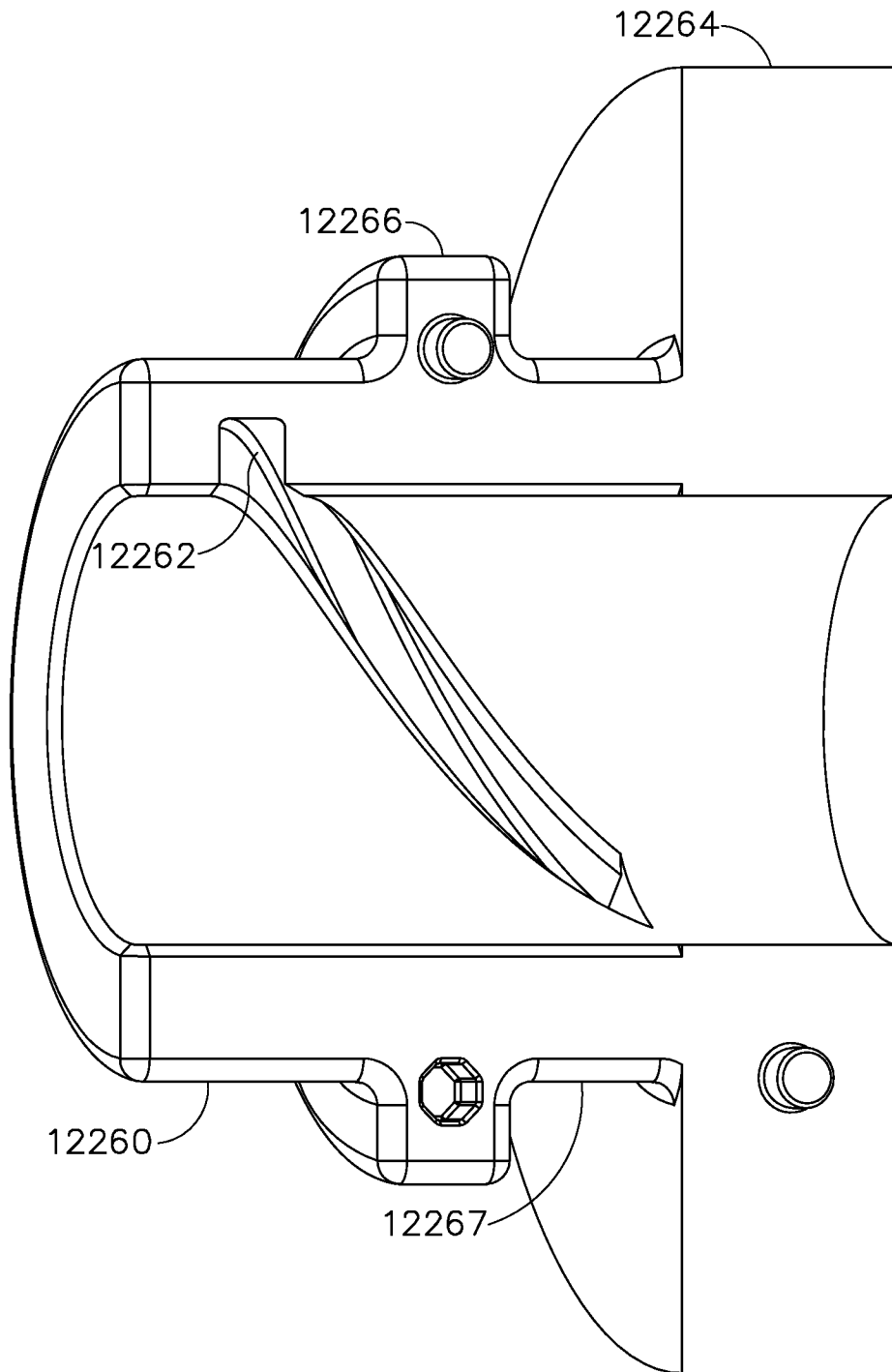


FIG. 74

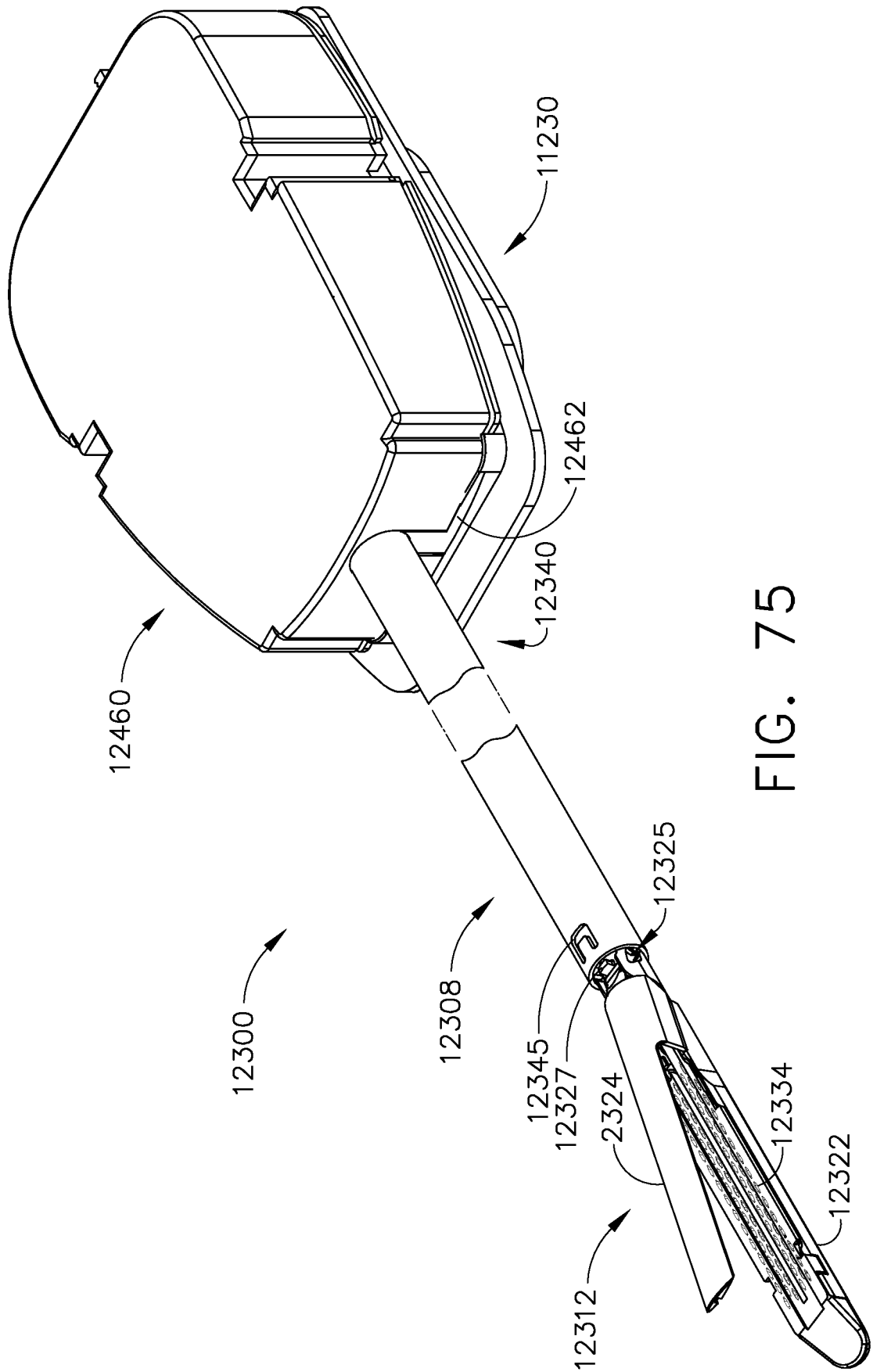


FIG. 75

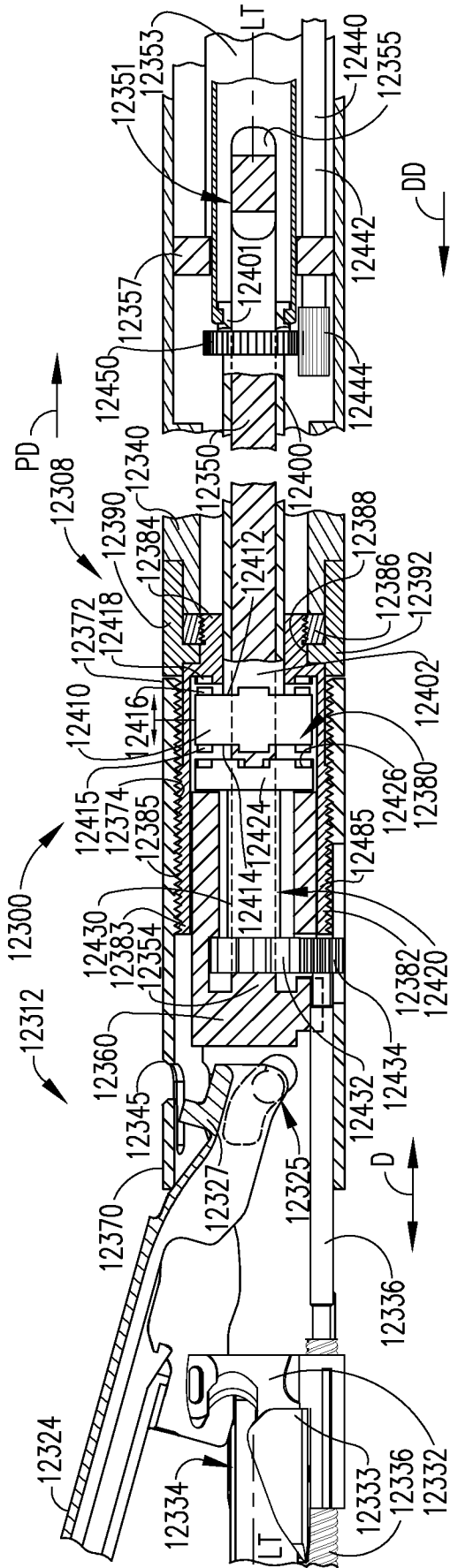


FIG. 76

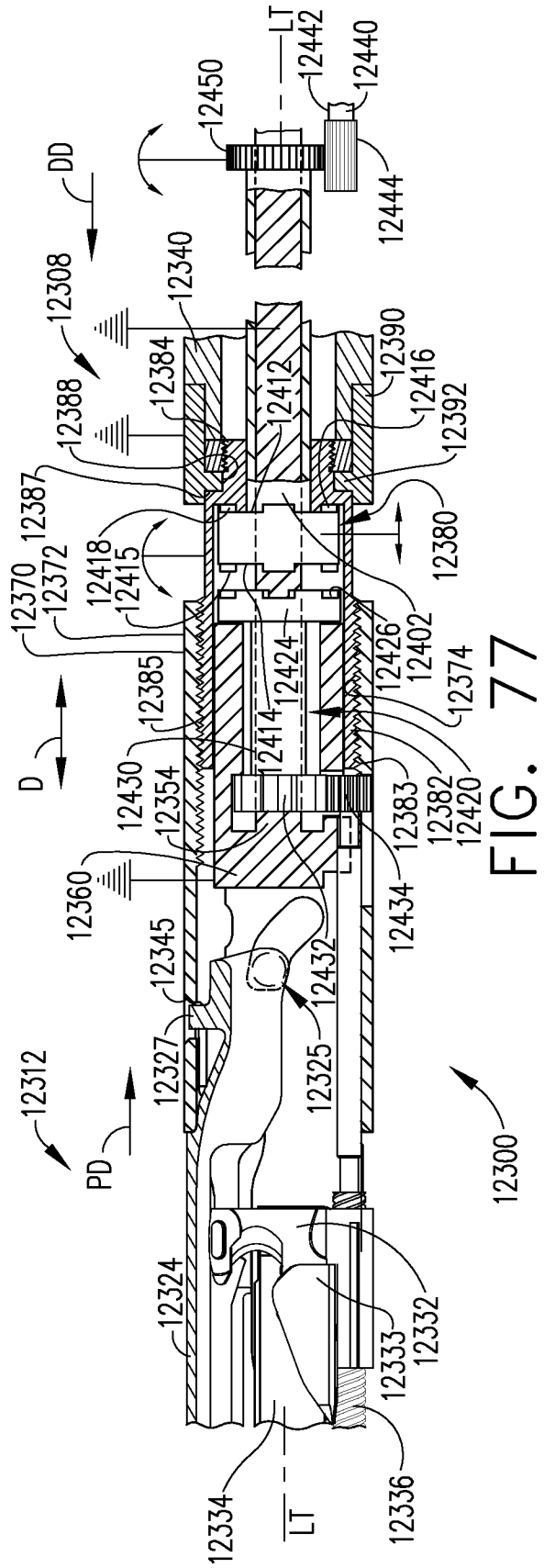


FIG. 77

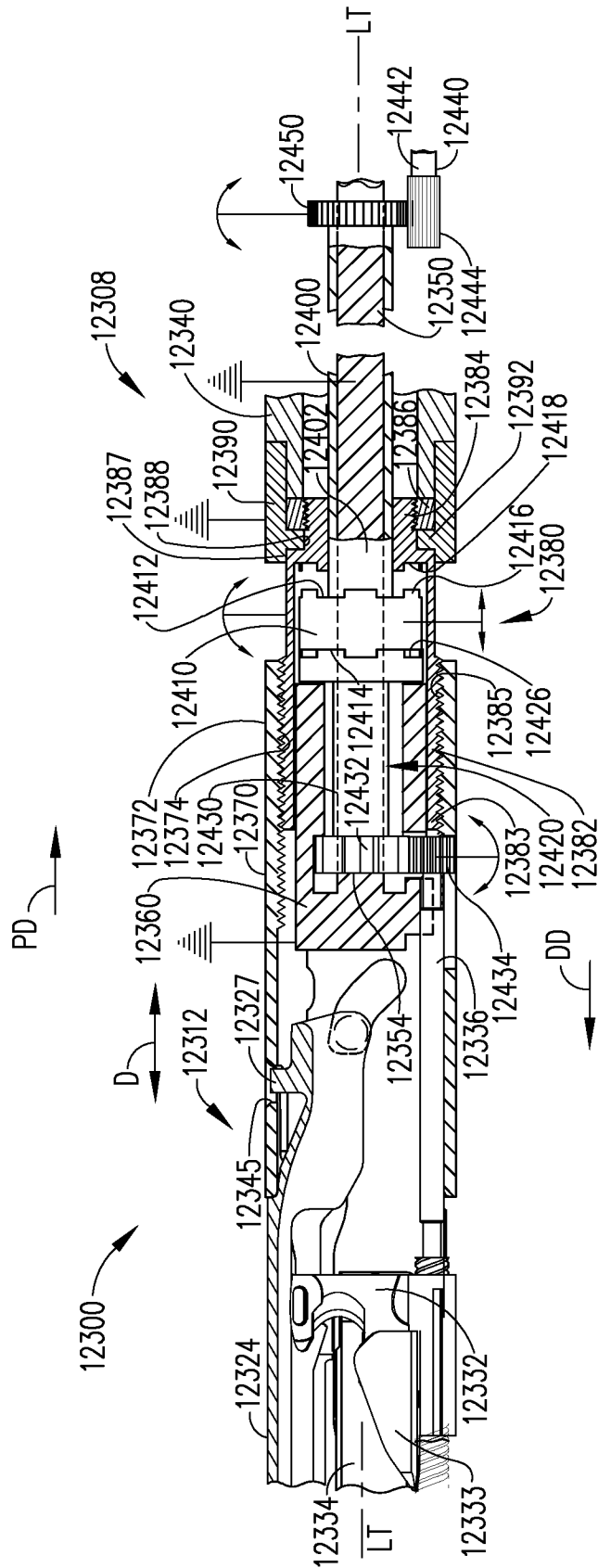


FIG. 78

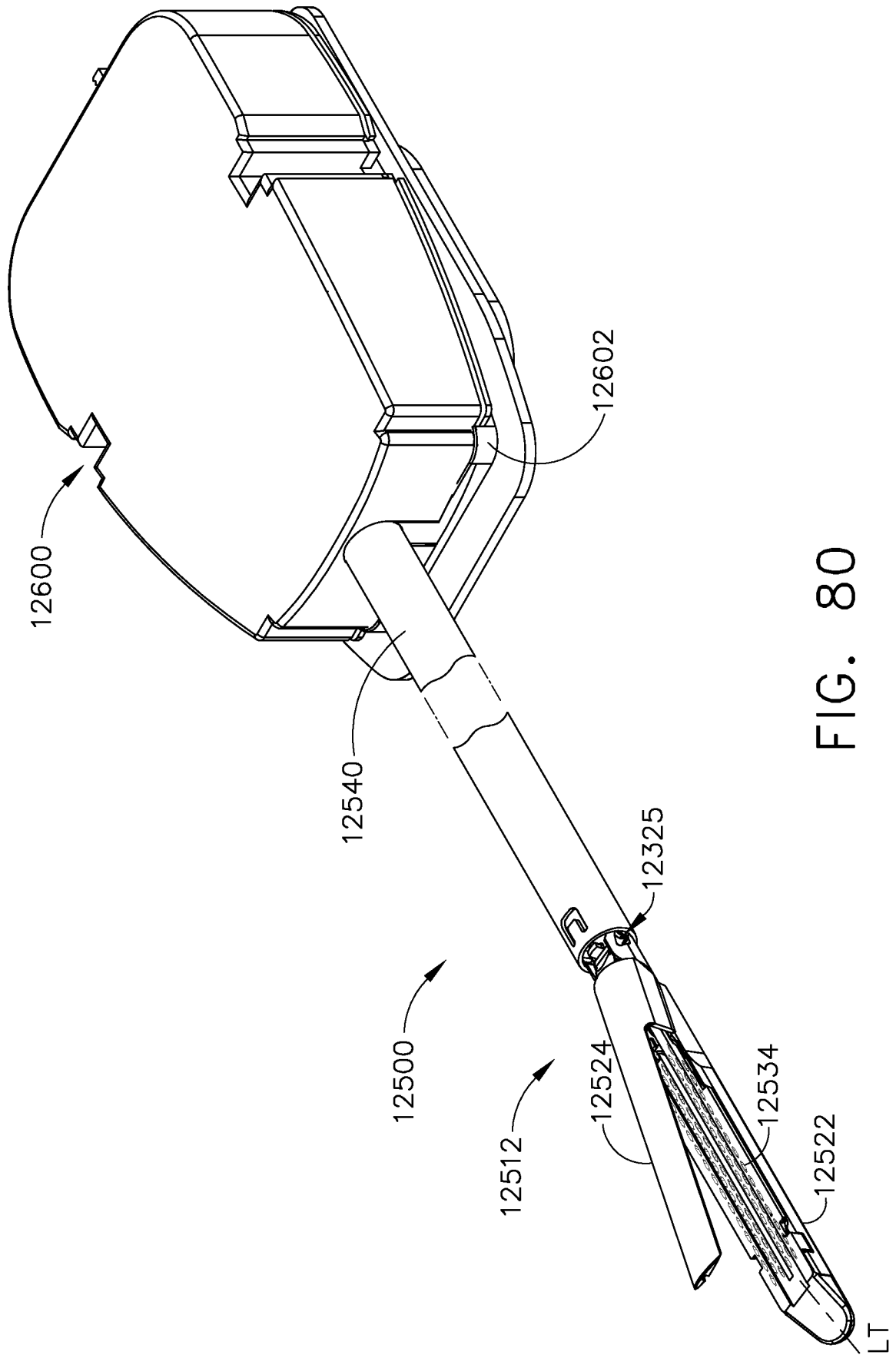


FIG. 80

LT

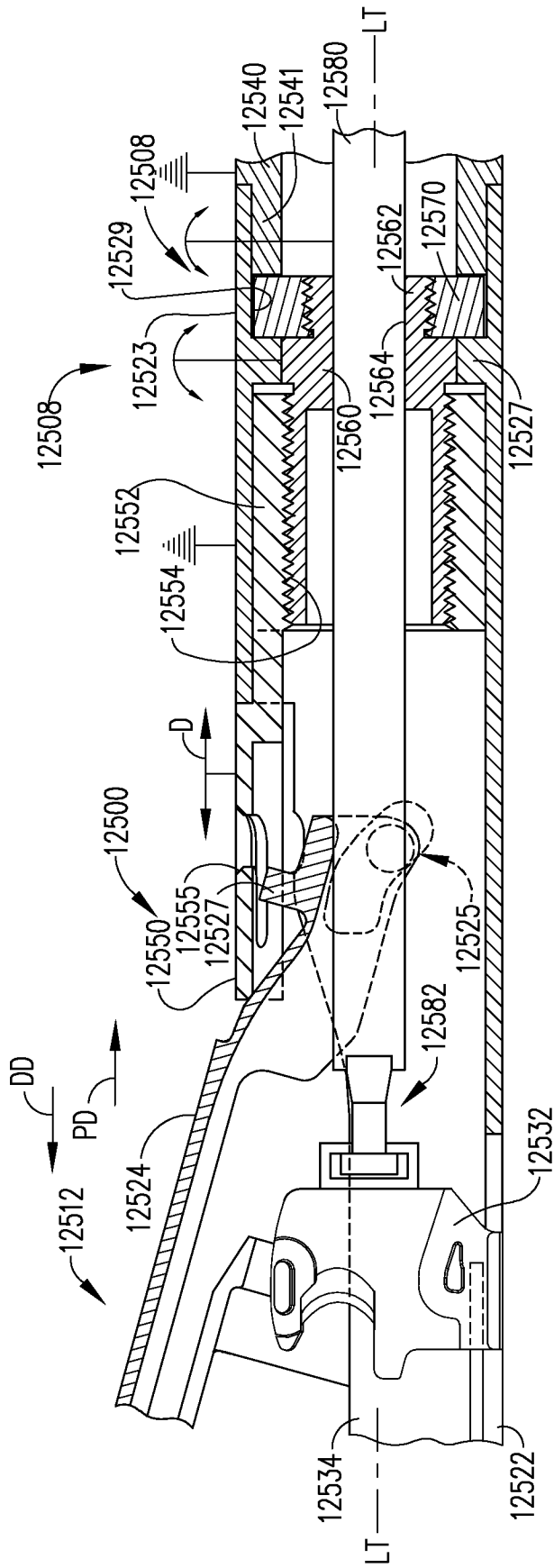


FIG. 81

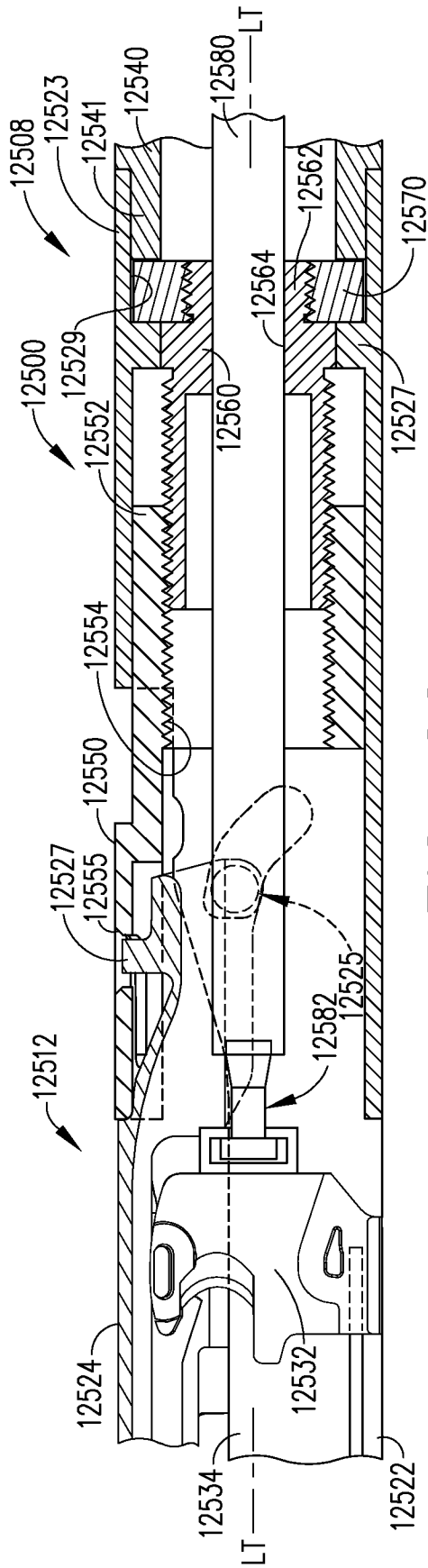


FIG. 82

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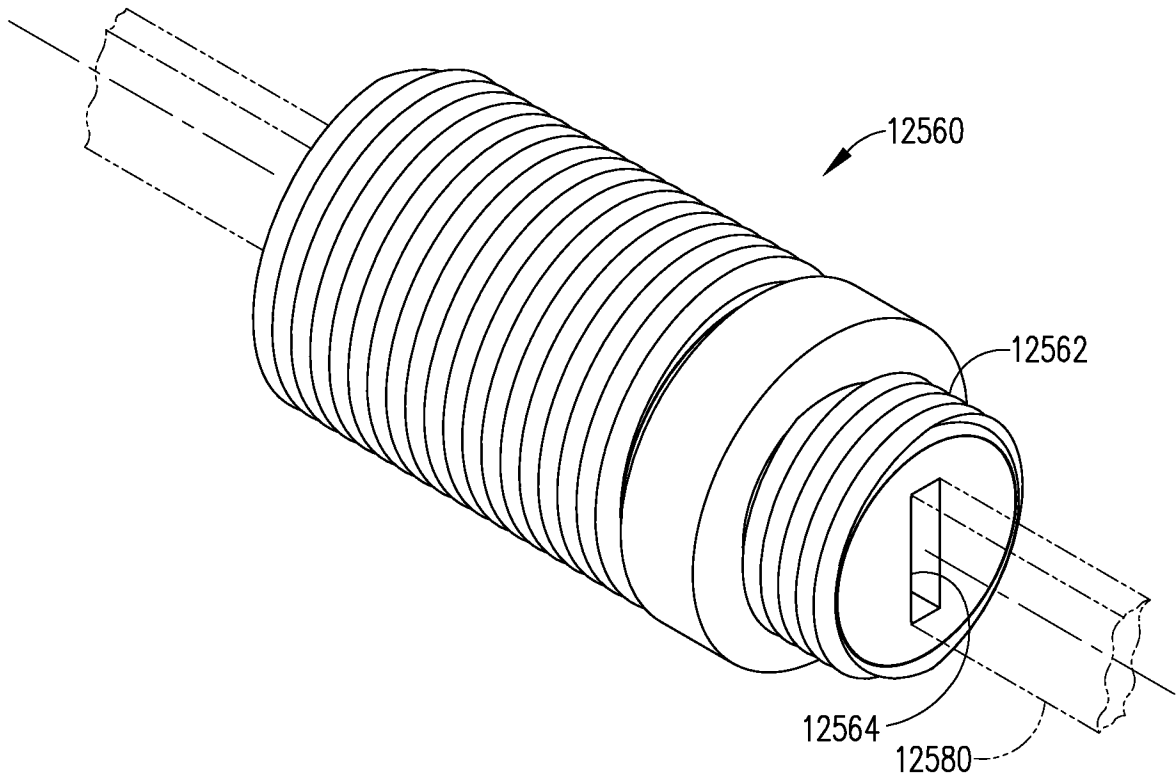


FIG. 83

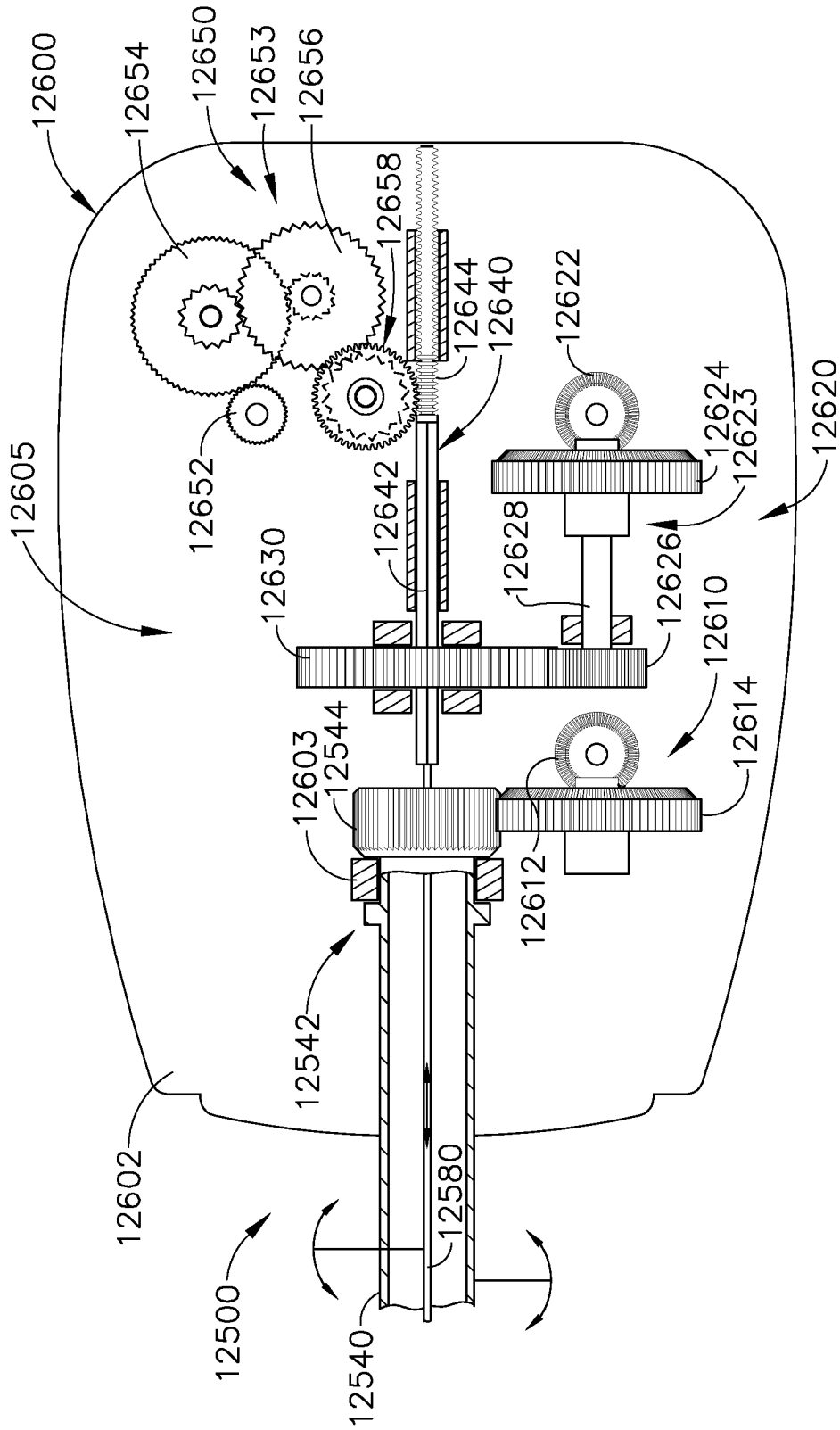


FIG. 84

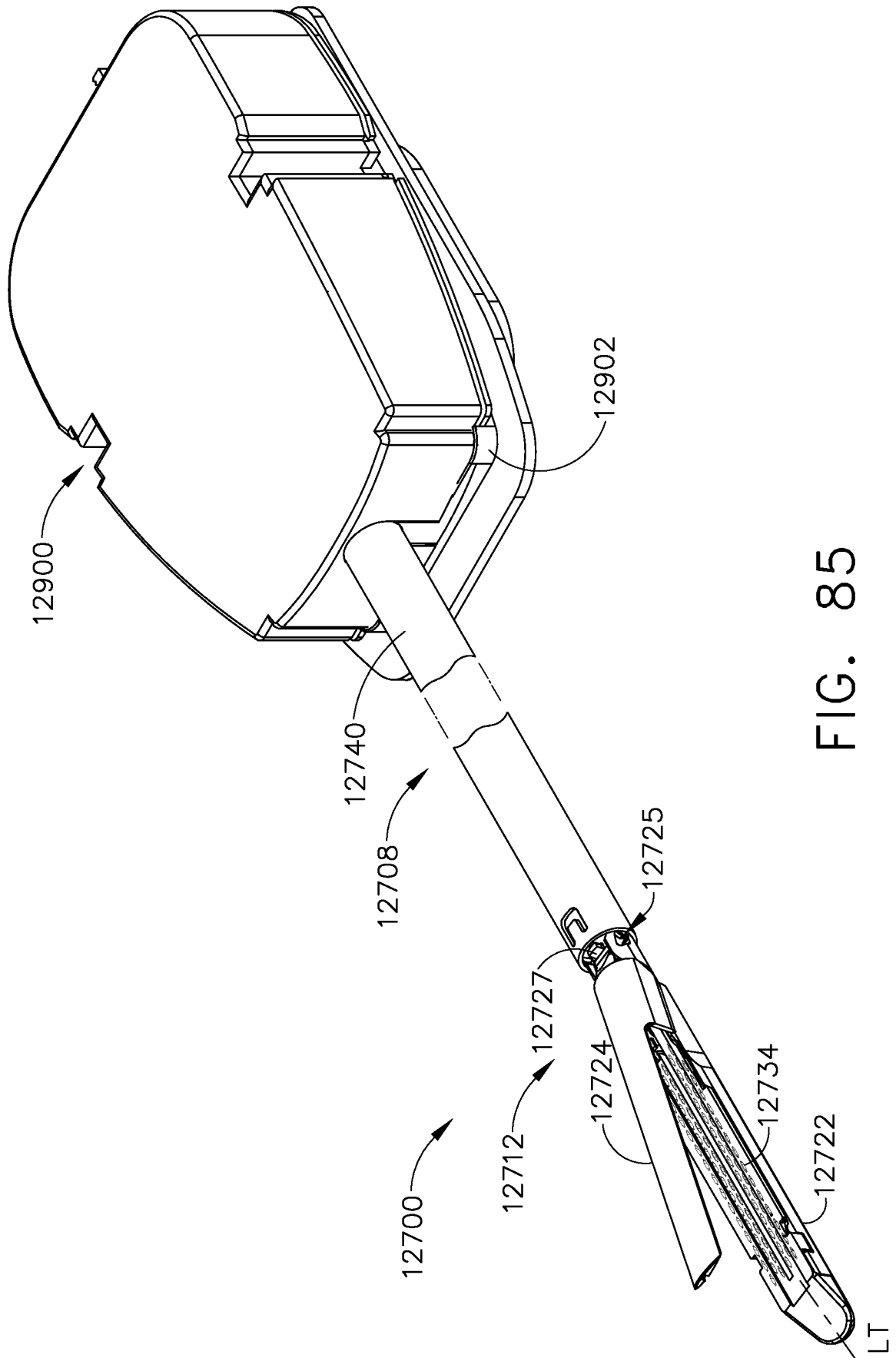


FIG. 85

LT

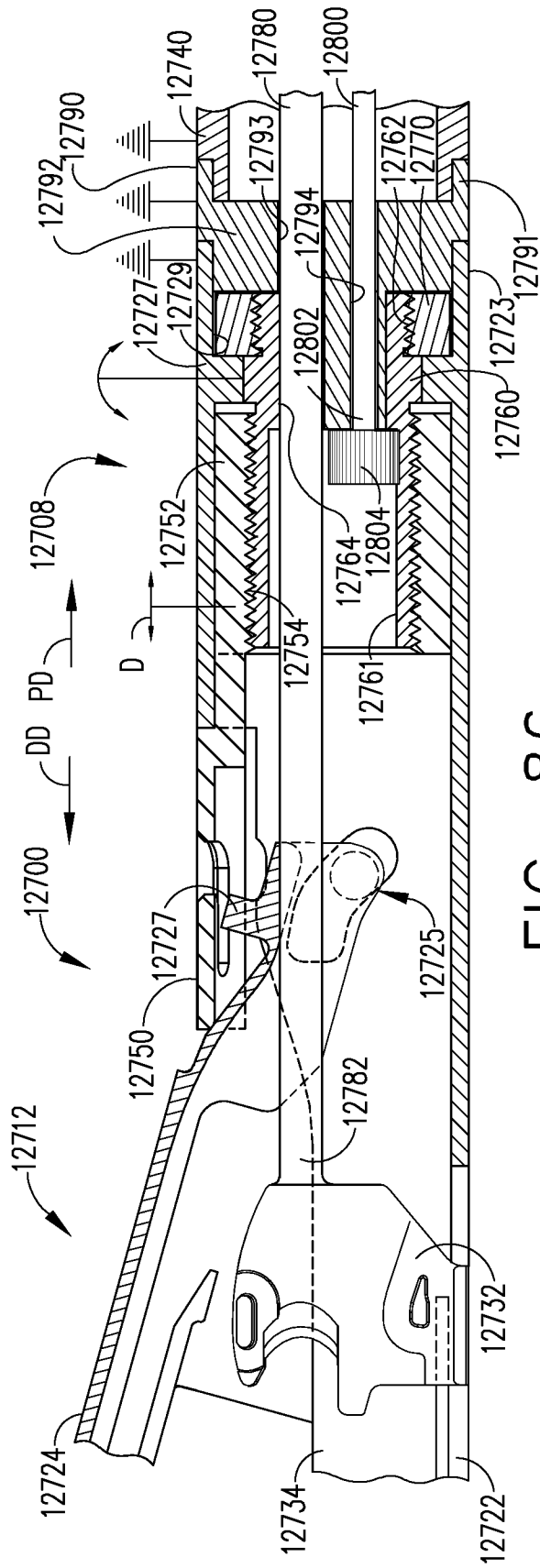


FIG. 86

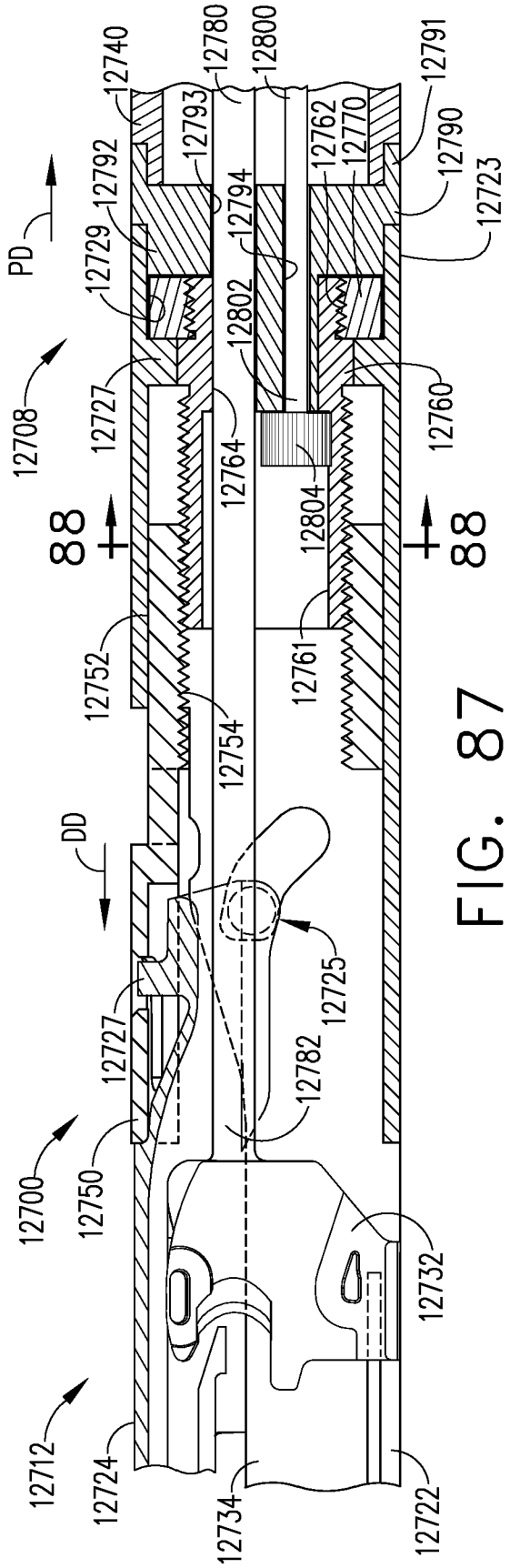


FIG. 87

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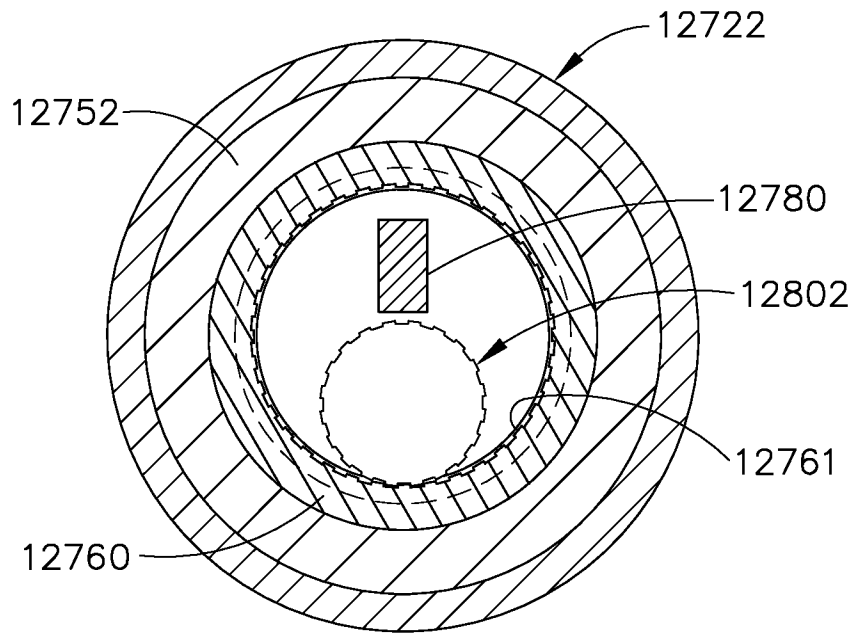


FIG. 88

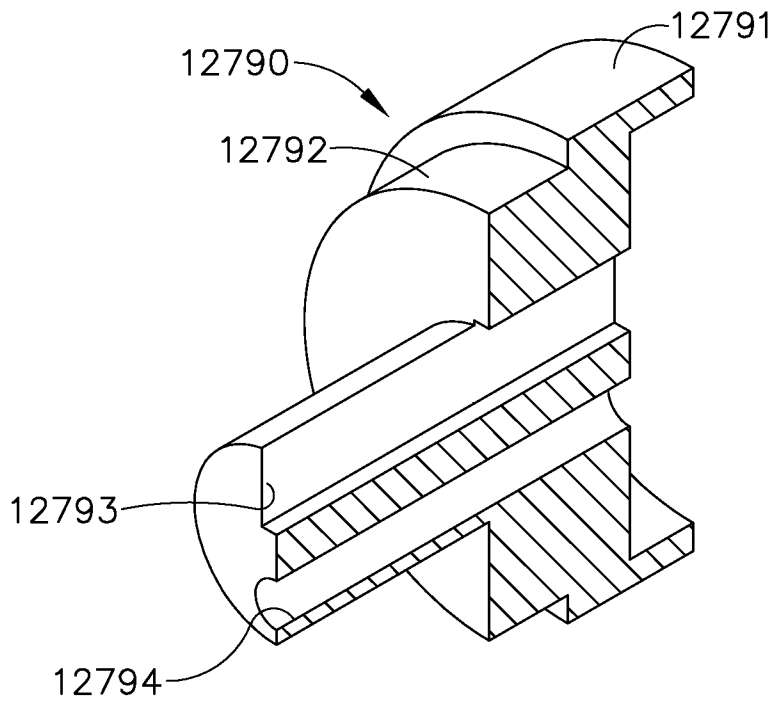


FIG. 89

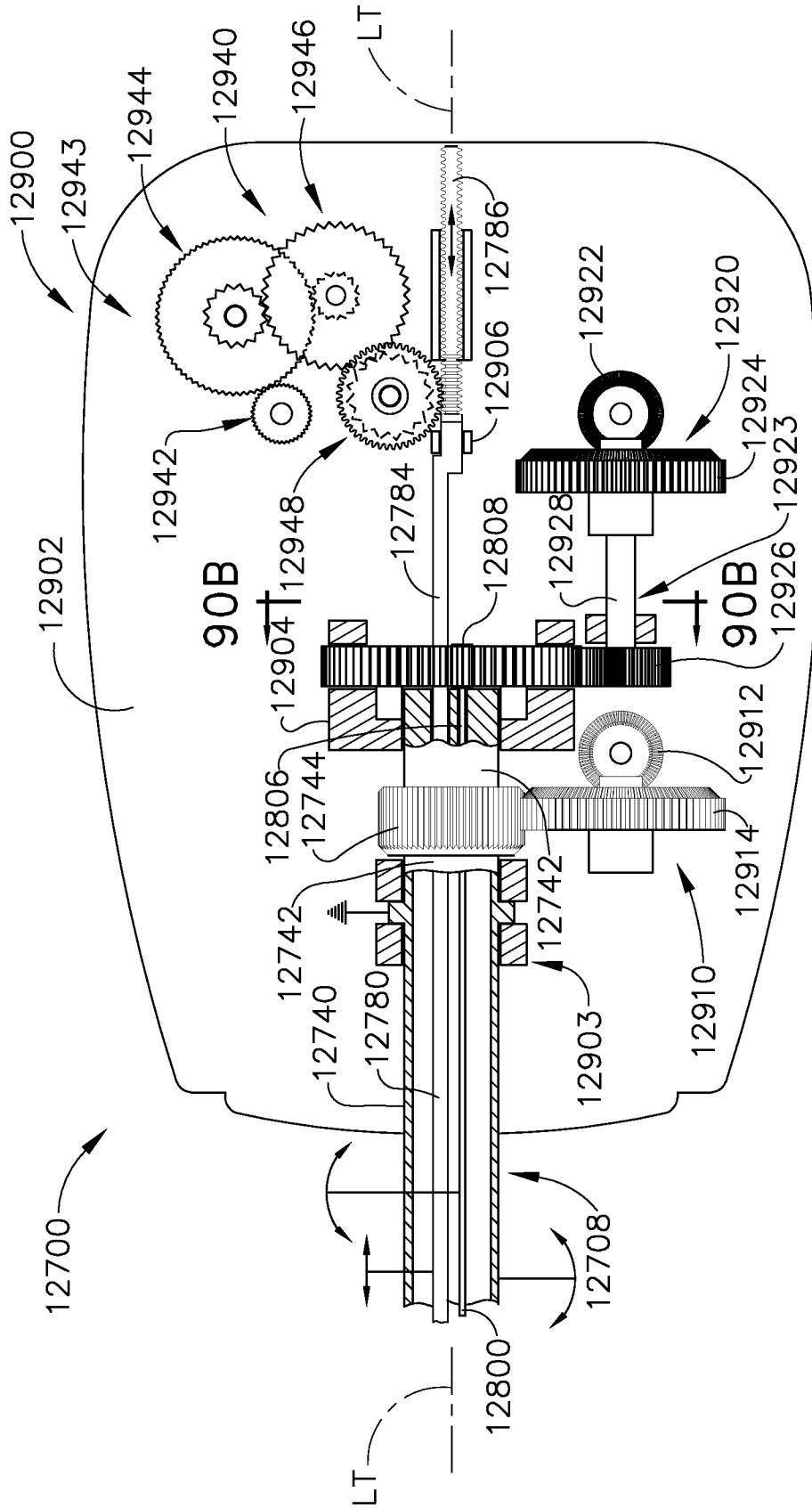


FIG. 90

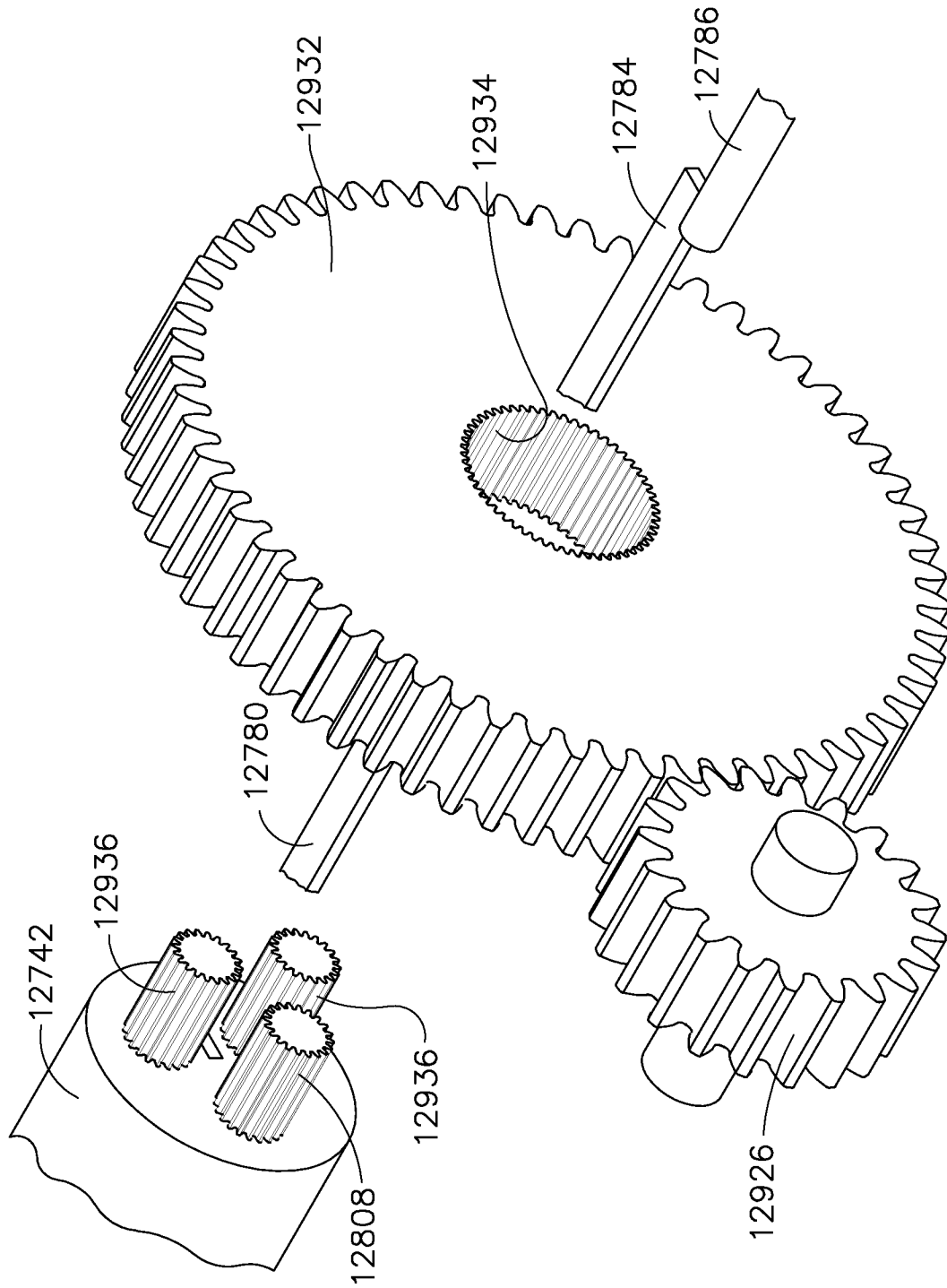


FIG. 90A

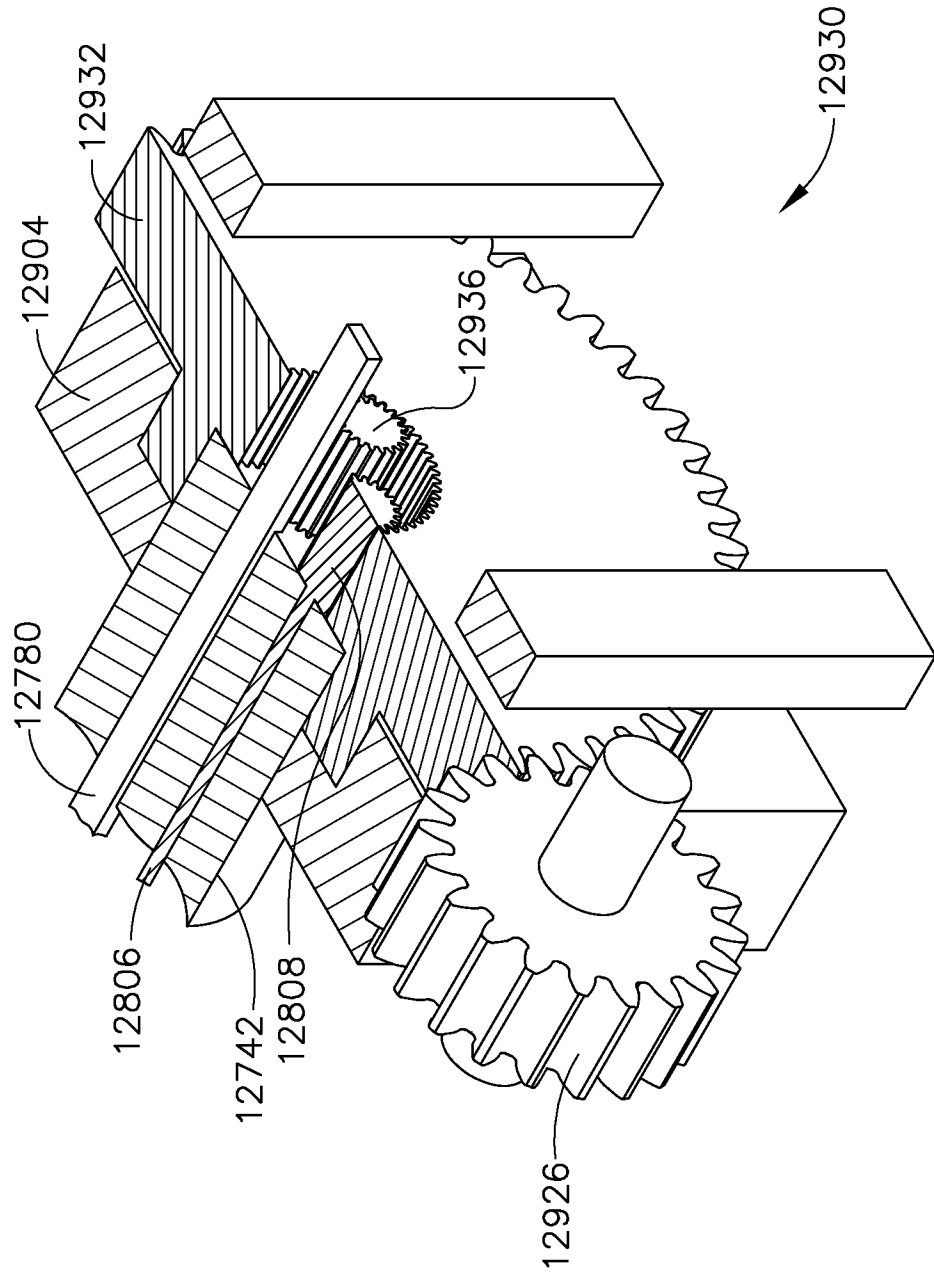


FIG. 90B

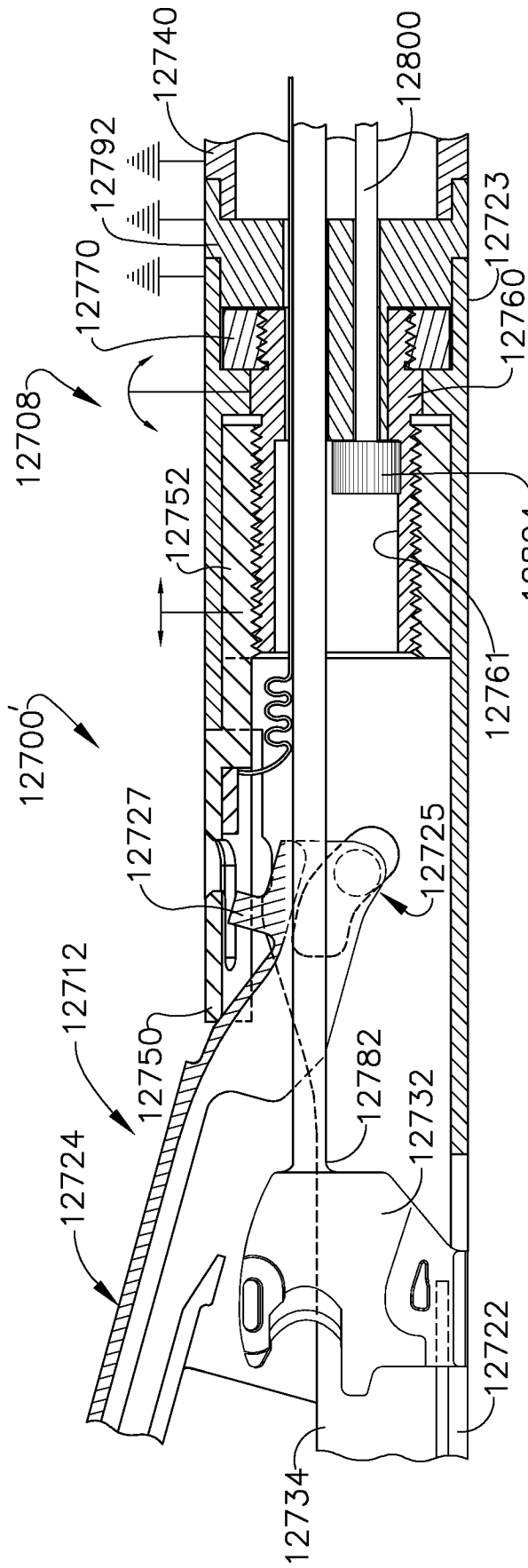


FIG. 91

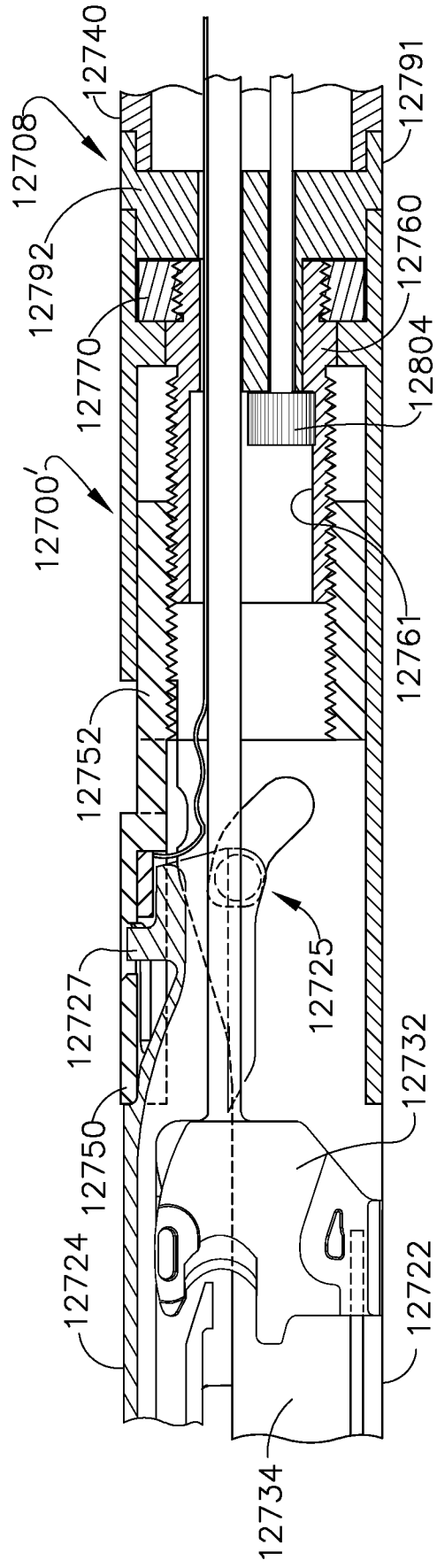


FIG. 92

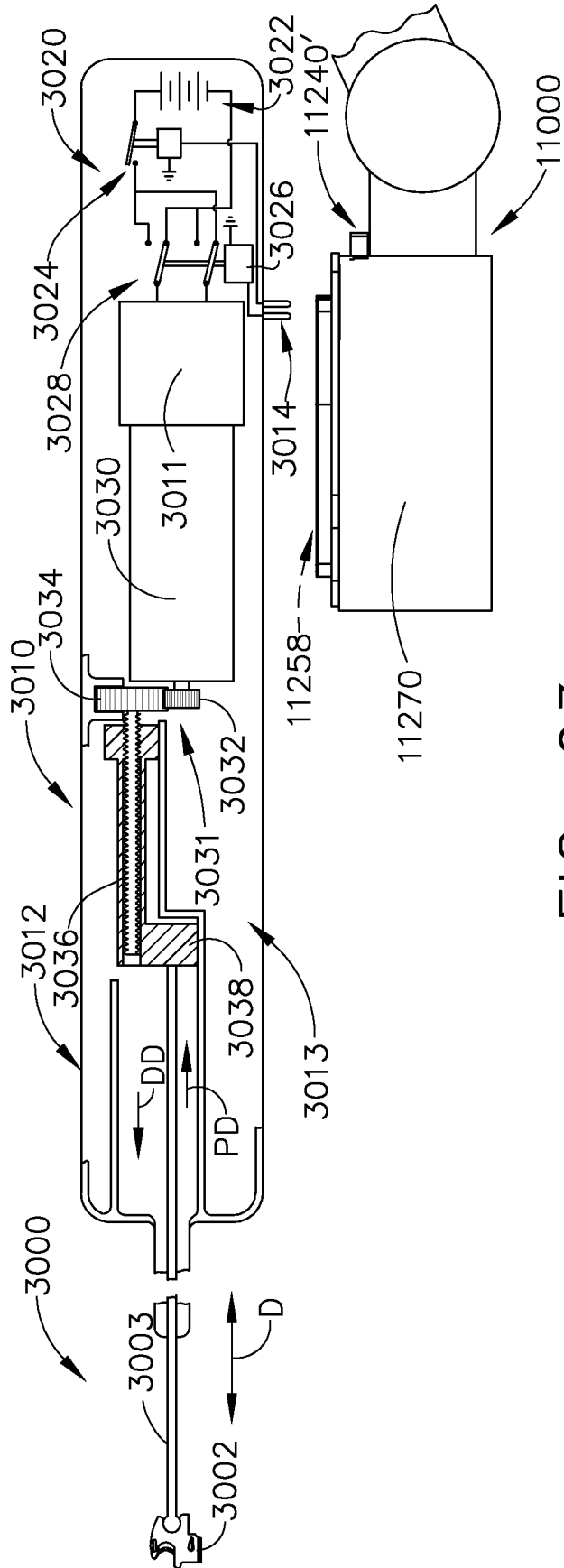


FIG. 93

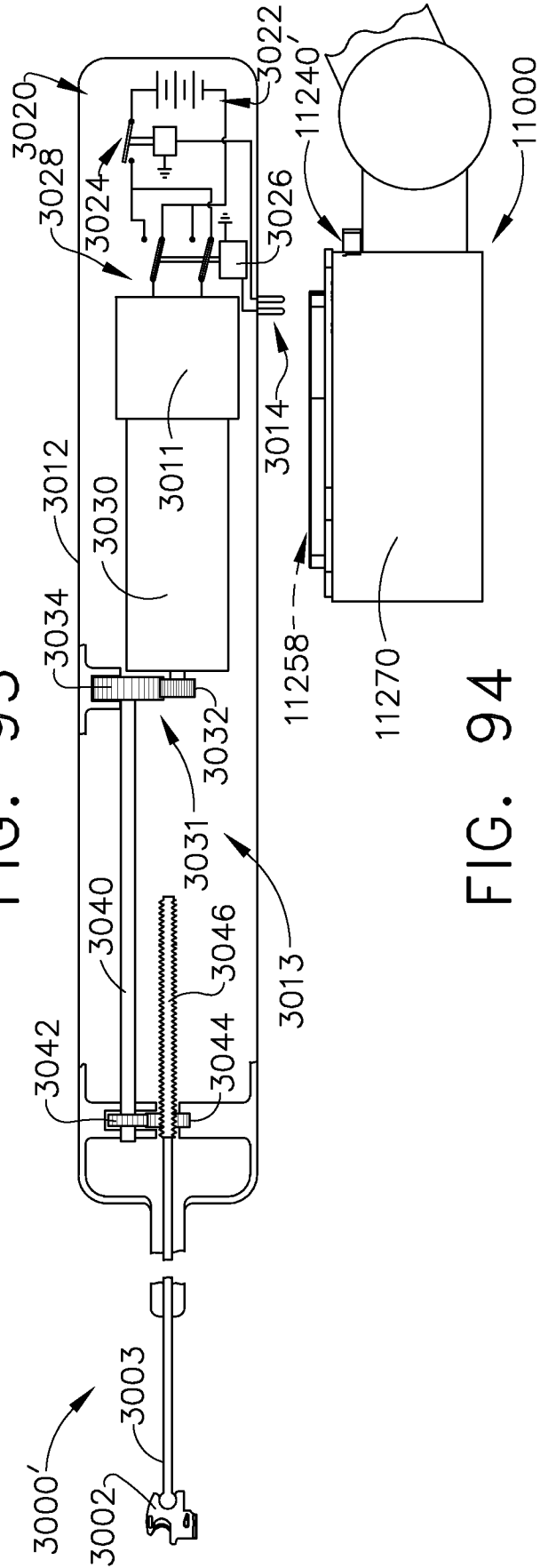


FIG. 94

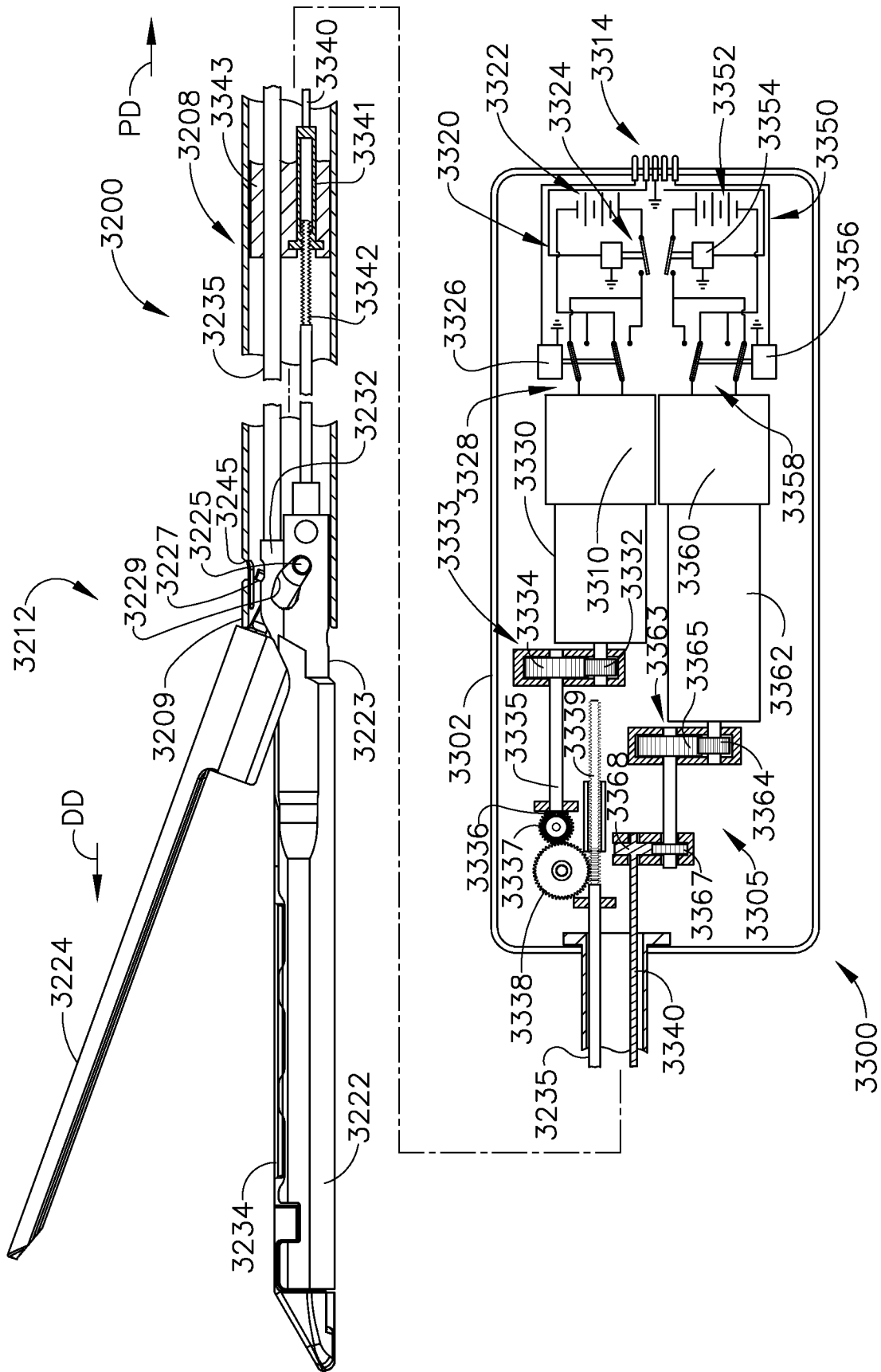


FIG. 95

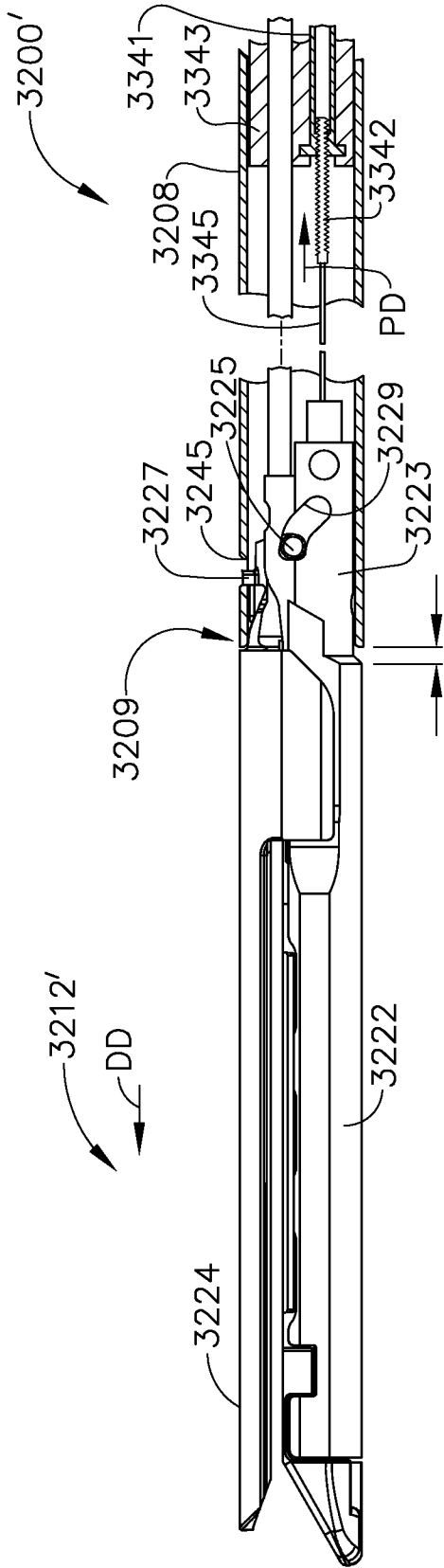


FIG. 96

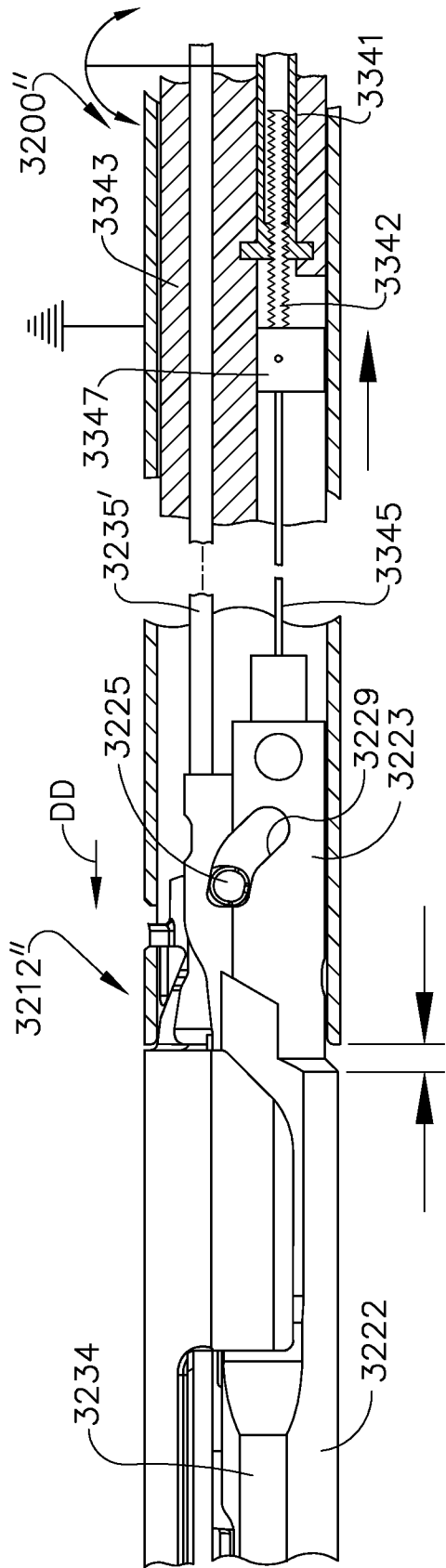


FIG. 97

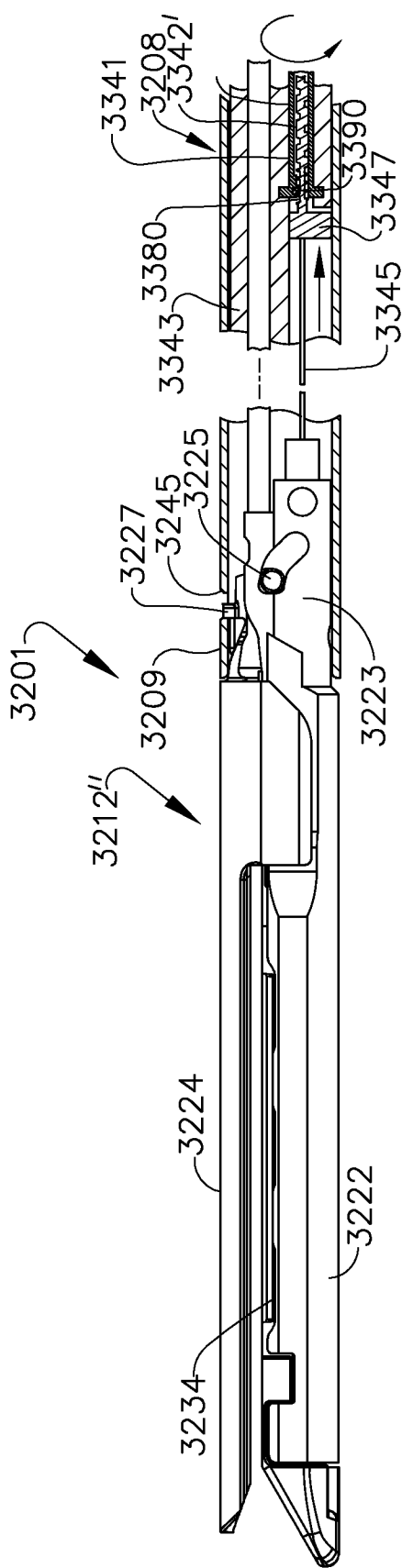


FIG. 98

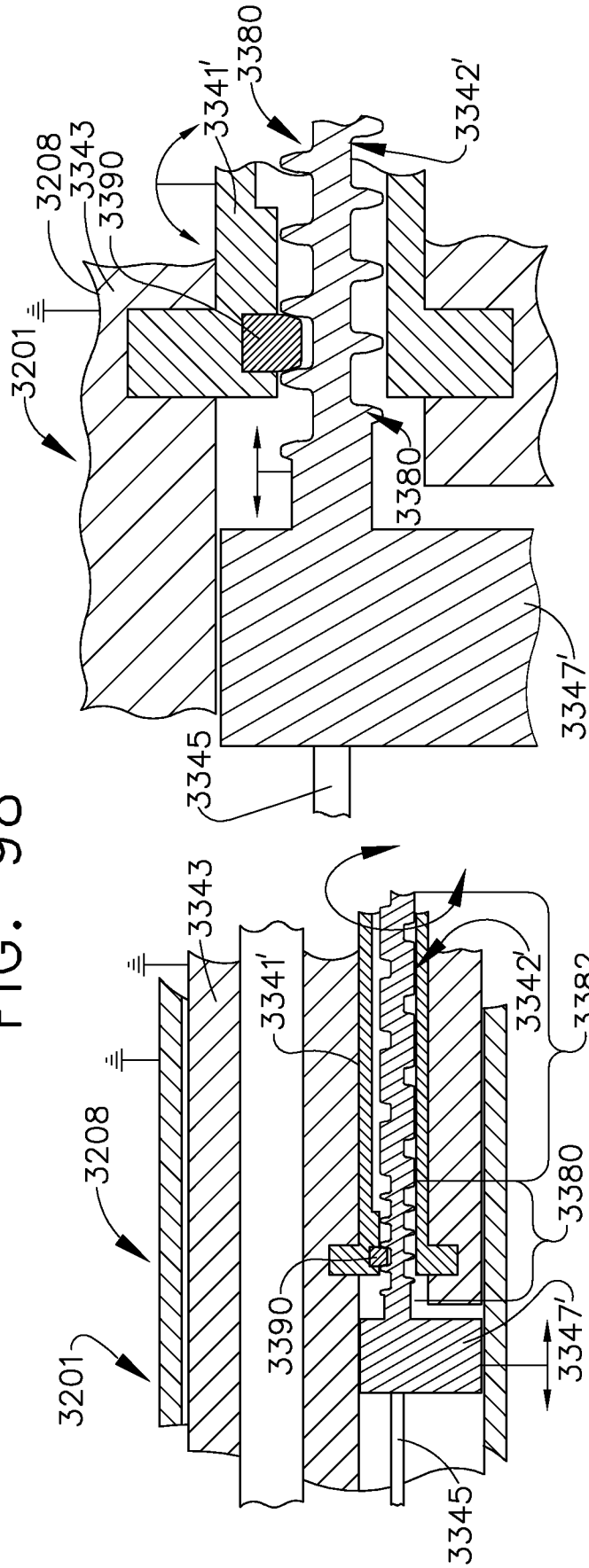


FIG. 100

FIG. 99

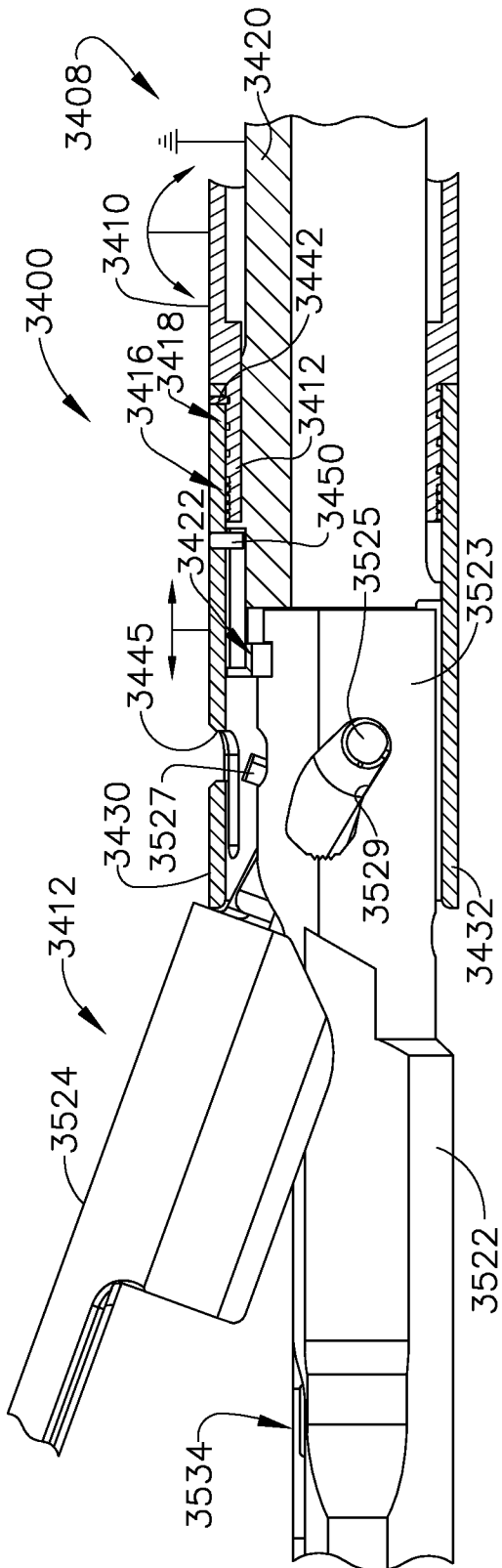


FIG. 101

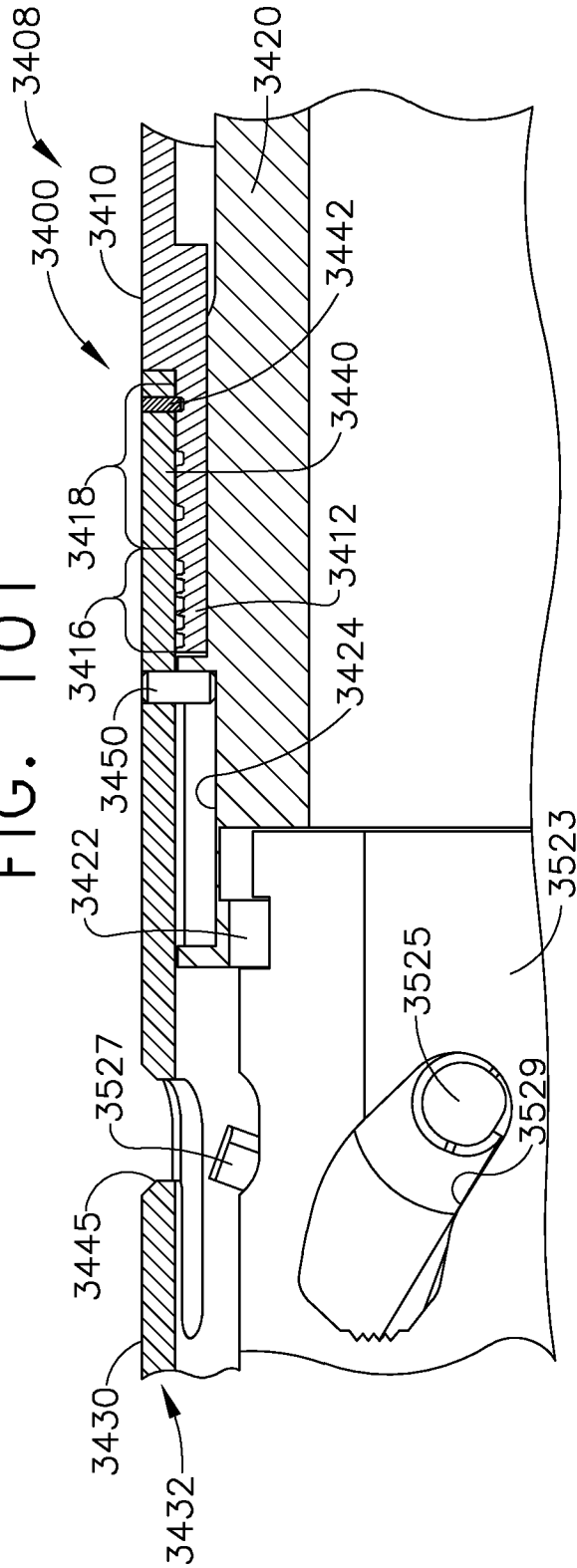


FIG. 102

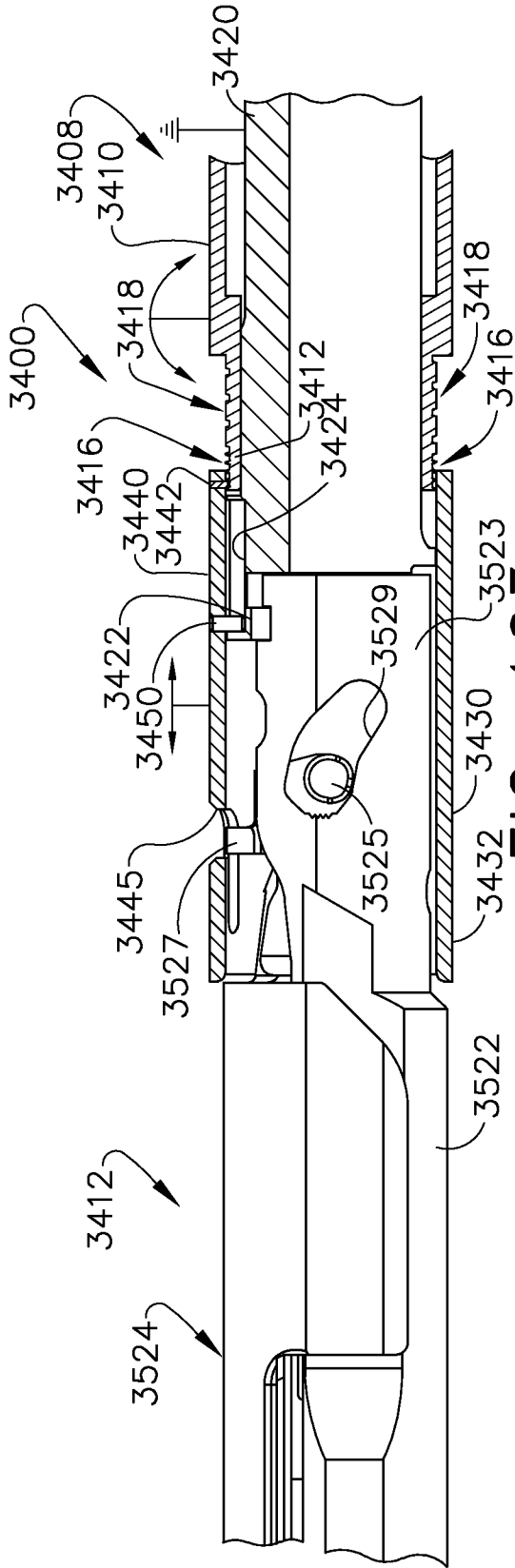


FIG. 103

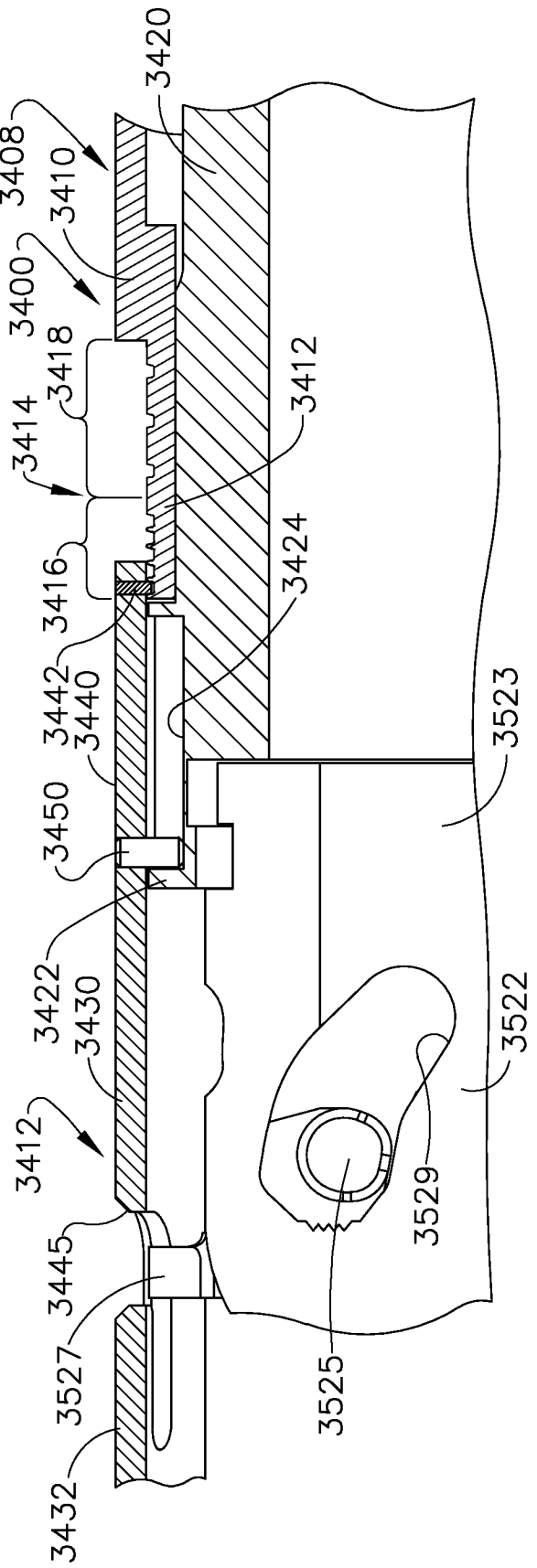


FIG. 104

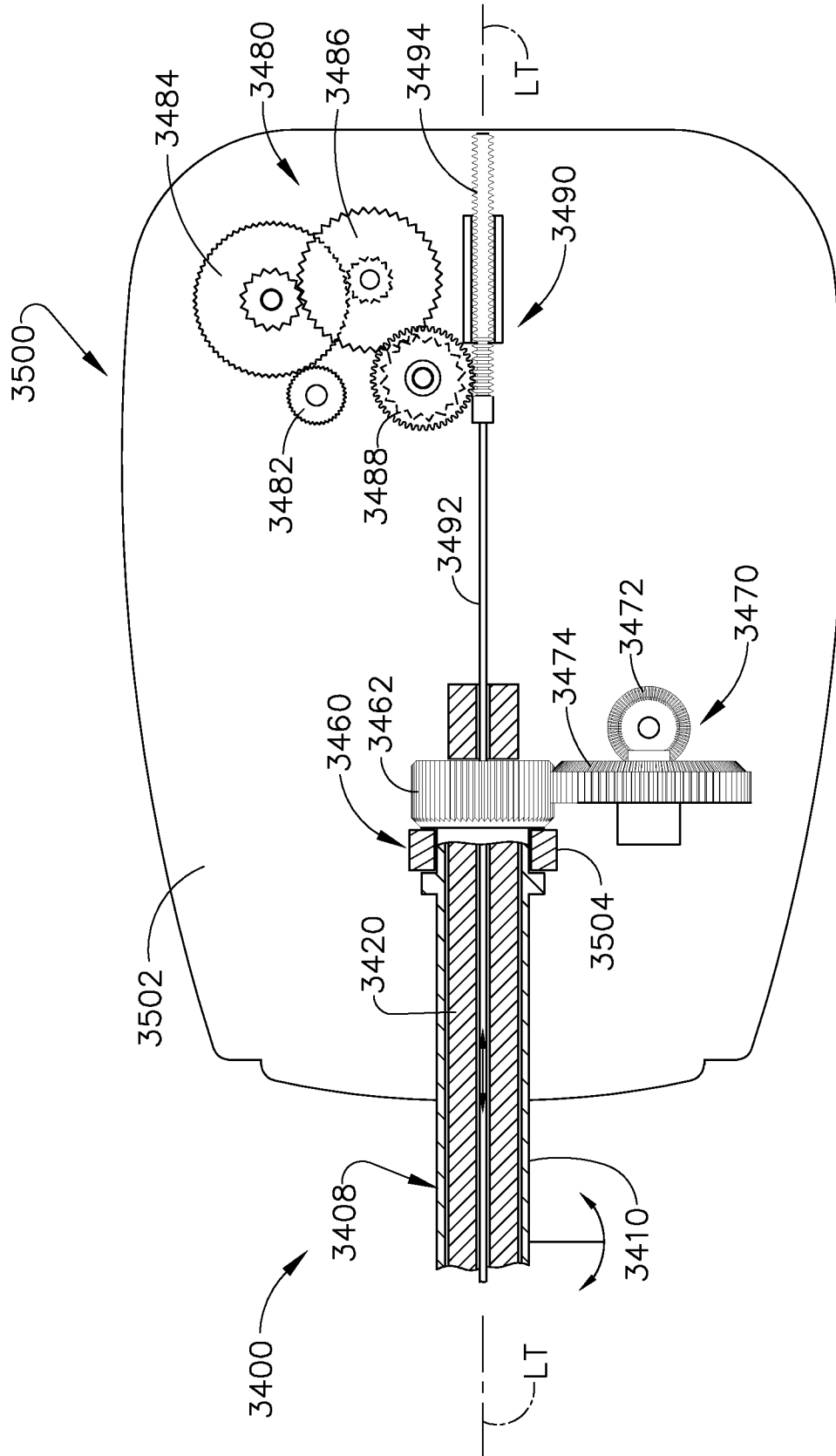


FIG. 105

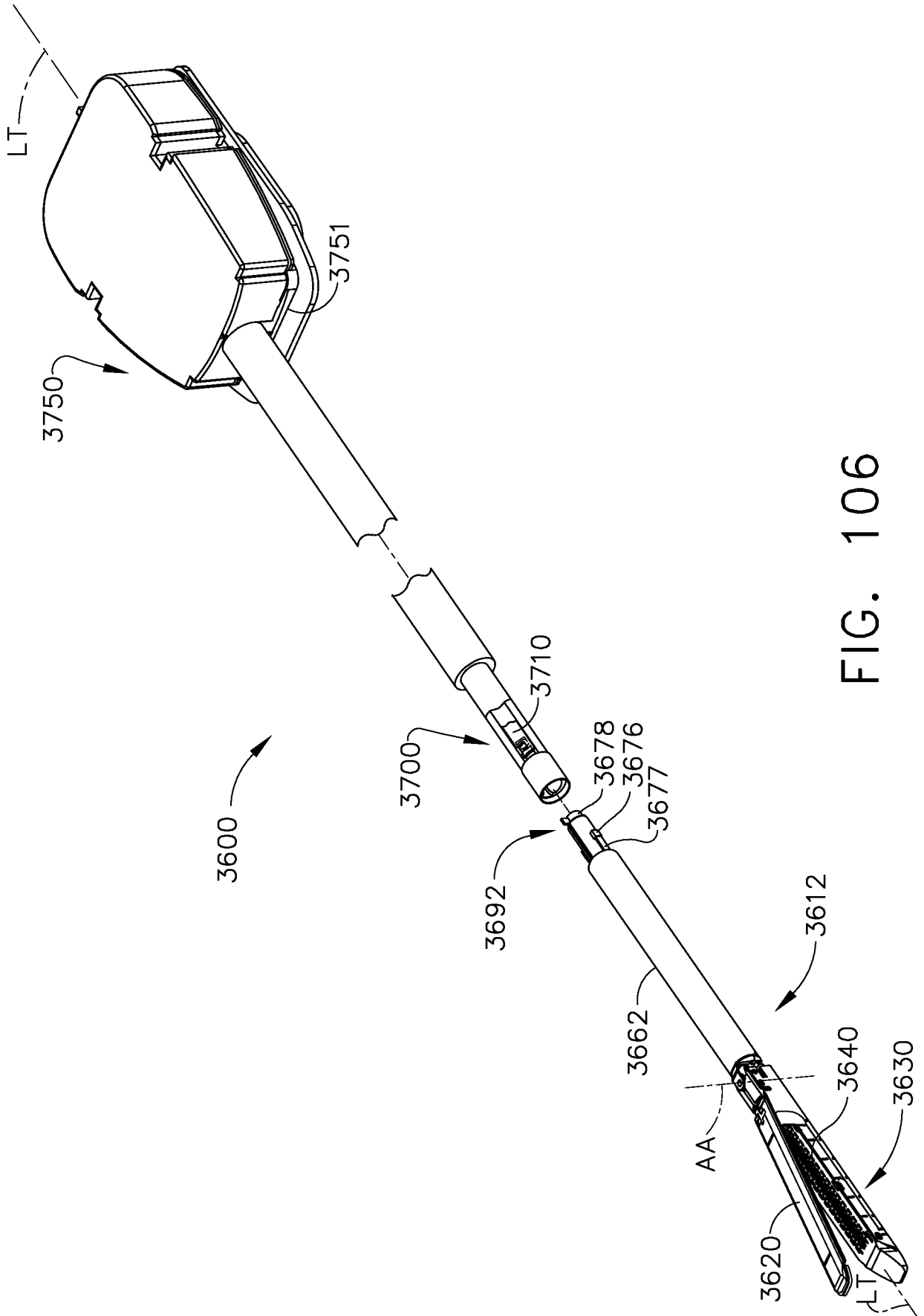


FIG. 106

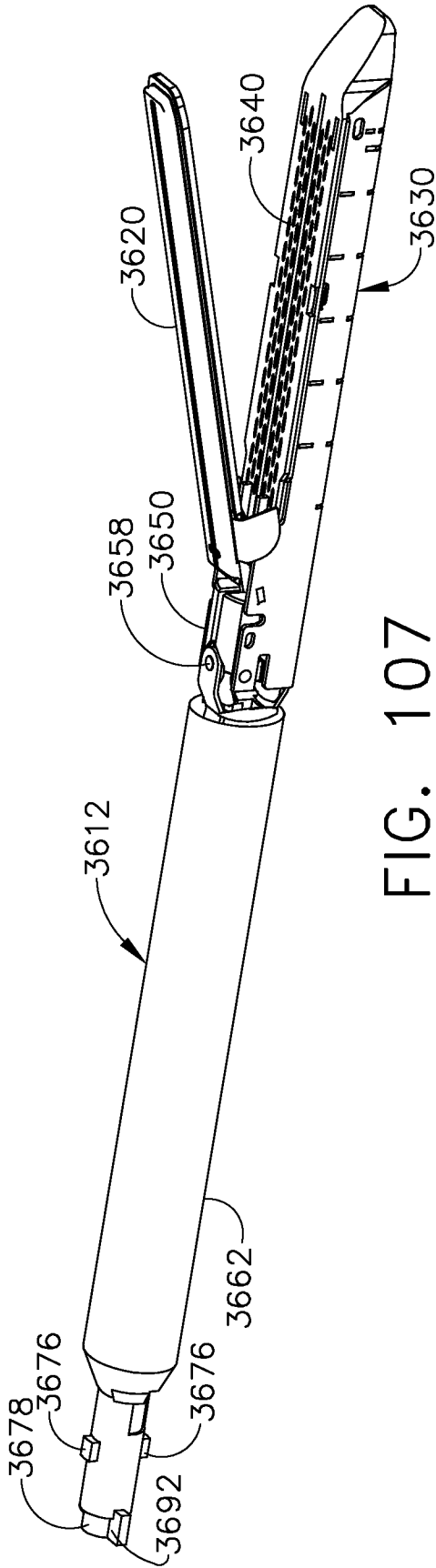


FIG. 107

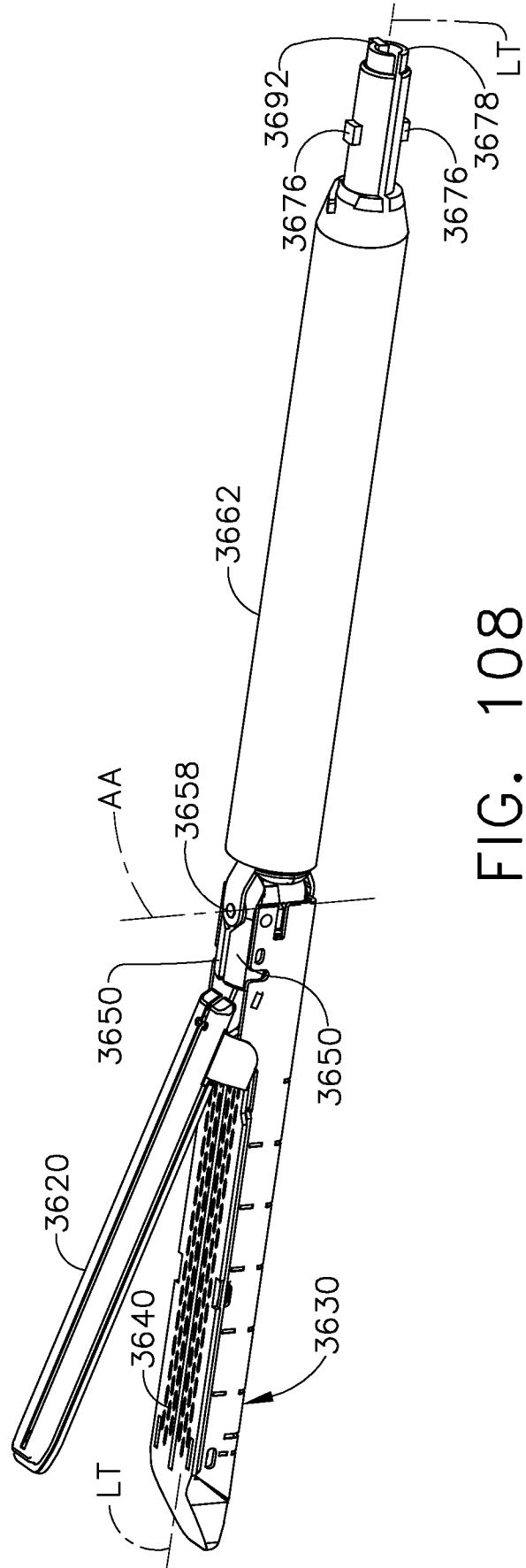


FIG. 108

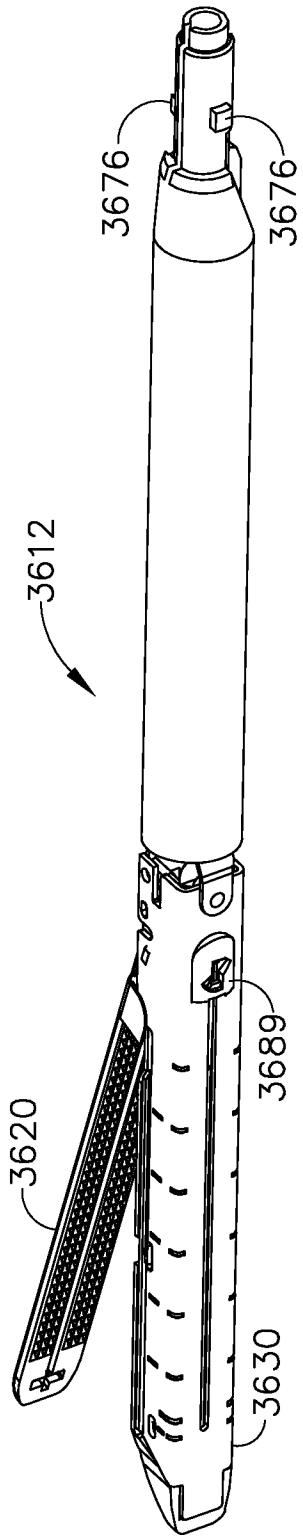


FIG. 109

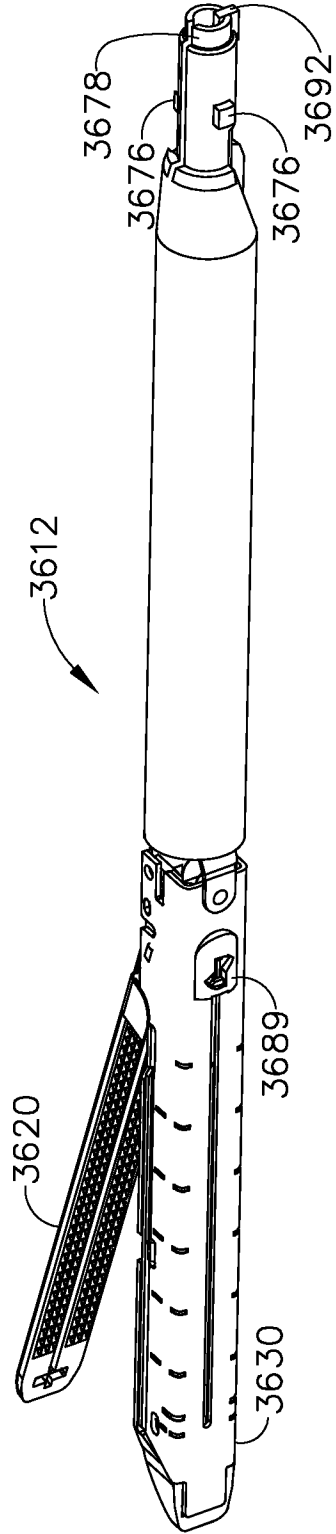


FIG. 110

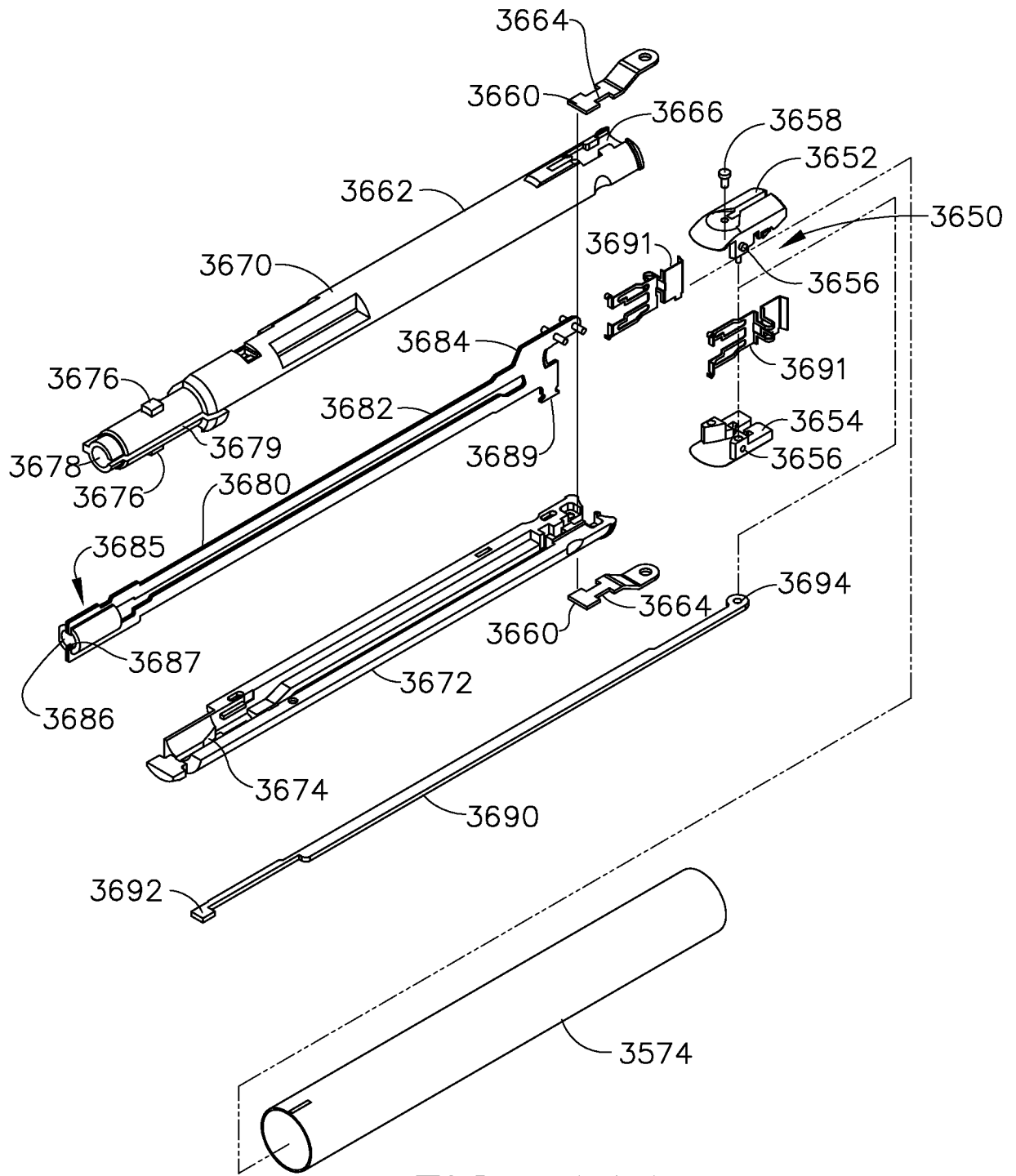
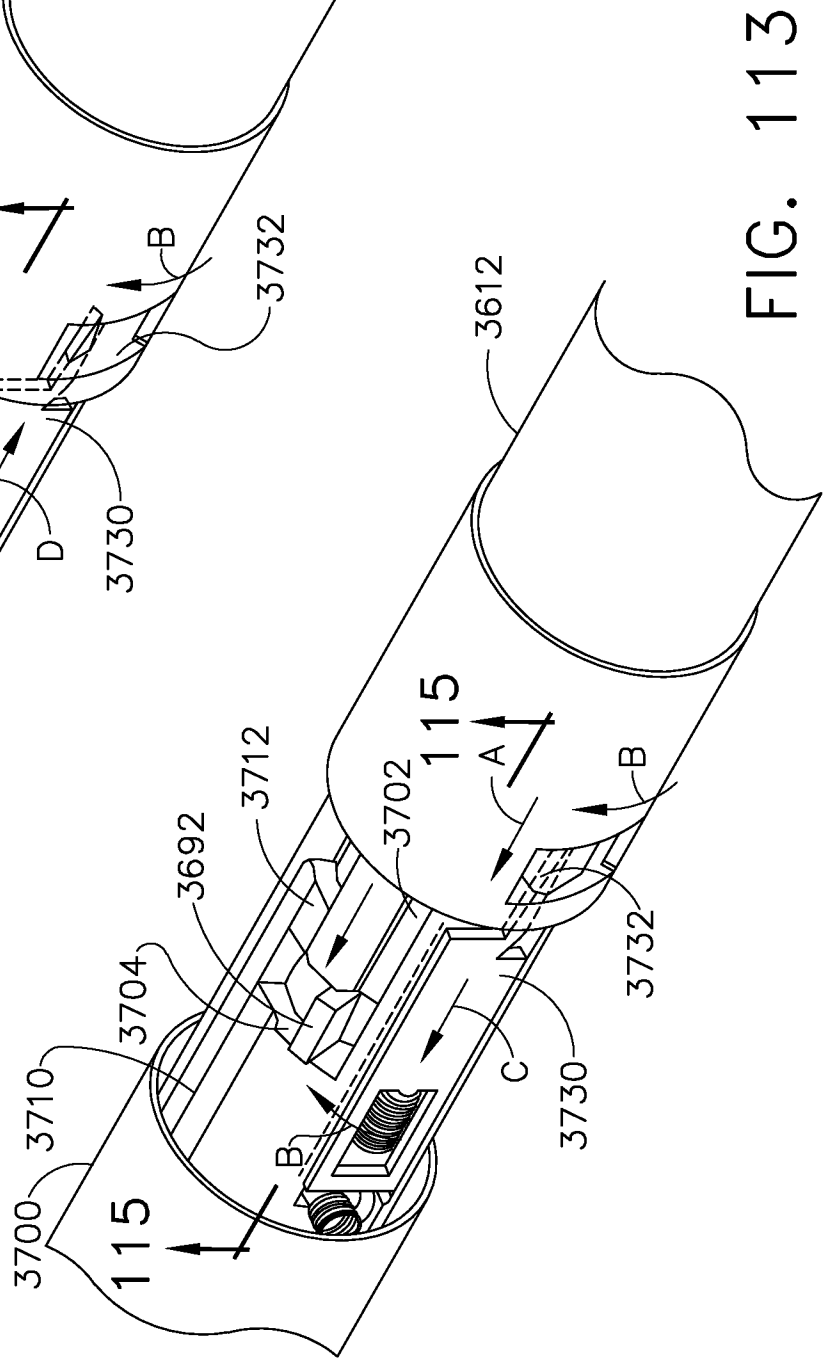
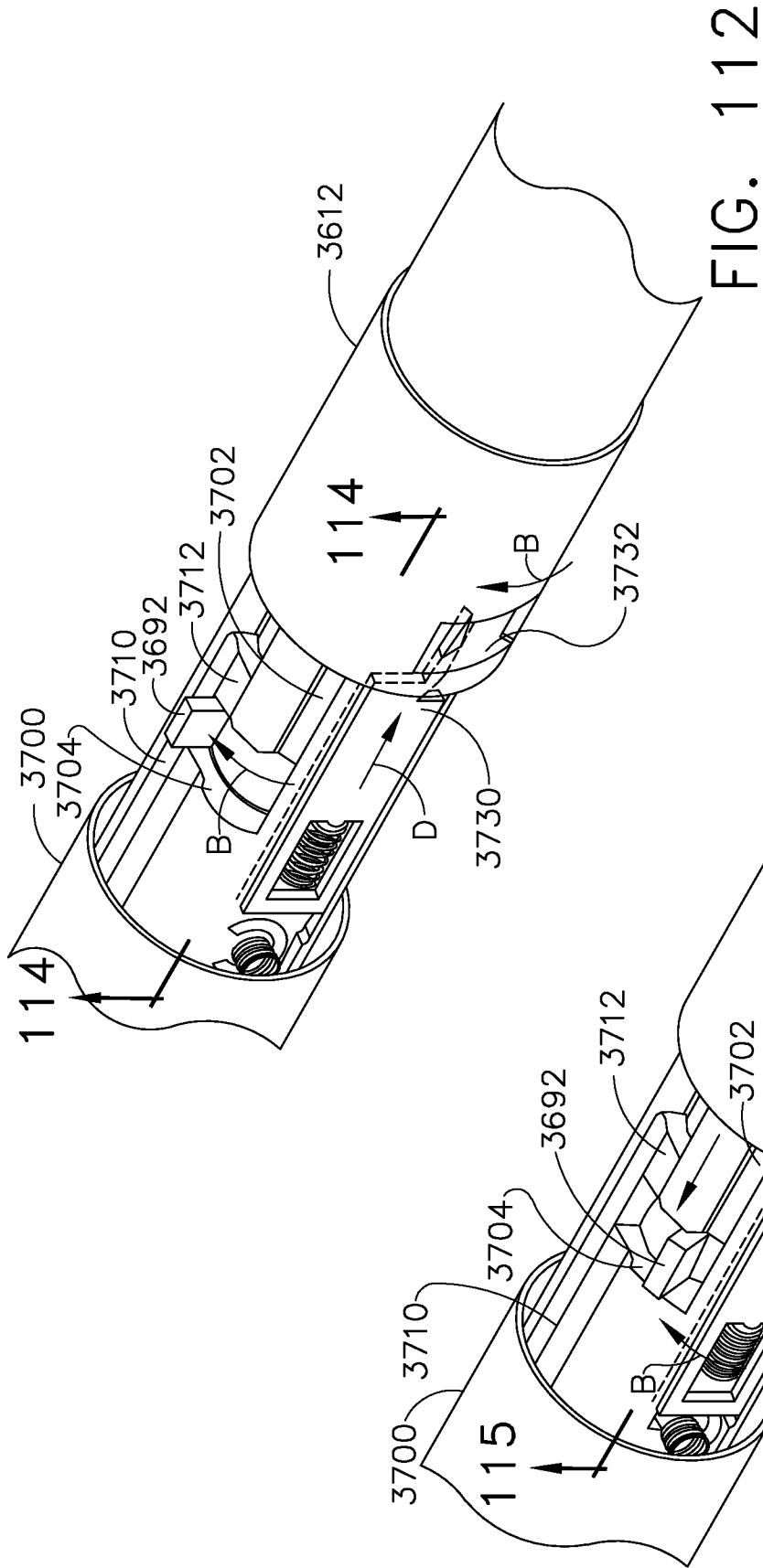


FIG. 111



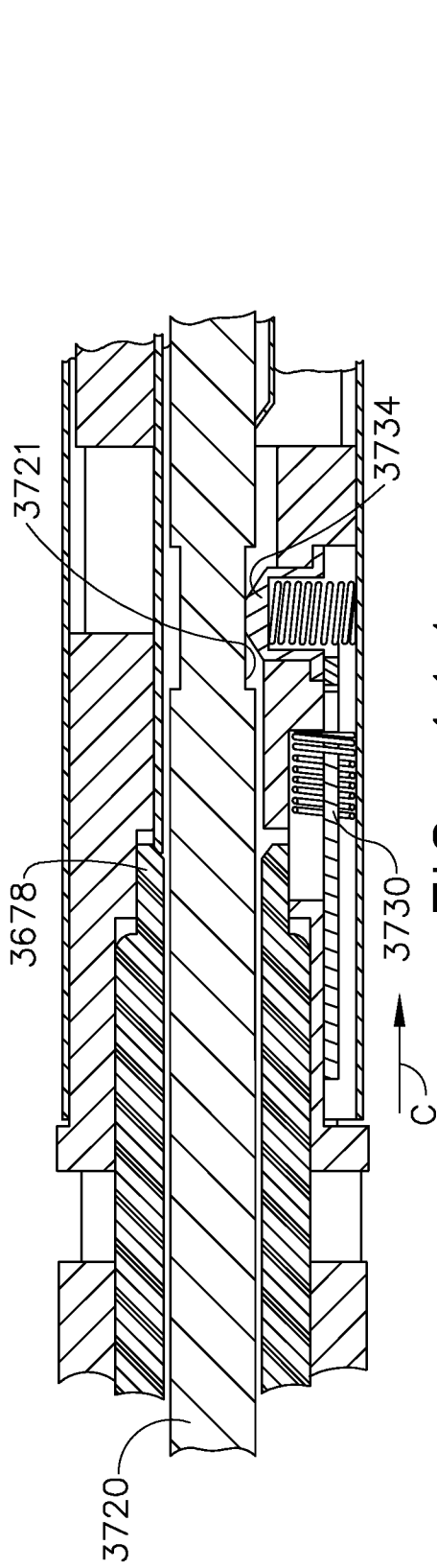


FIG. 114

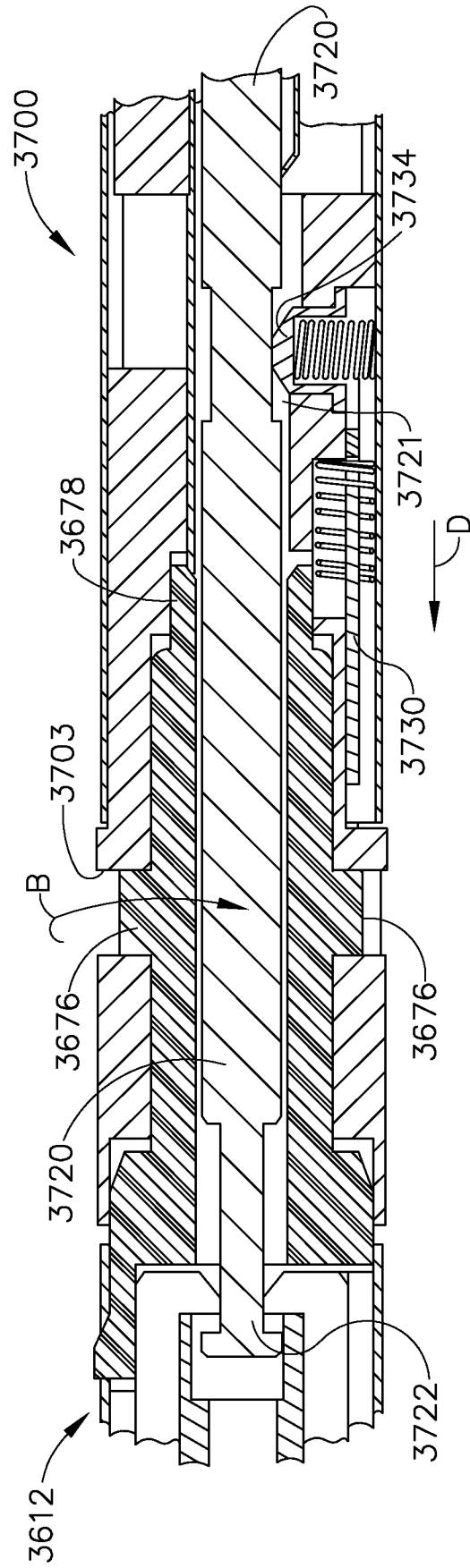
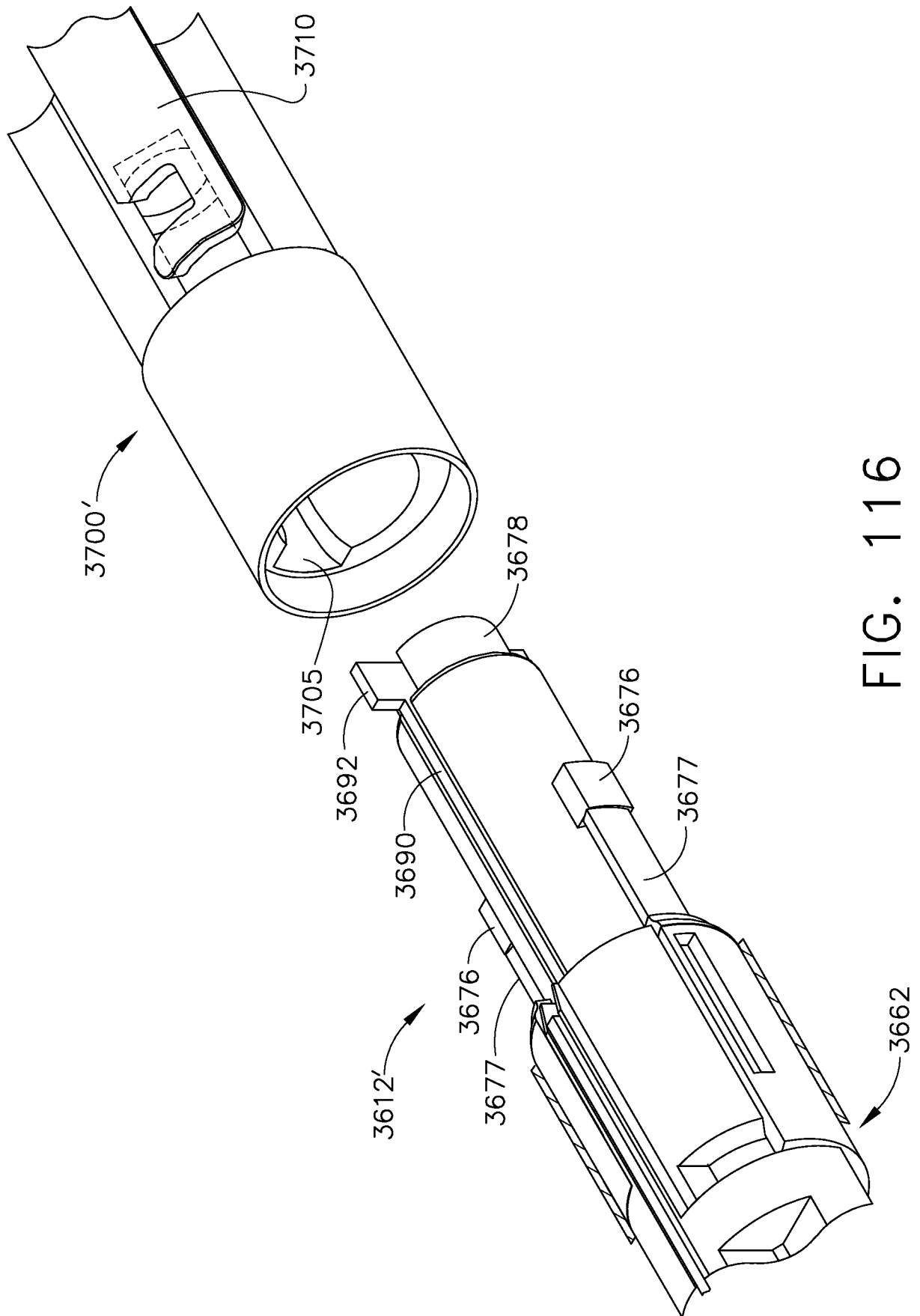


FIG. 115



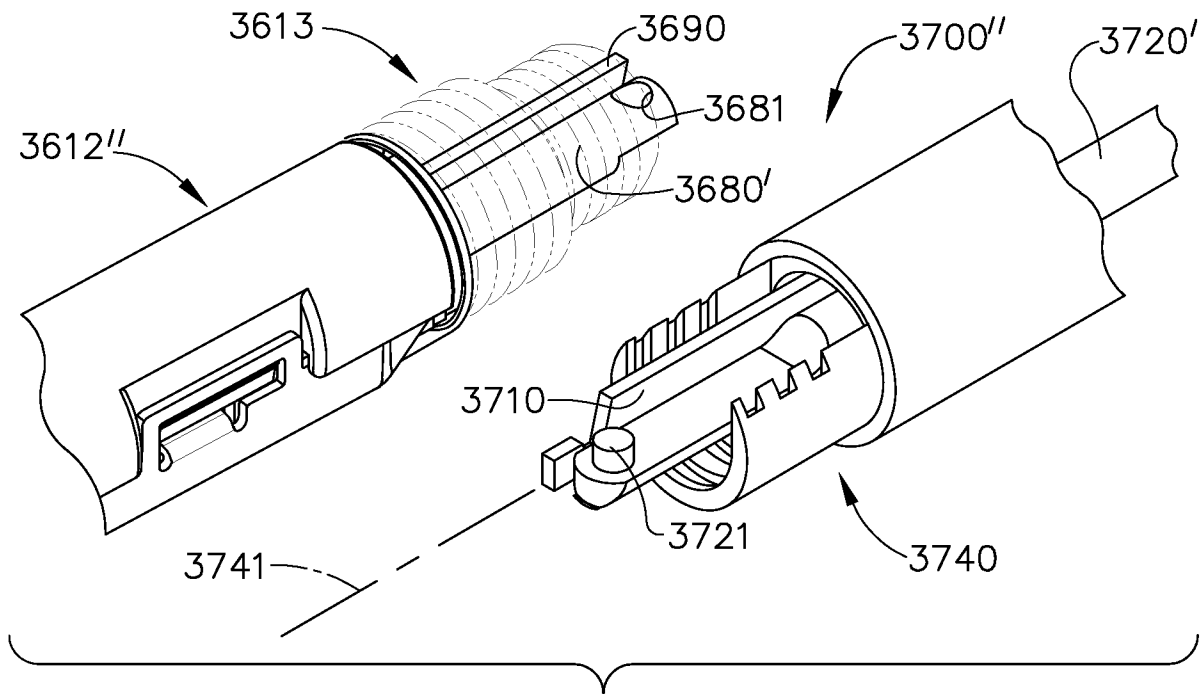


FIG. 117

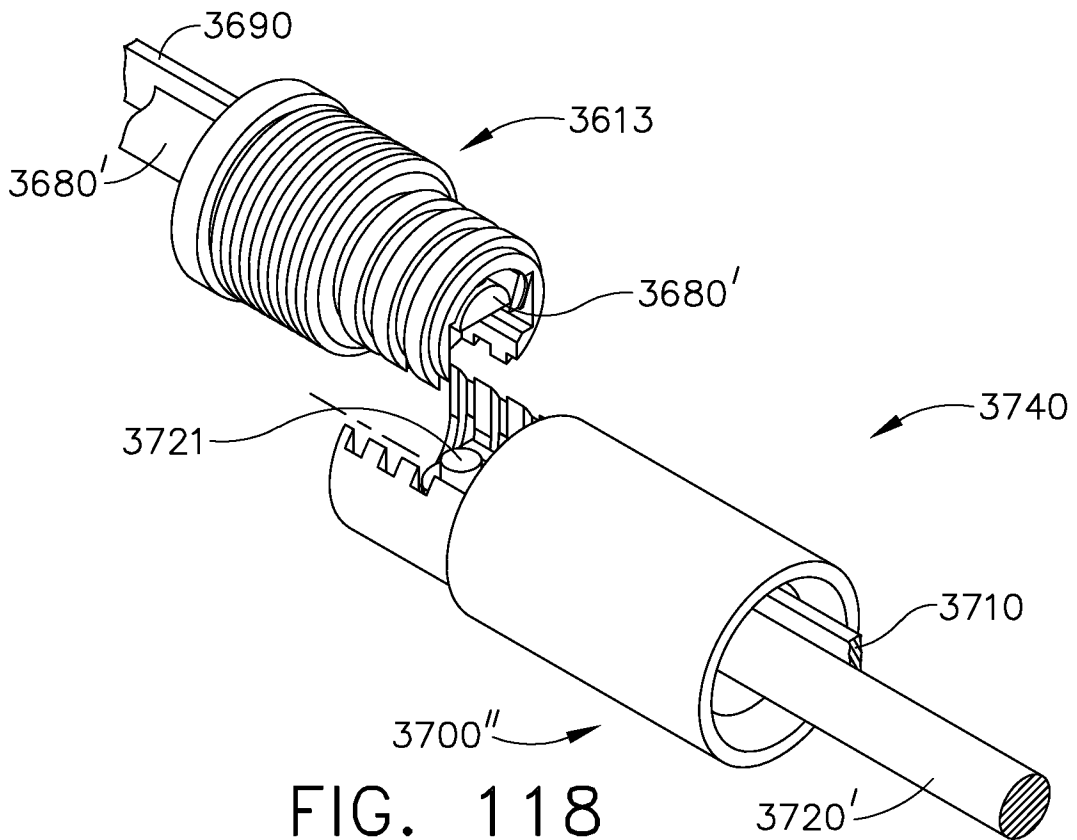


FIG. 118

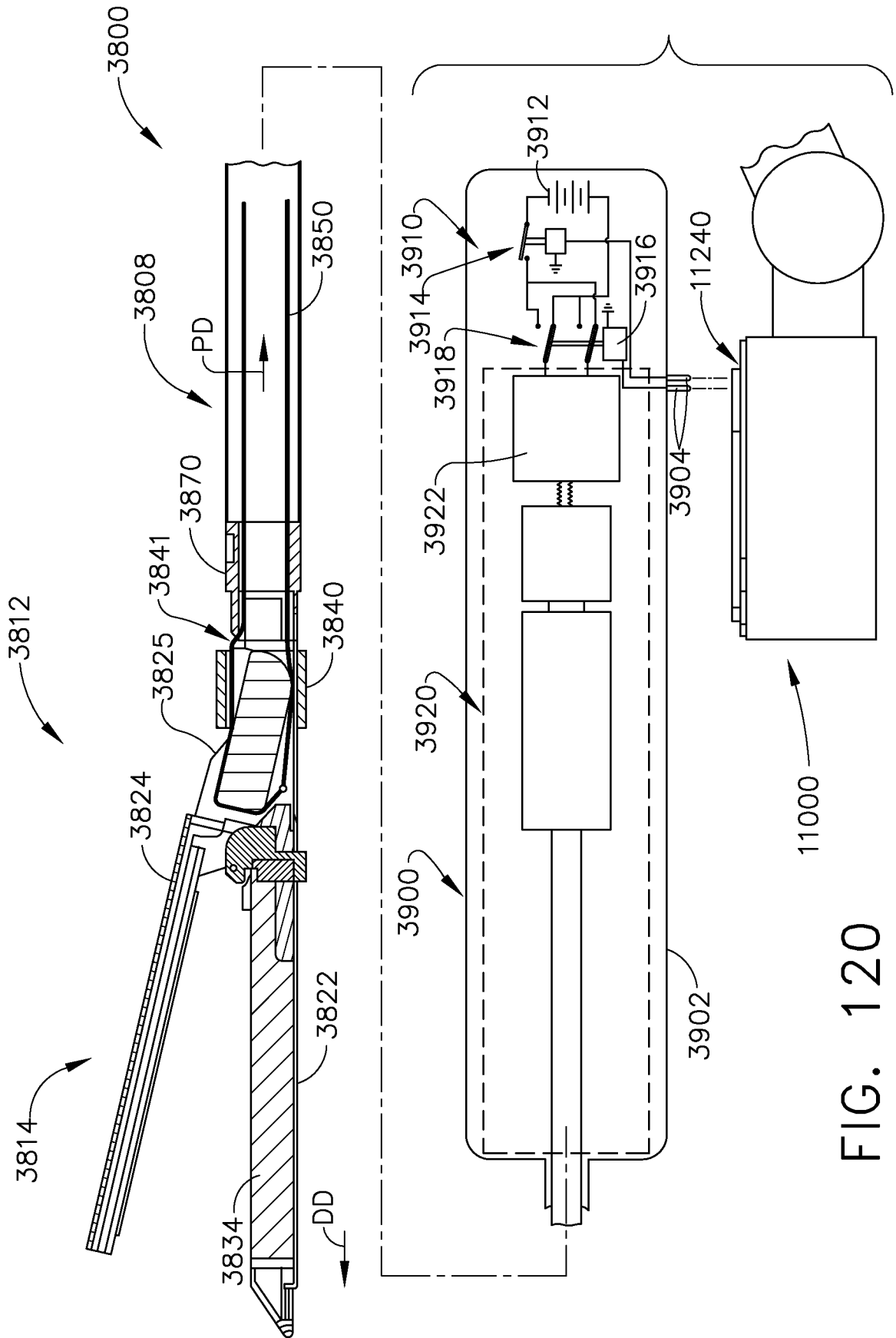


FIG. 120

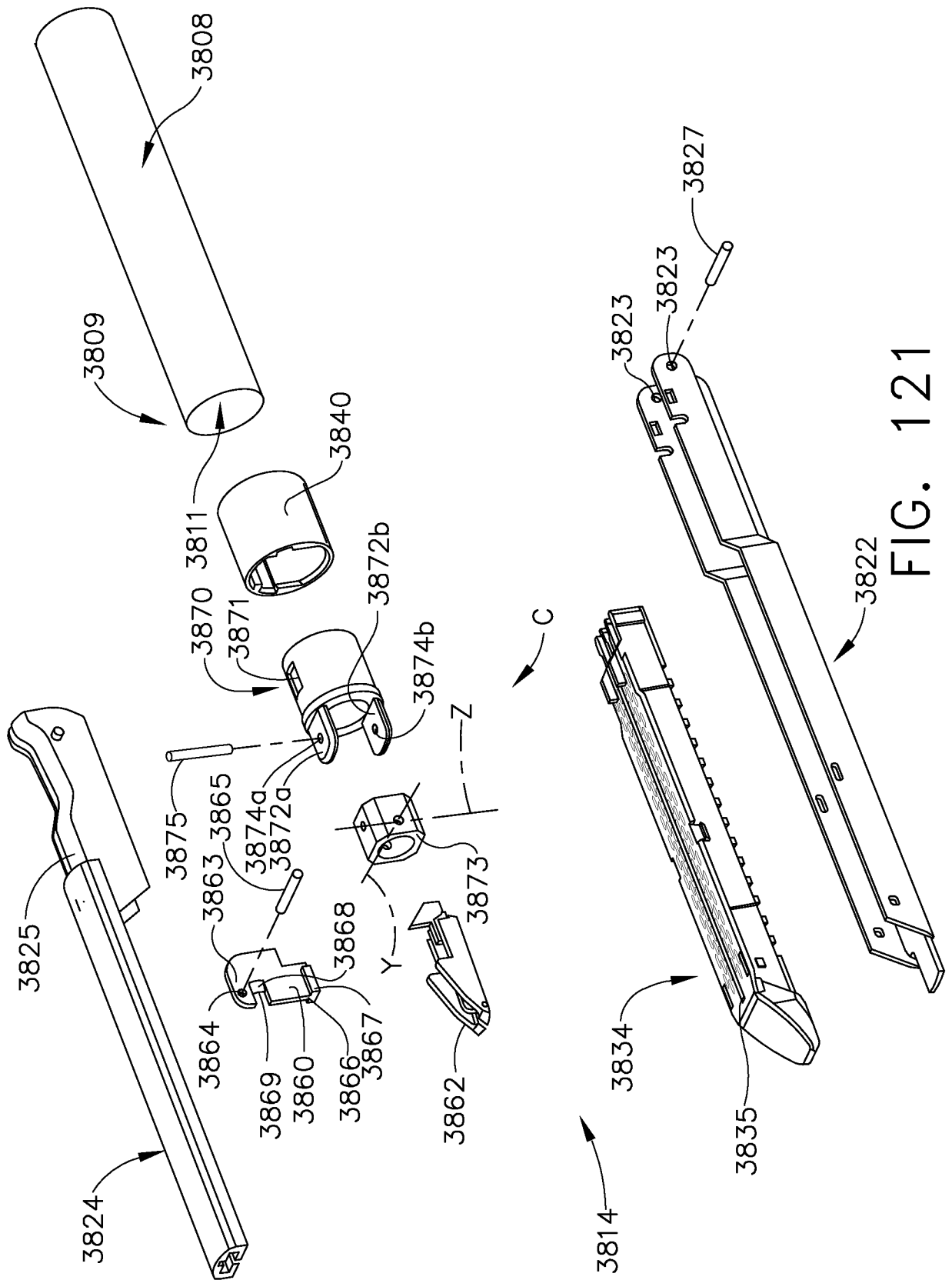


FIG. 121

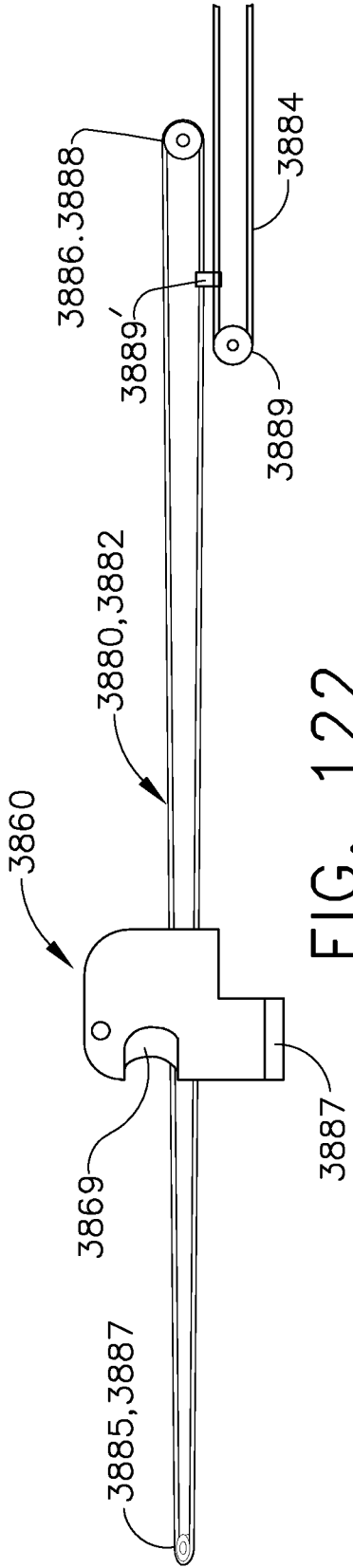


FIG. 122

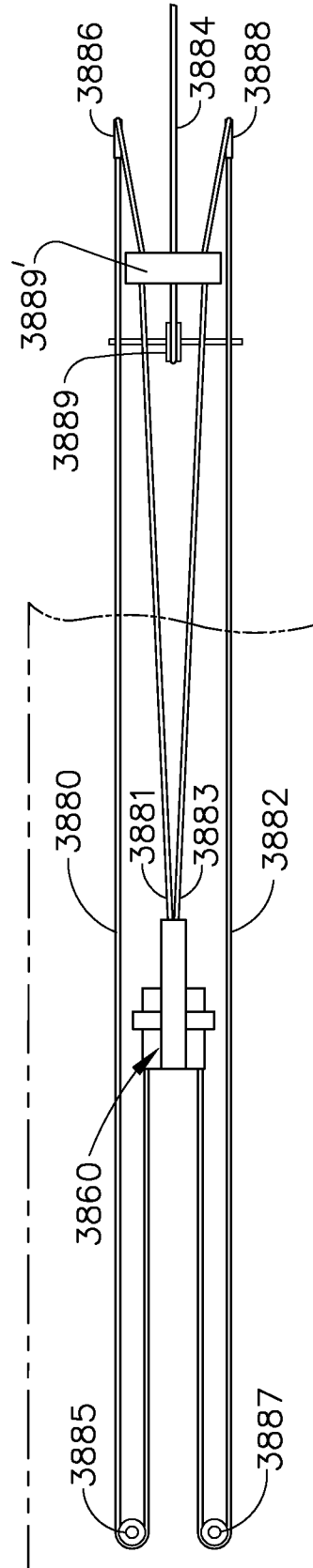


FIG. 123

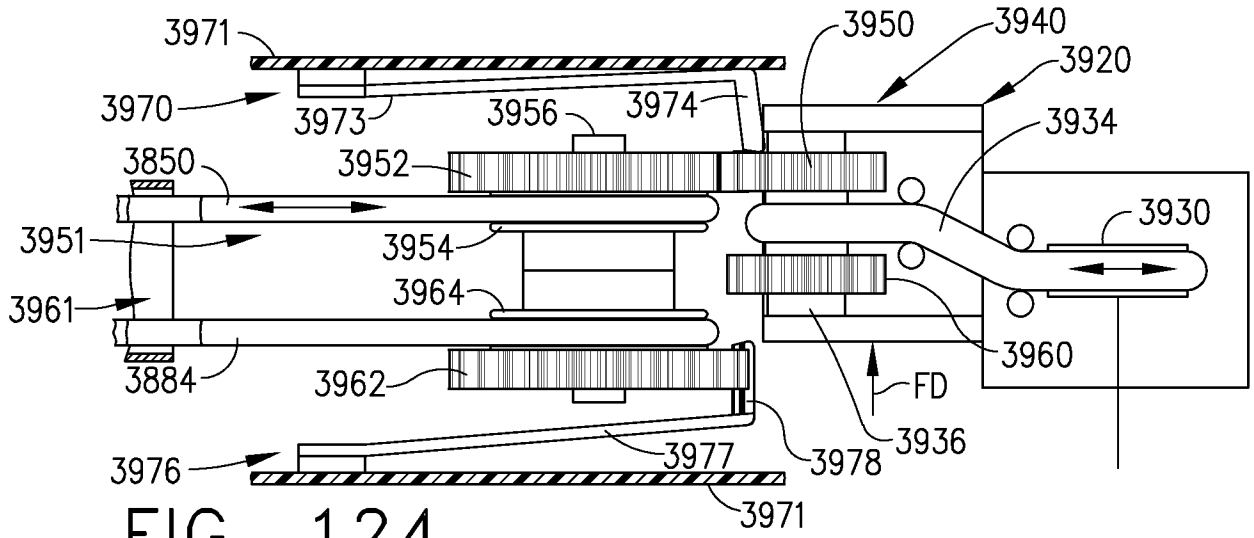


FIG. 124

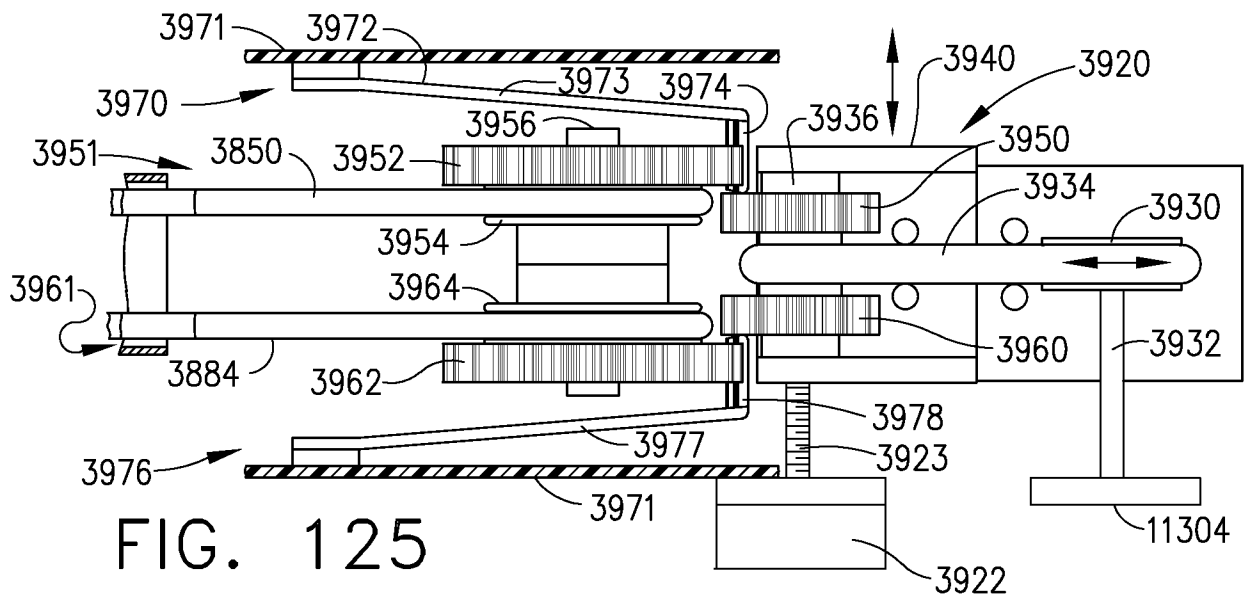


FIG. 125

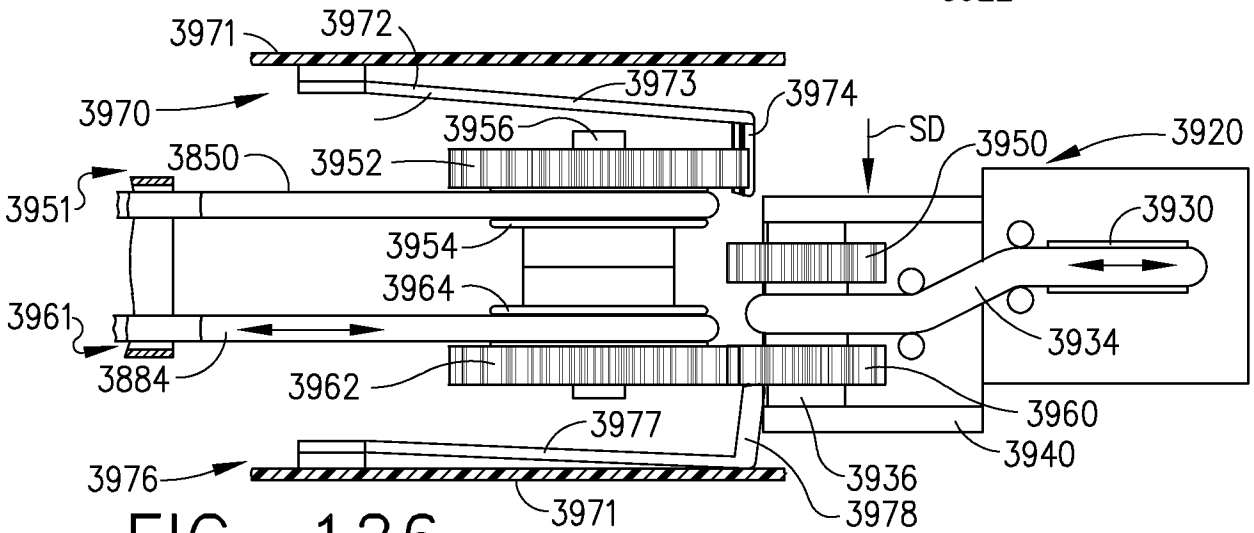


FIG. 126

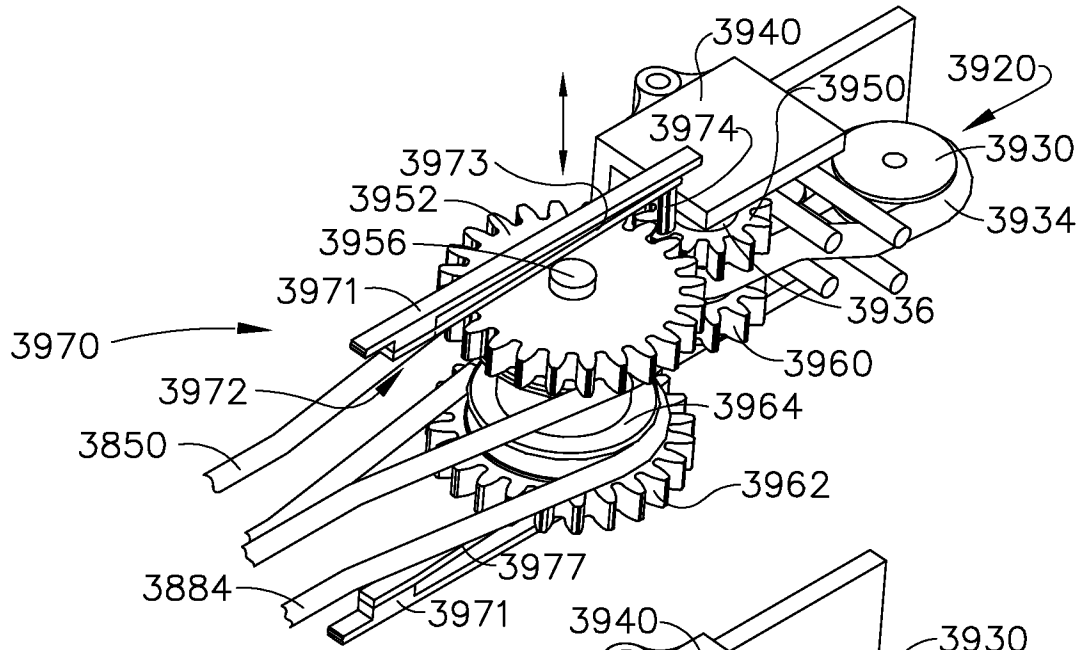


FIG. 127

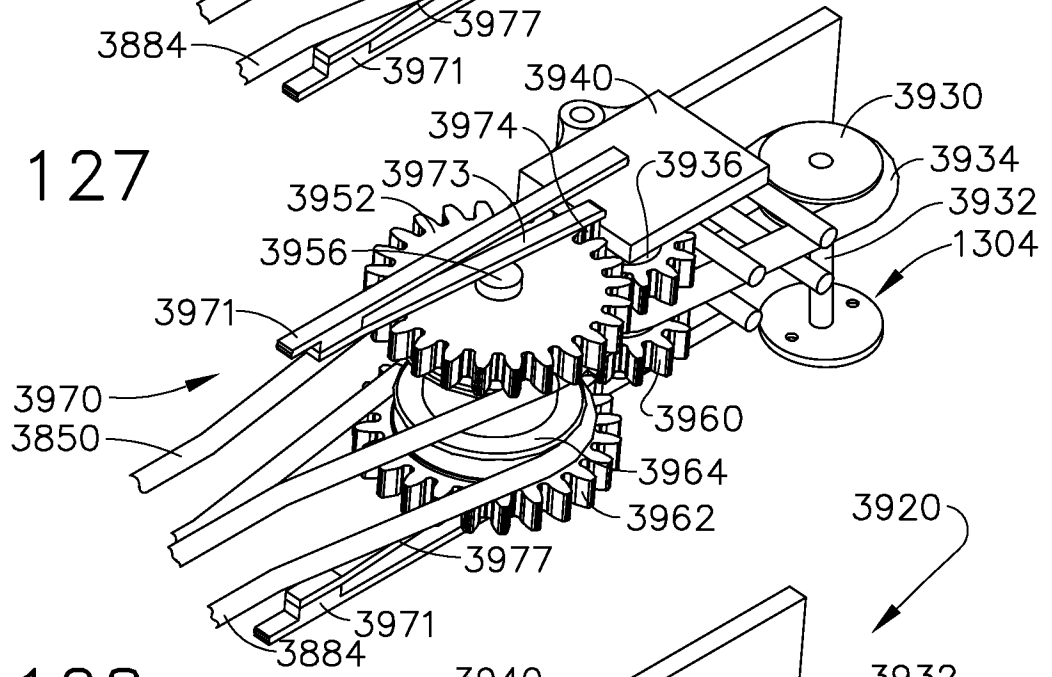


FIG. 128

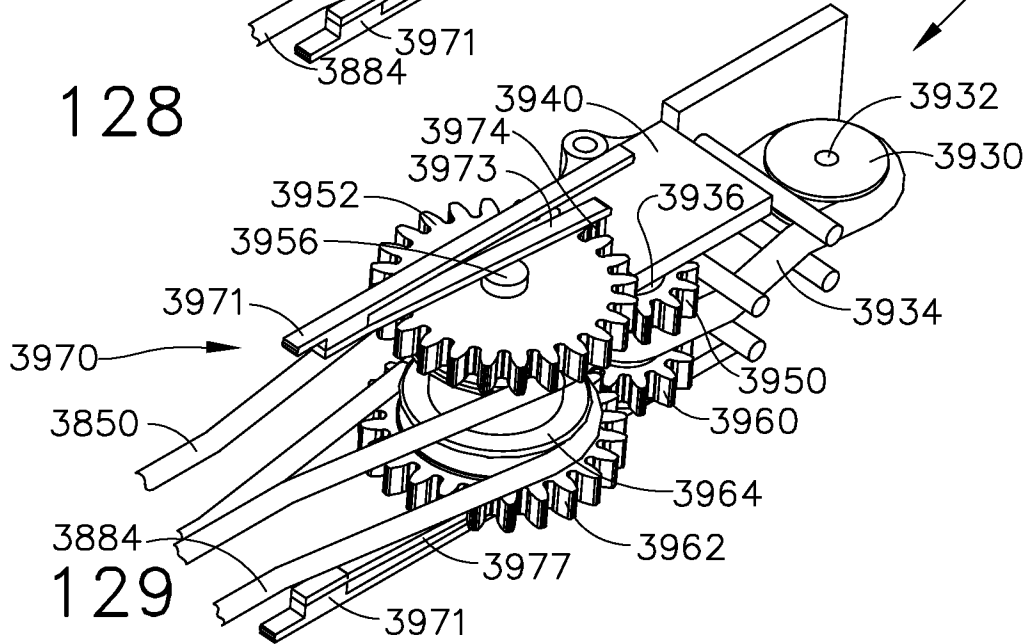


FIG. 129

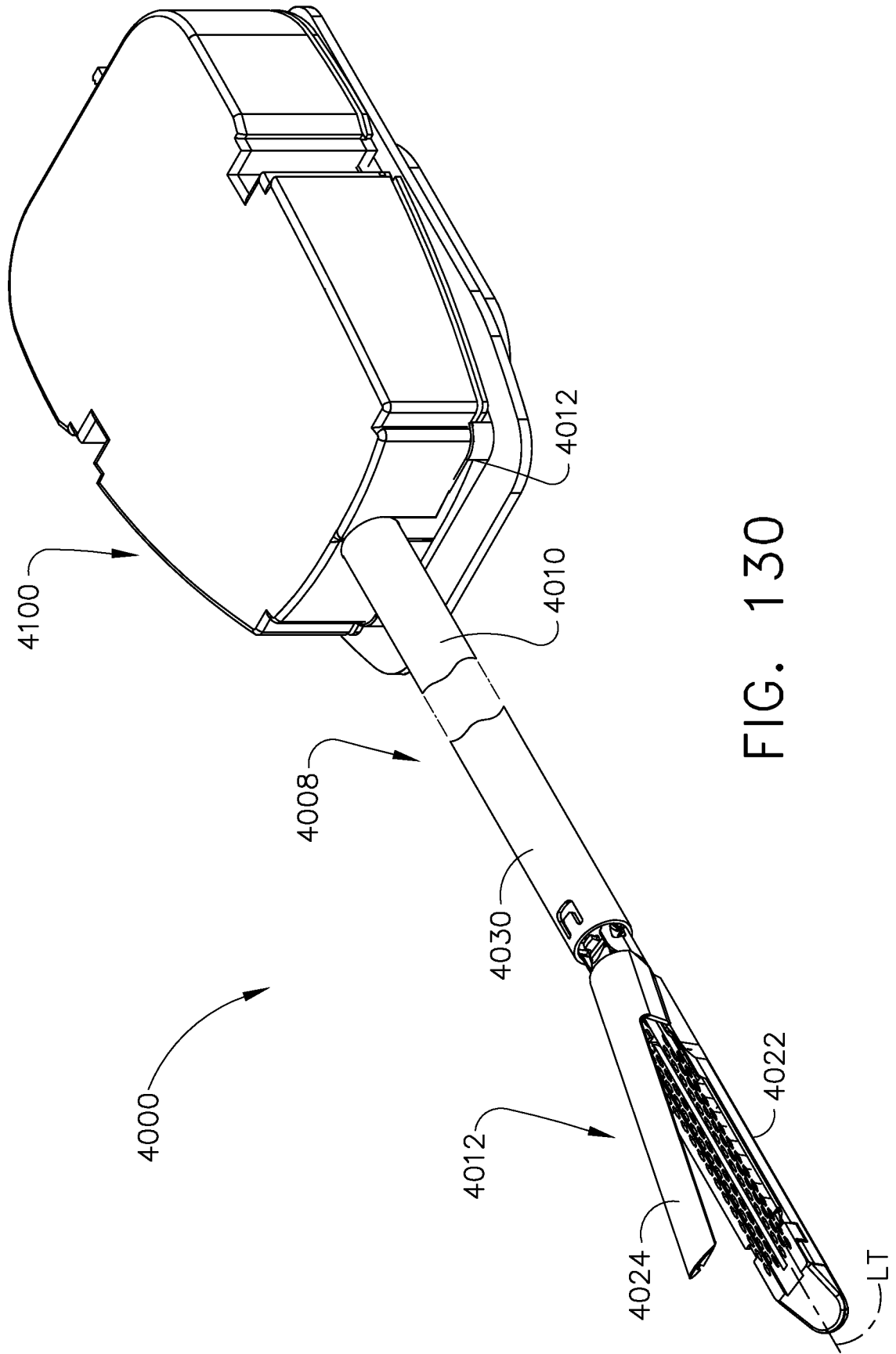


FIG. 130

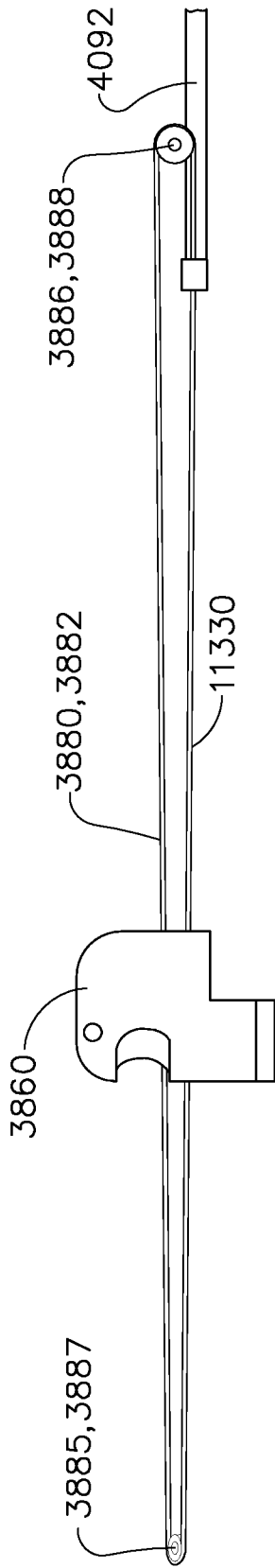


FIG. 131

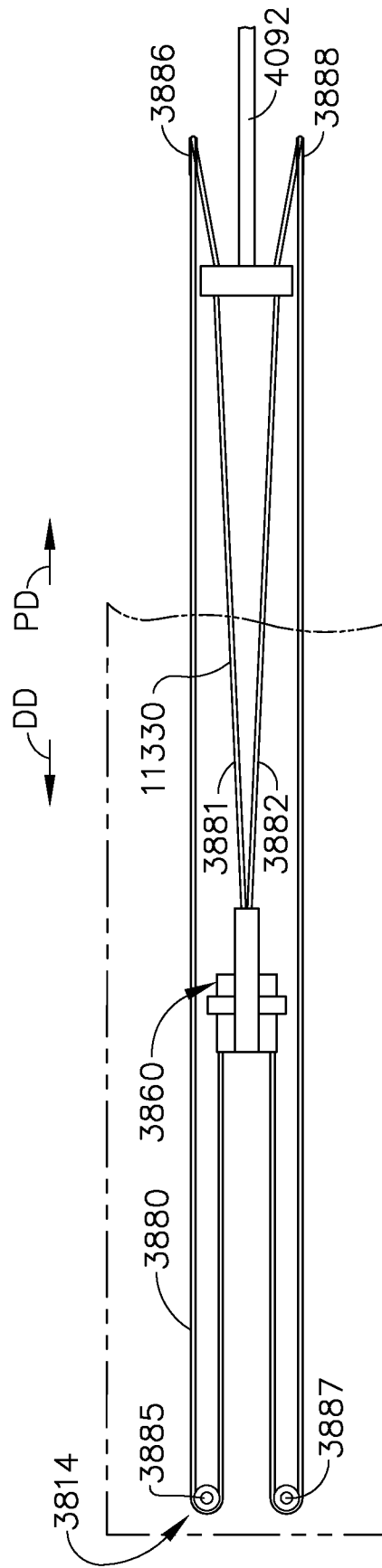


FIG. 132

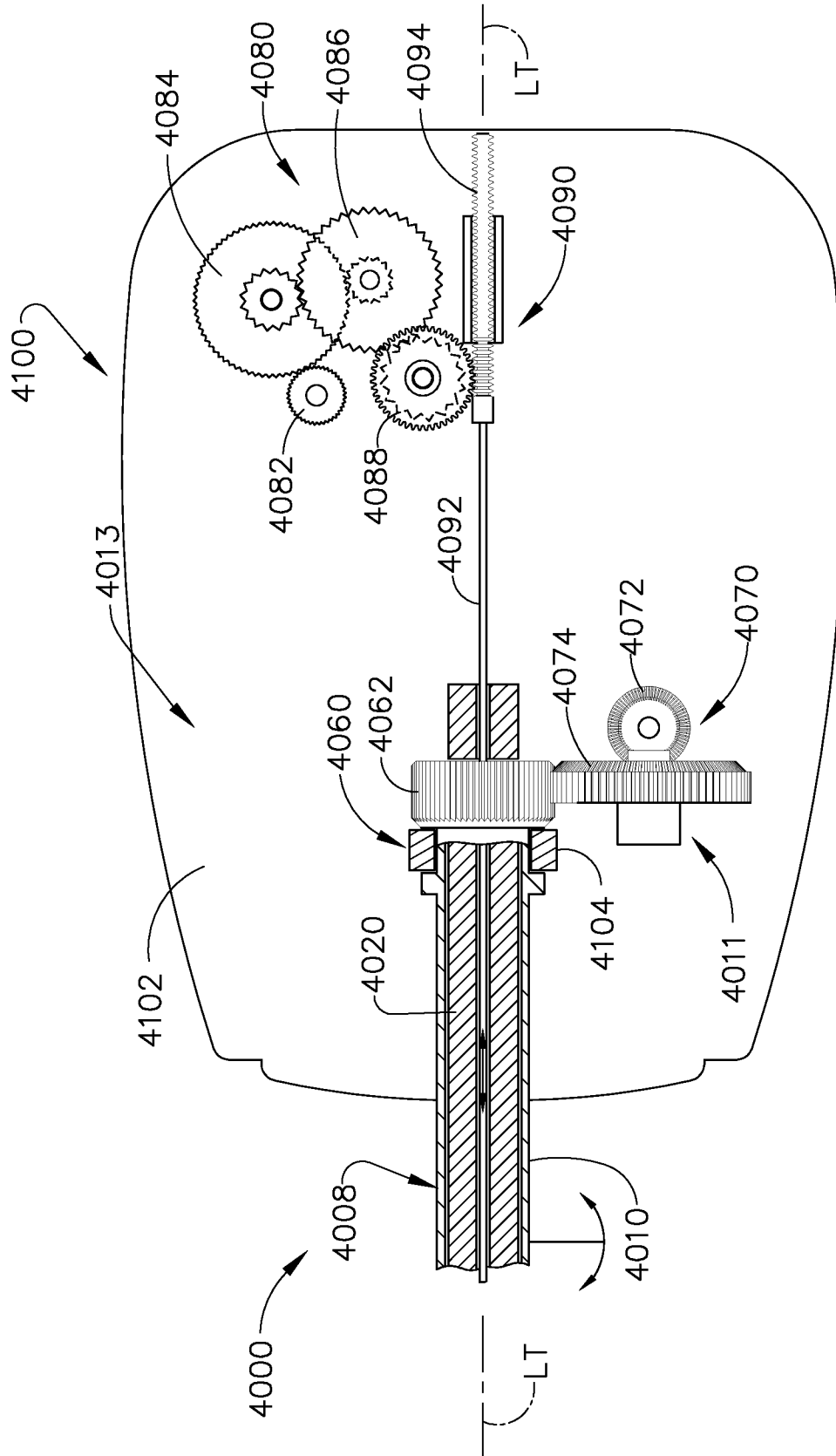


FIG. 133

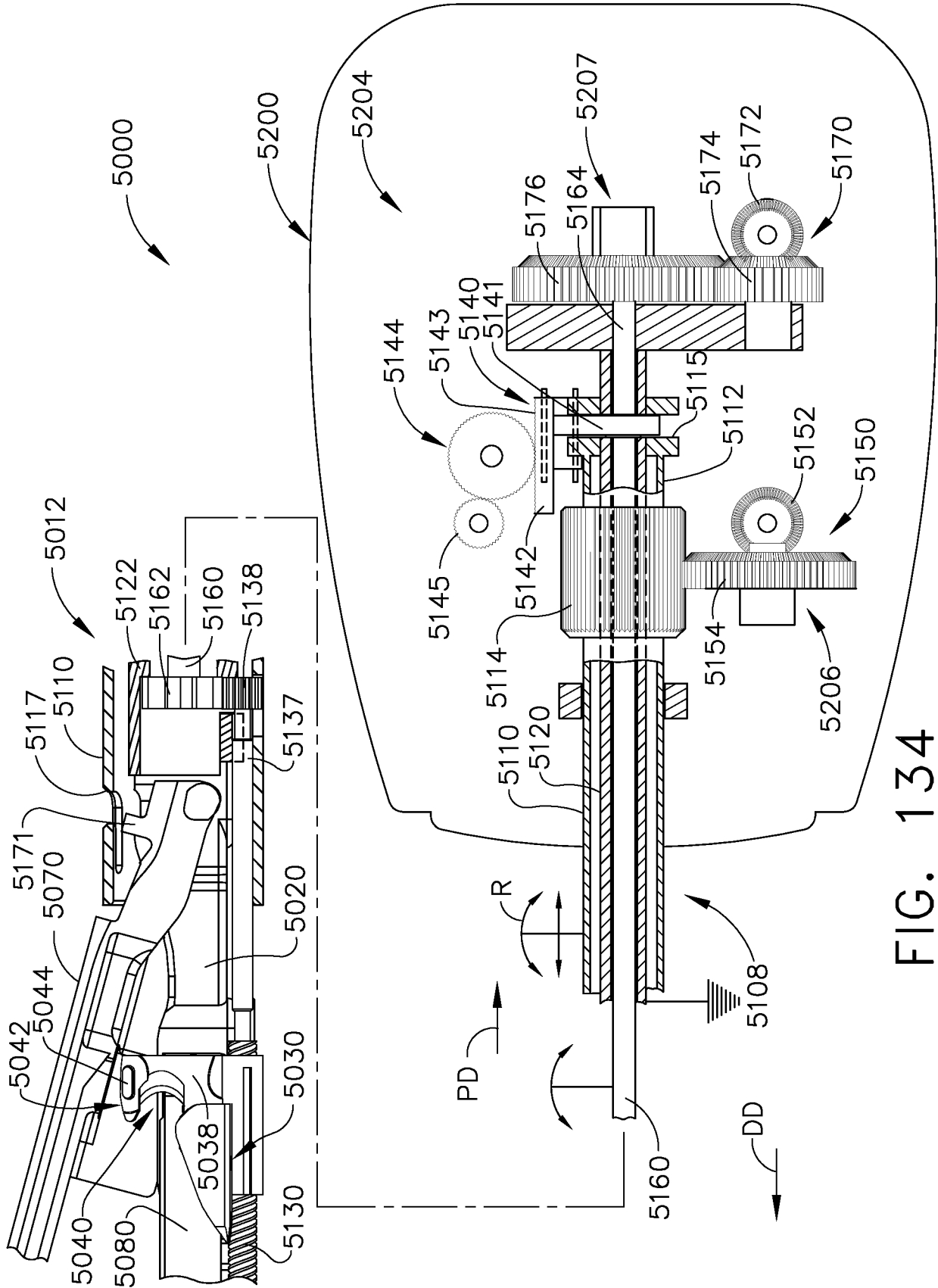


FIG. 134

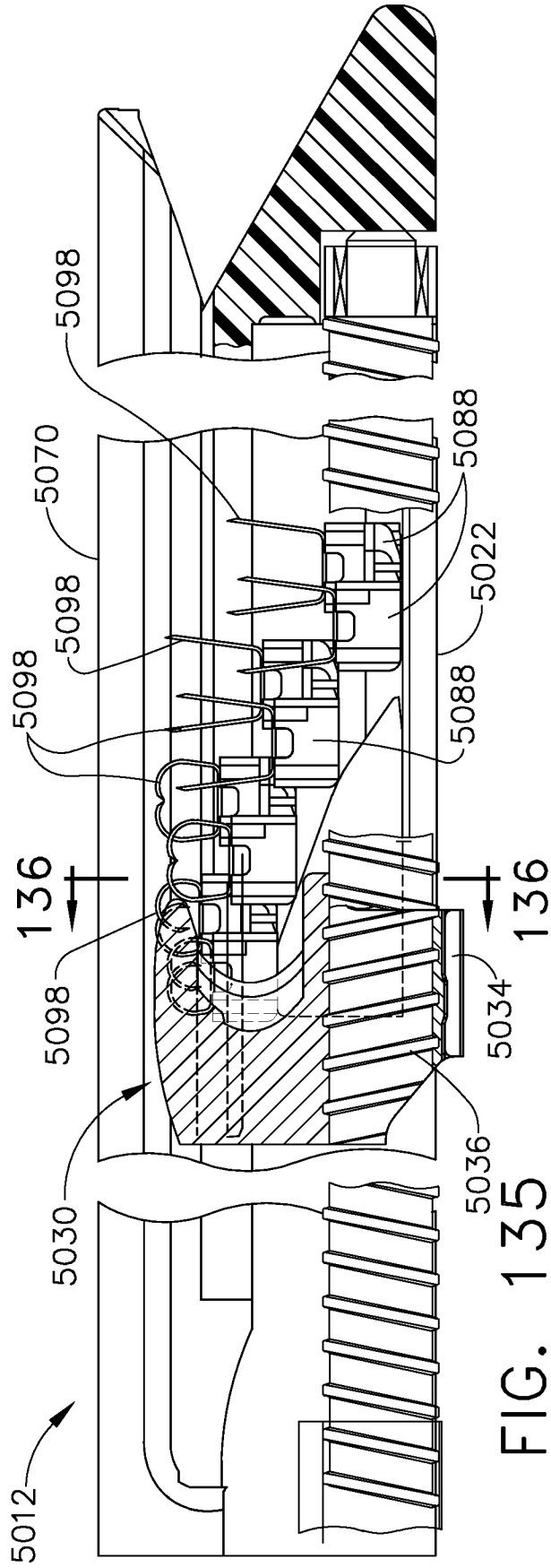


FIG. 135

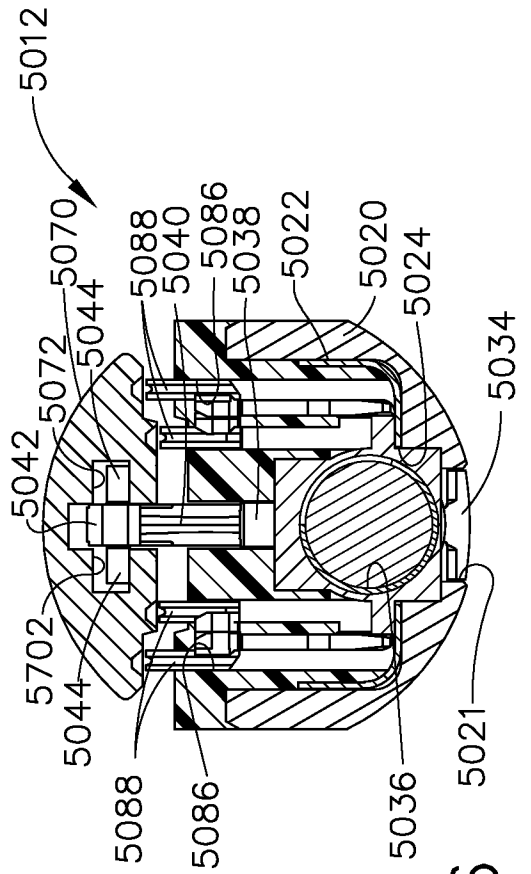


FIG. 136

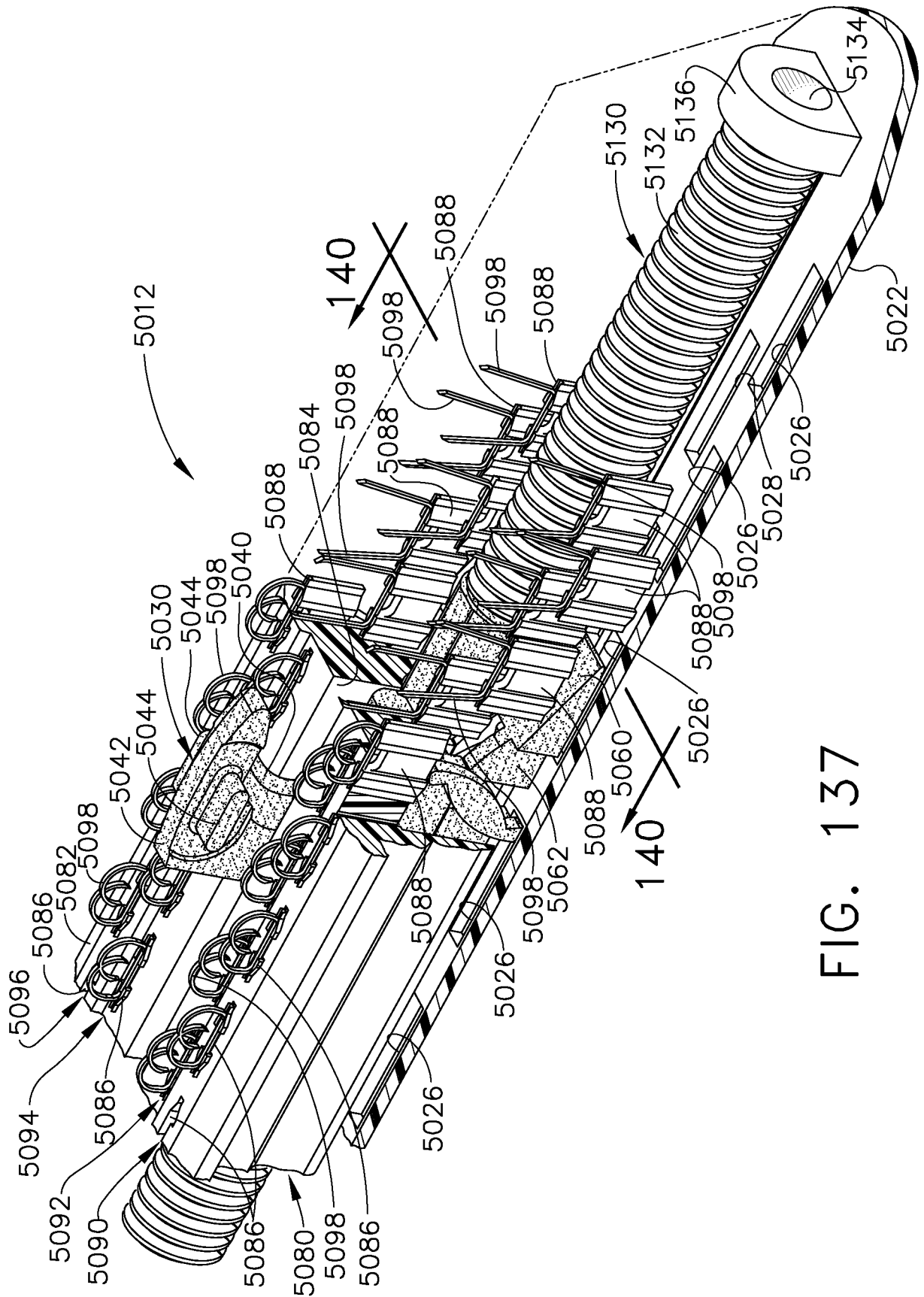


FIG. 137

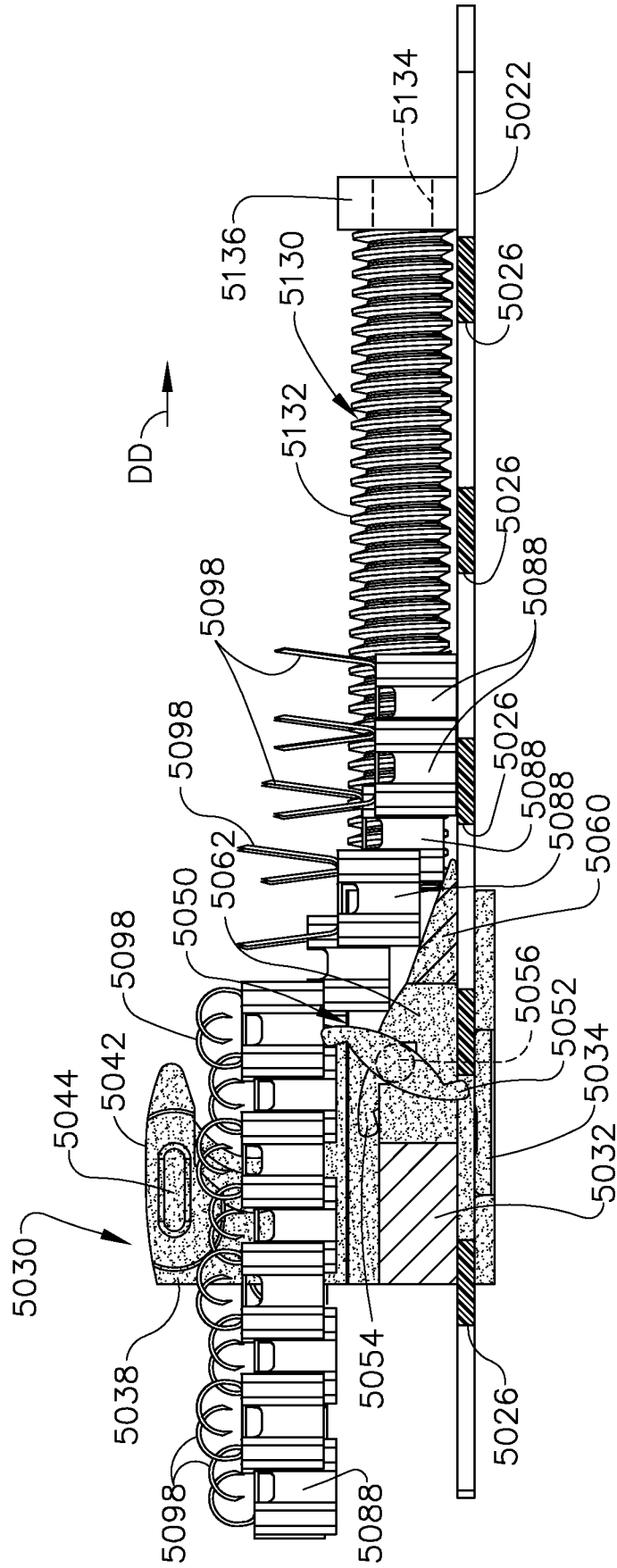


FIG. 138

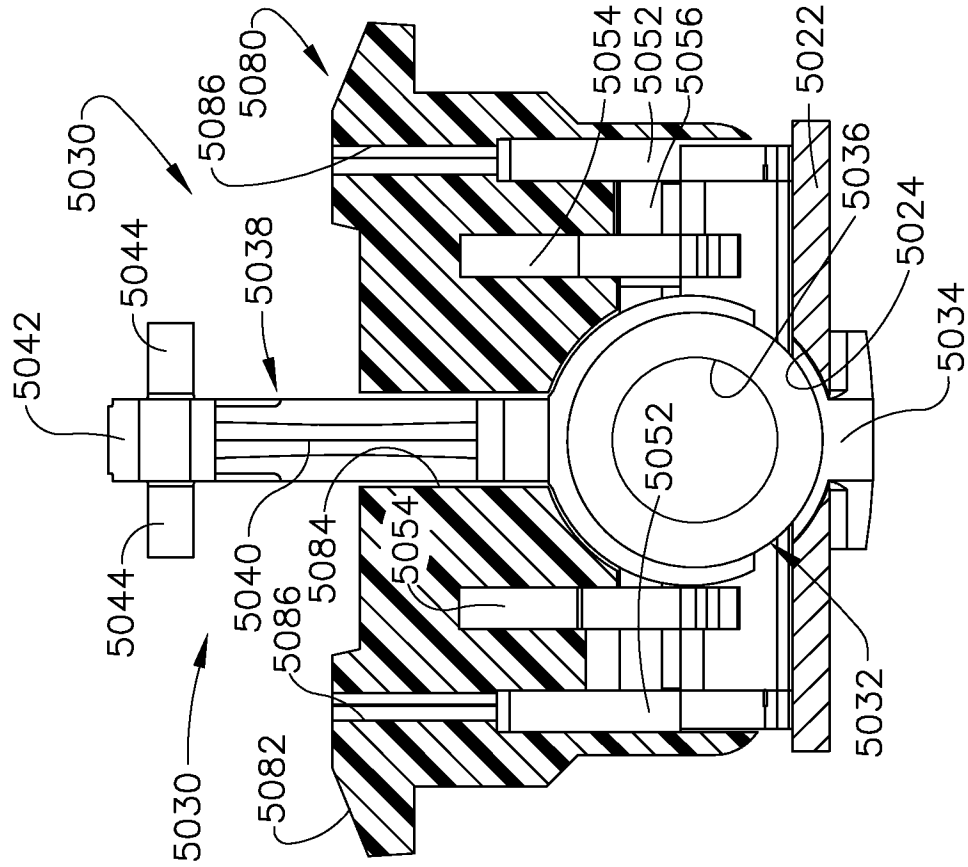


FIG. 140

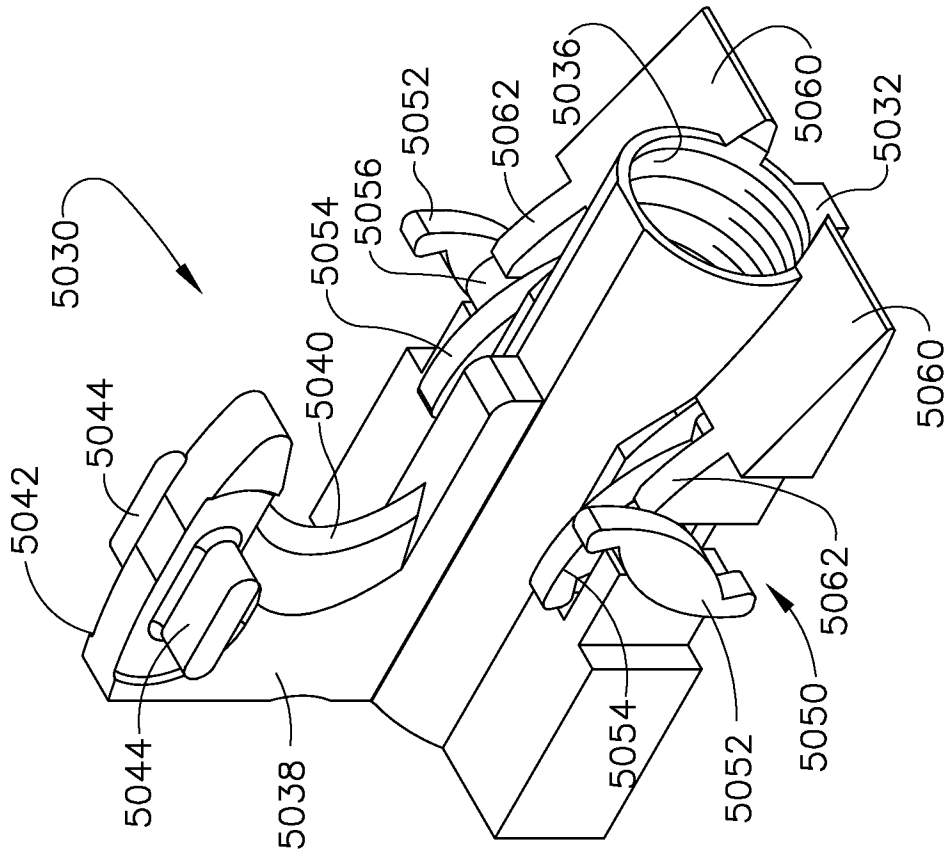


FIG. 139

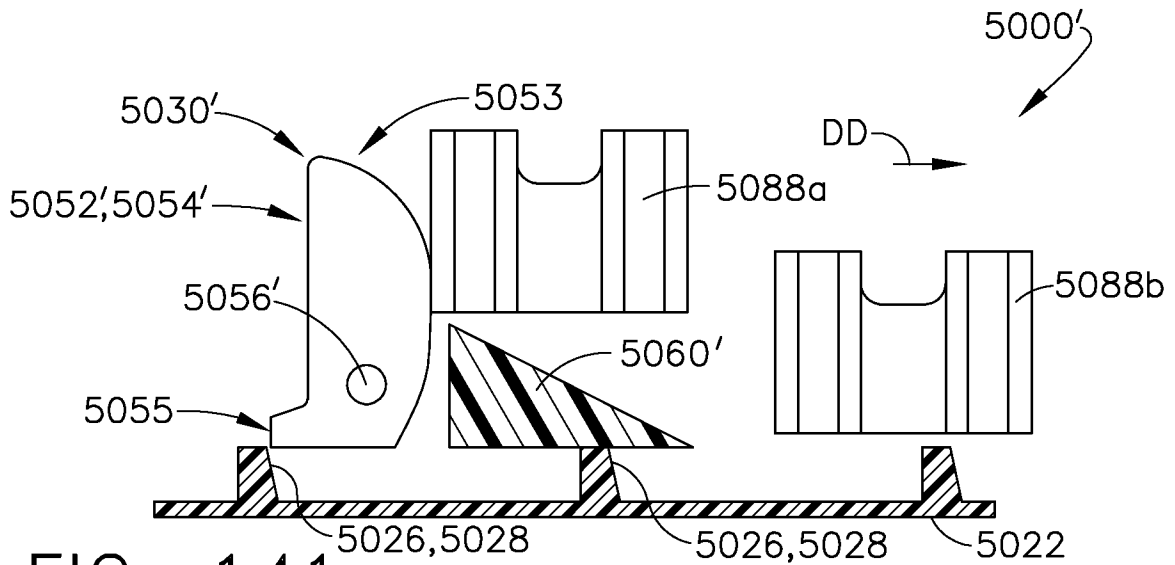


FIG. 141

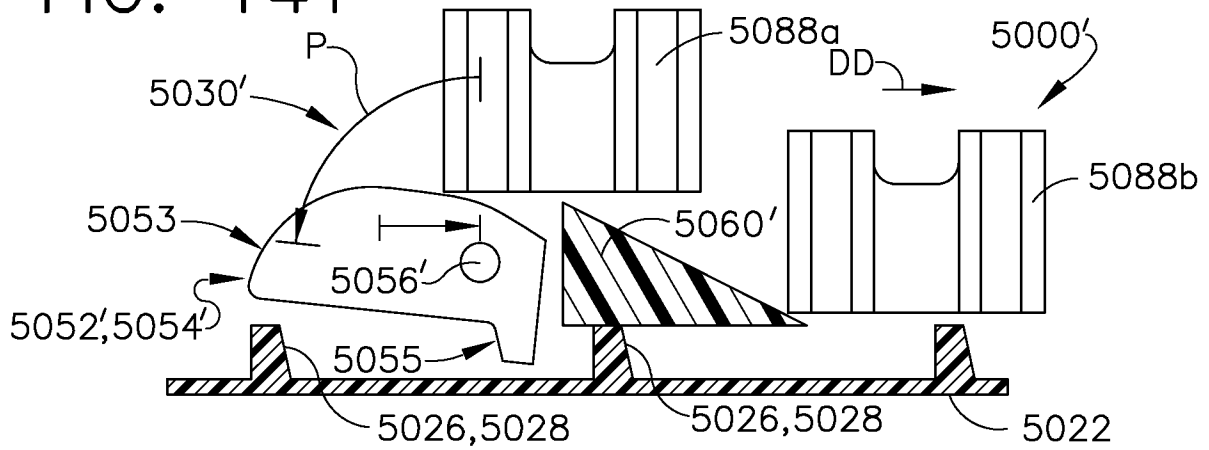


FIG. 142

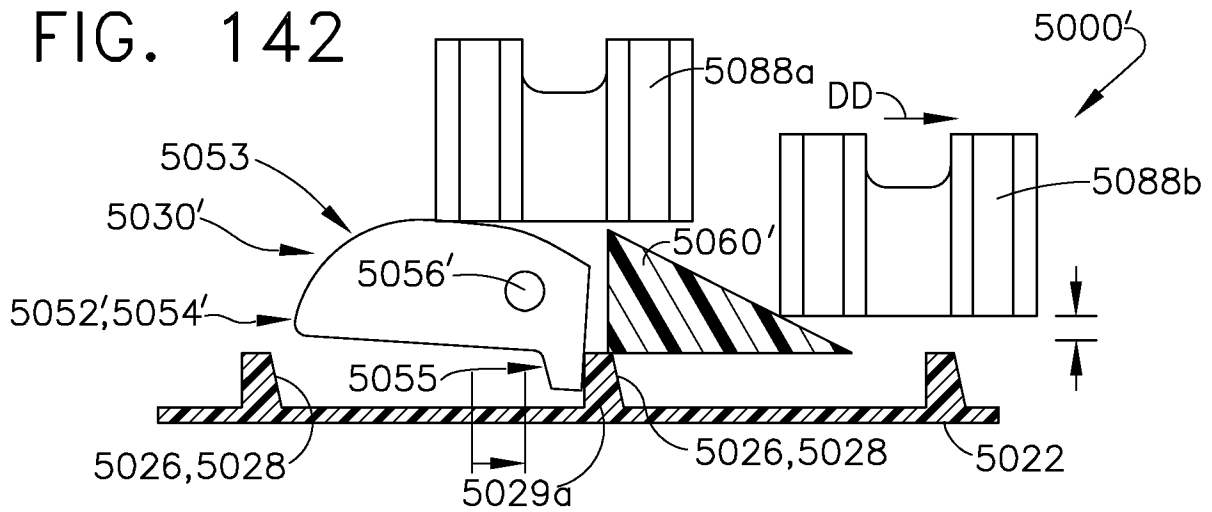


FIG. 143

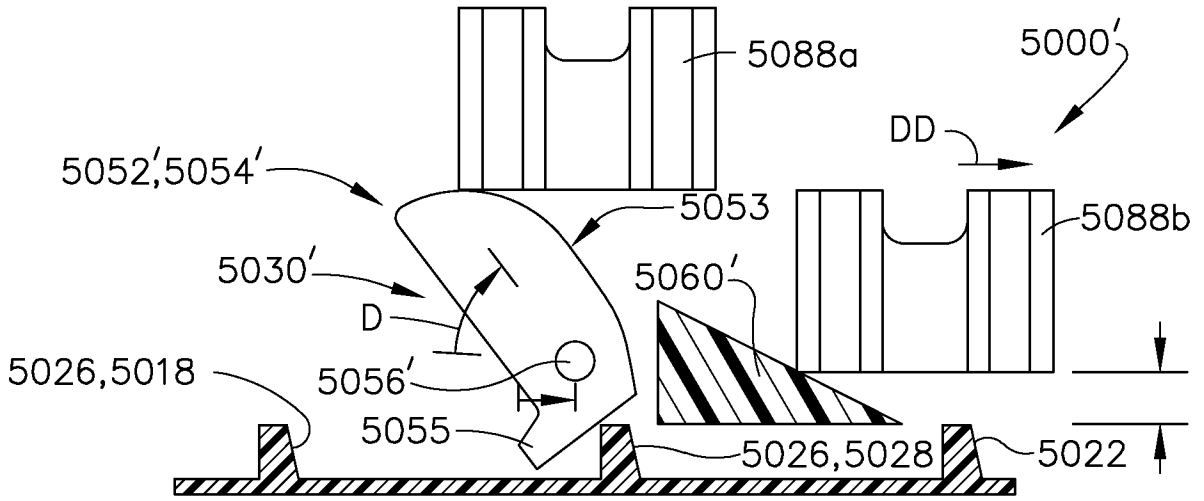


FIG. 144

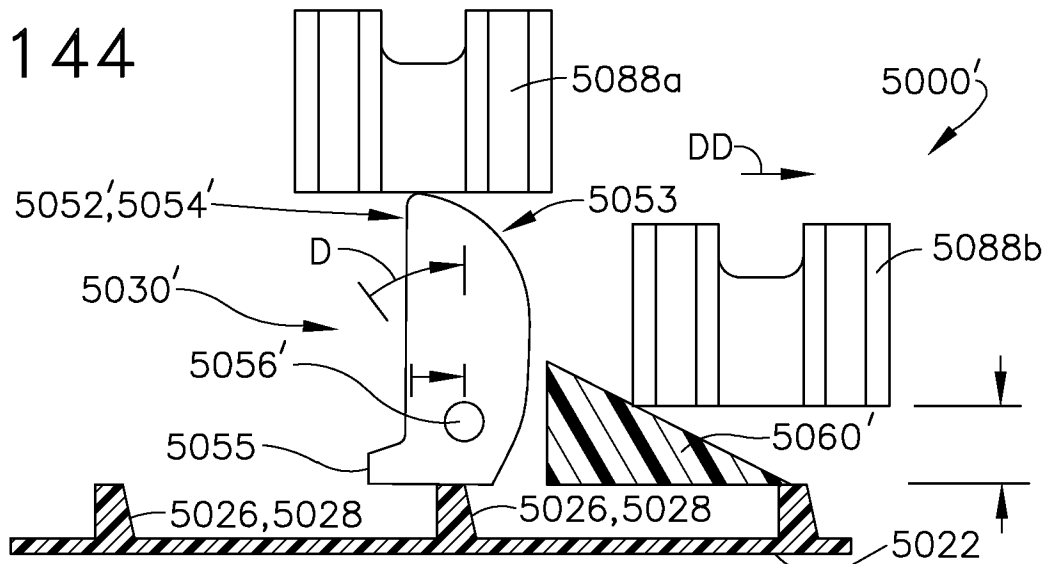


FIG. 145

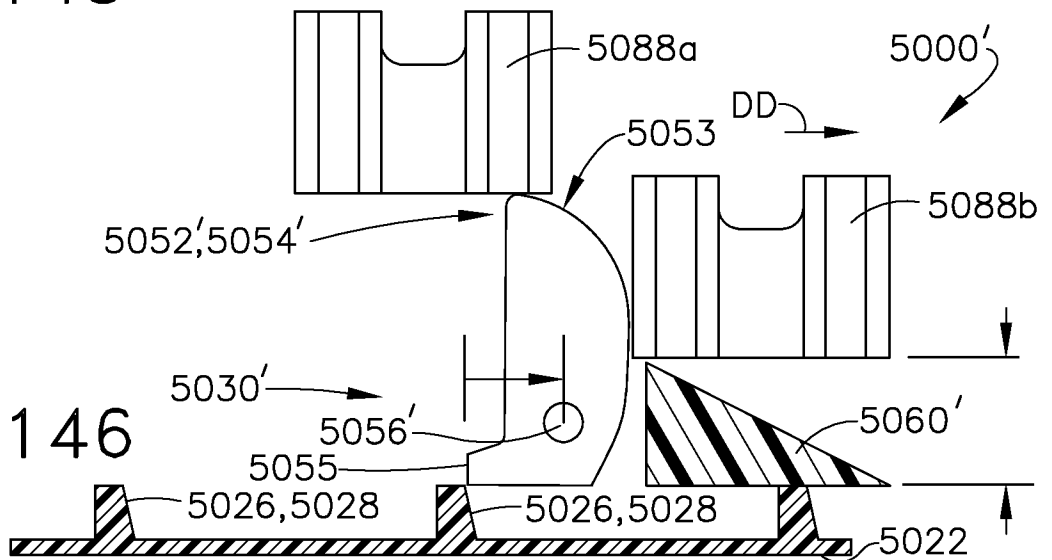


FIG. 146

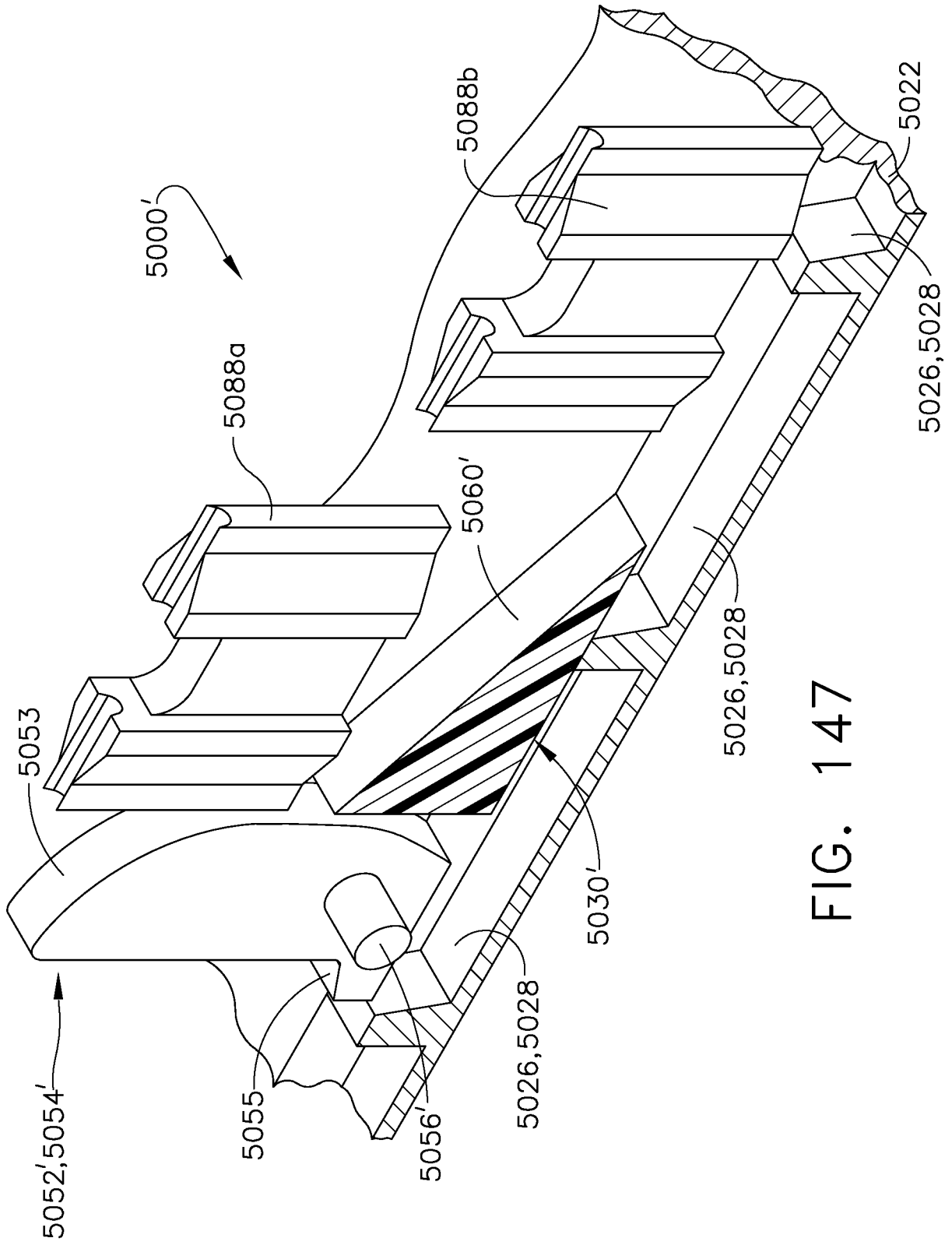


FIG. 147

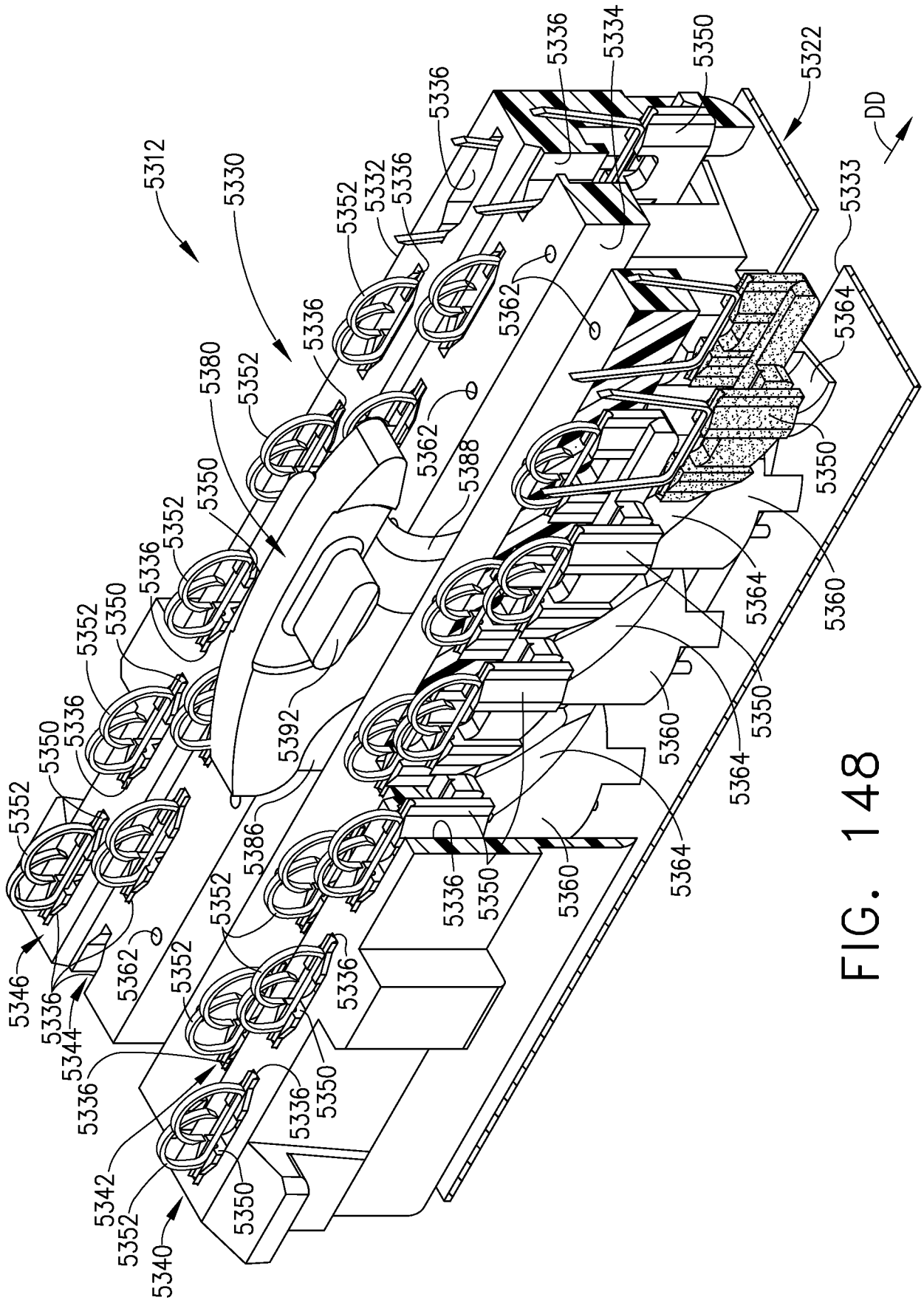


FIG. 148

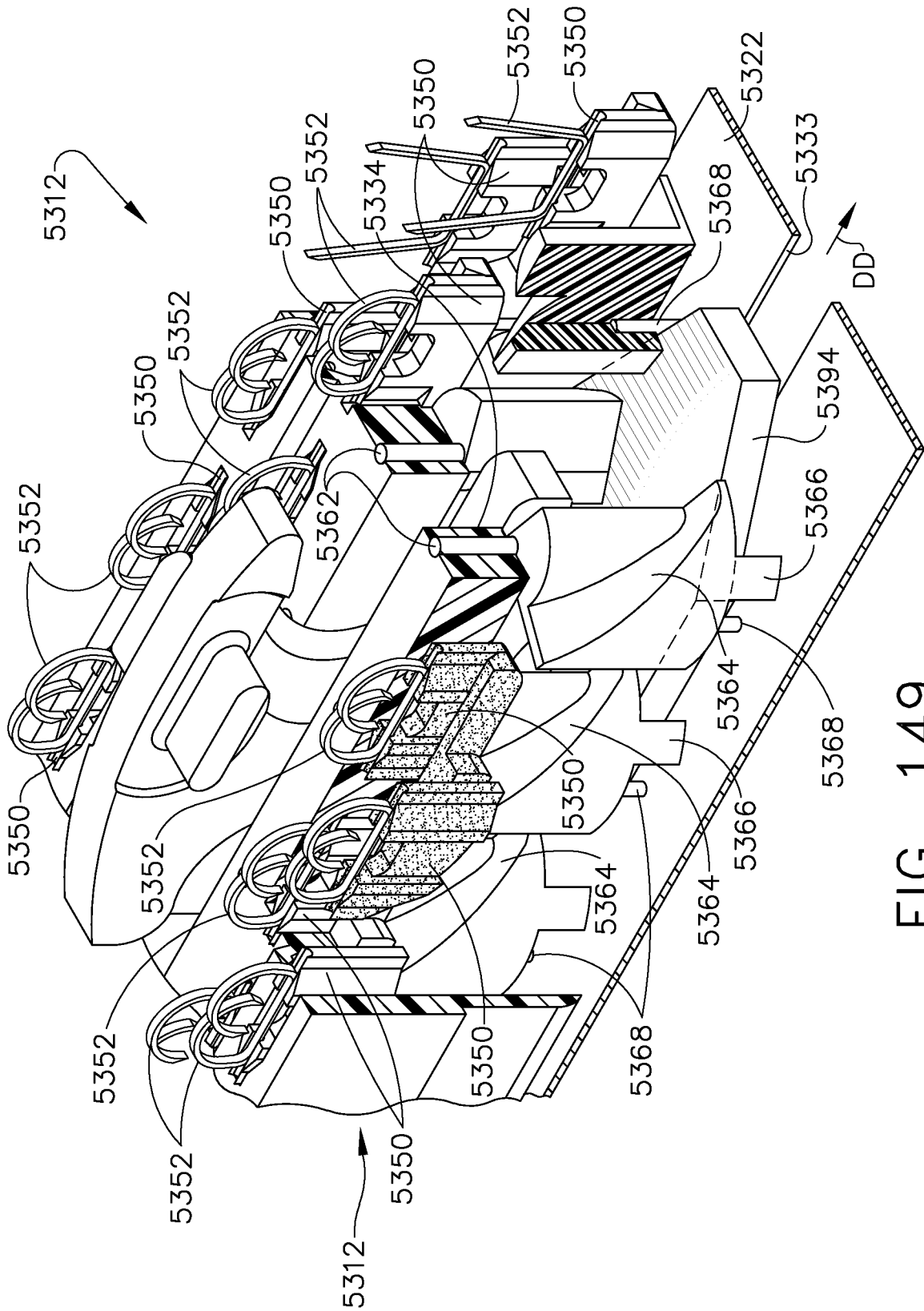


FIG. 149

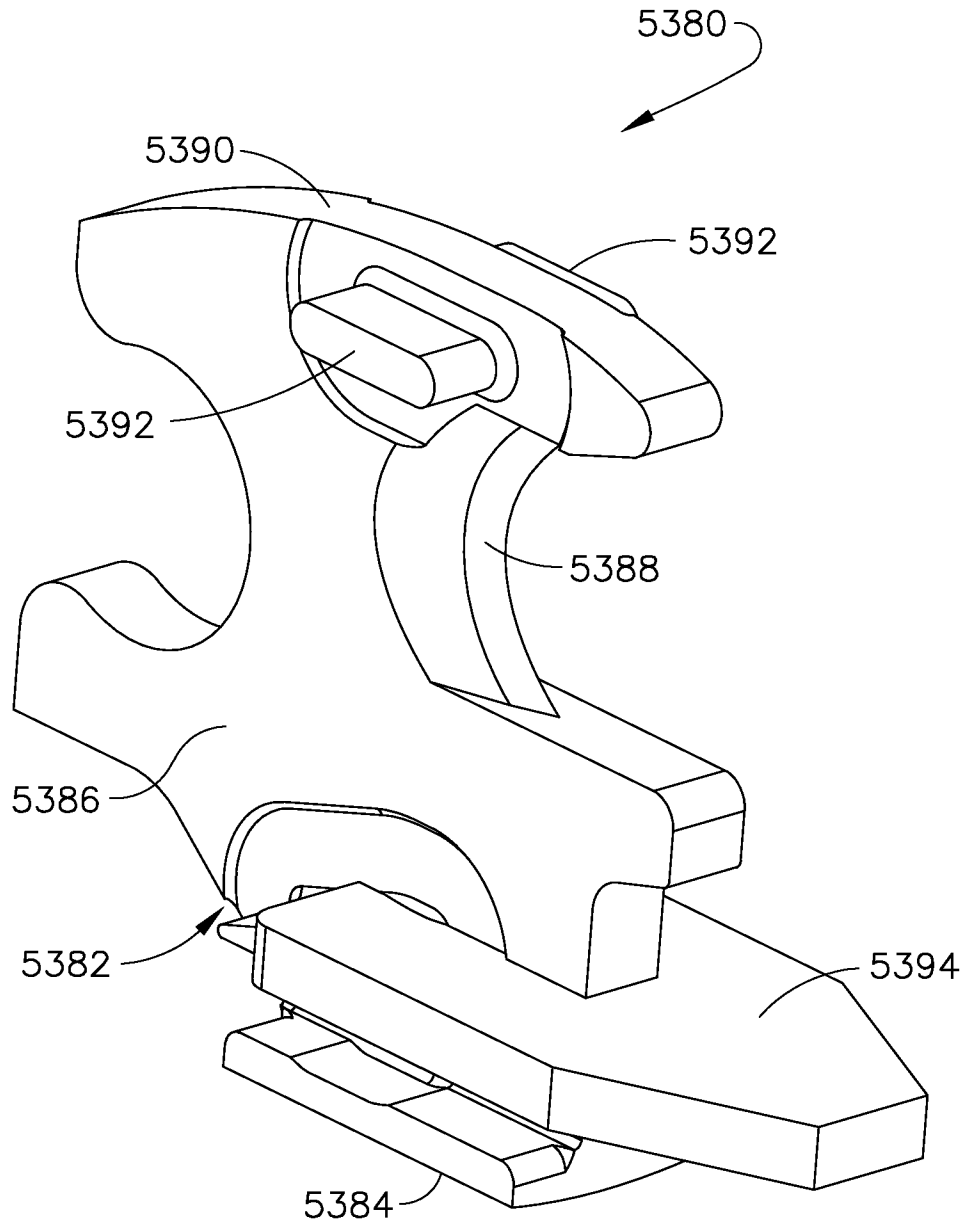


FIG. 150

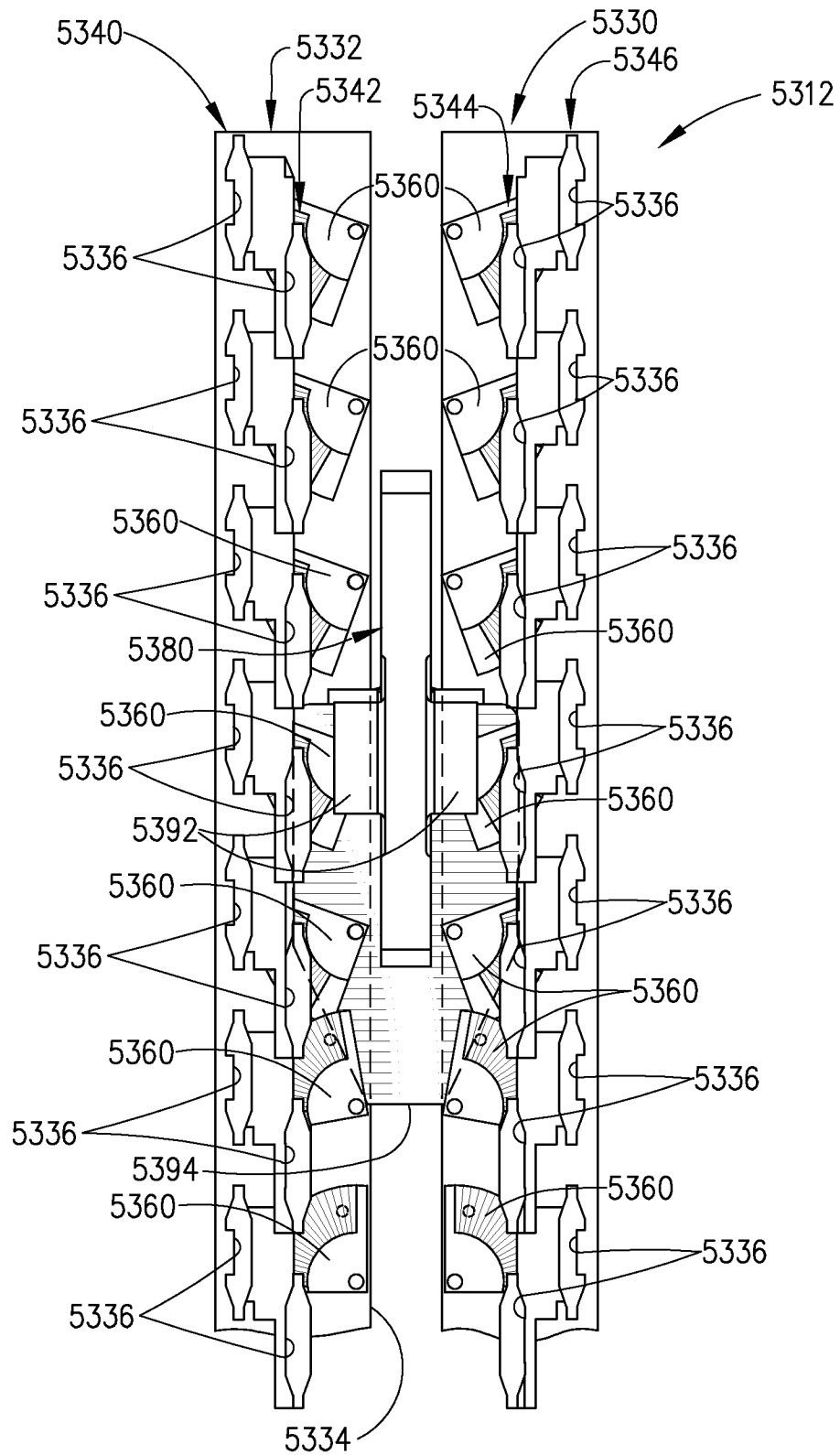


FIG. 151

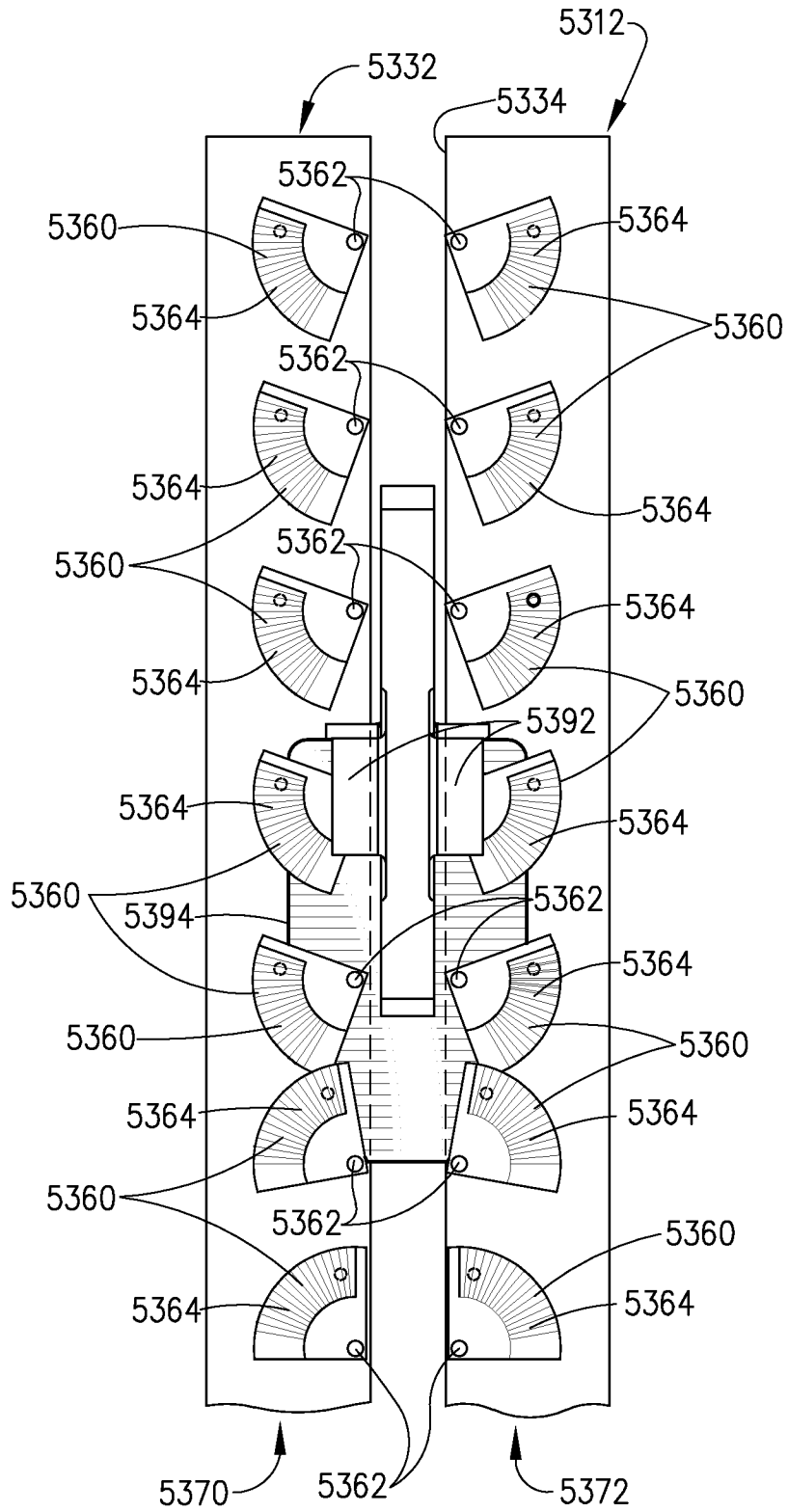


FIG. 152

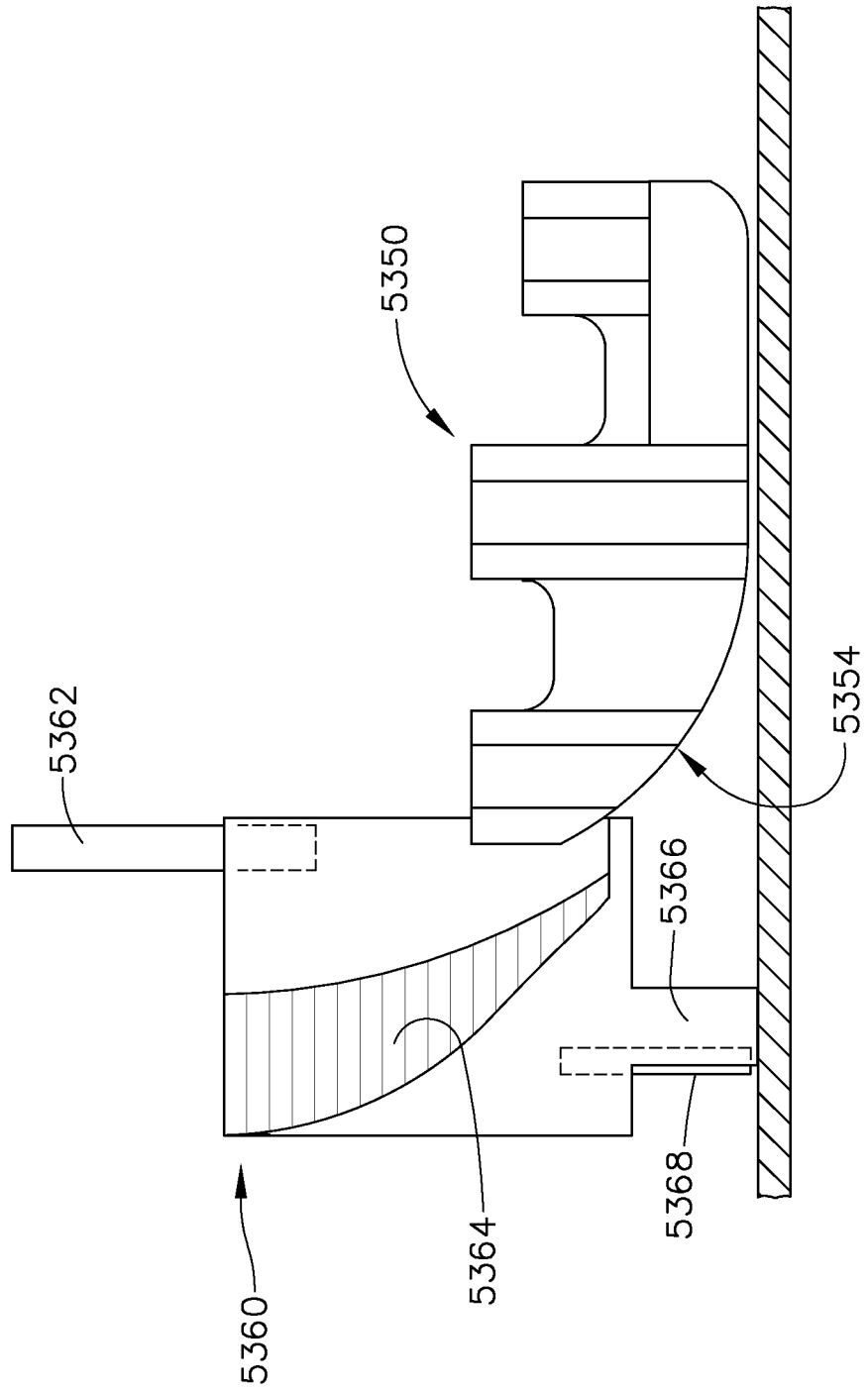


FIG. 153

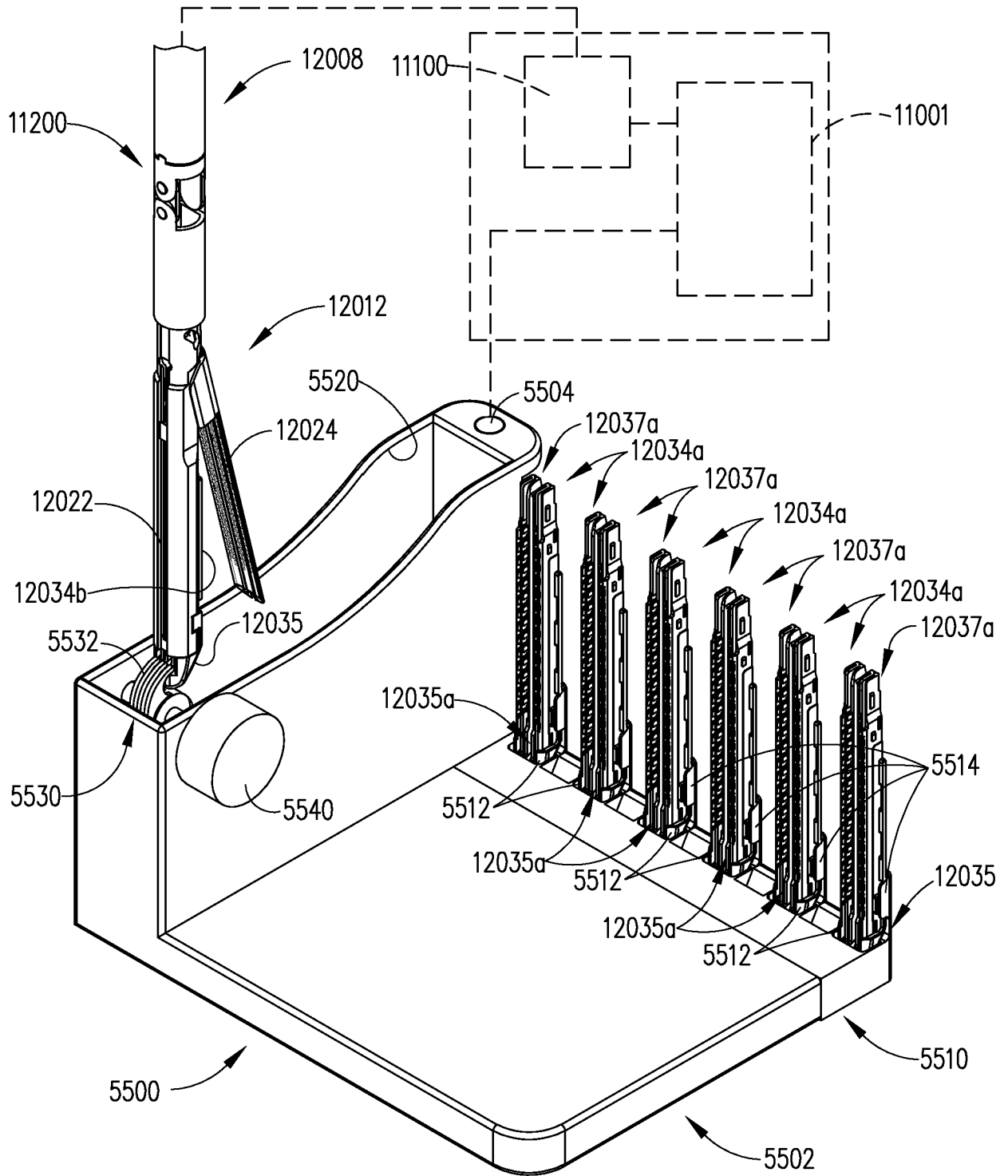


FIG. 154

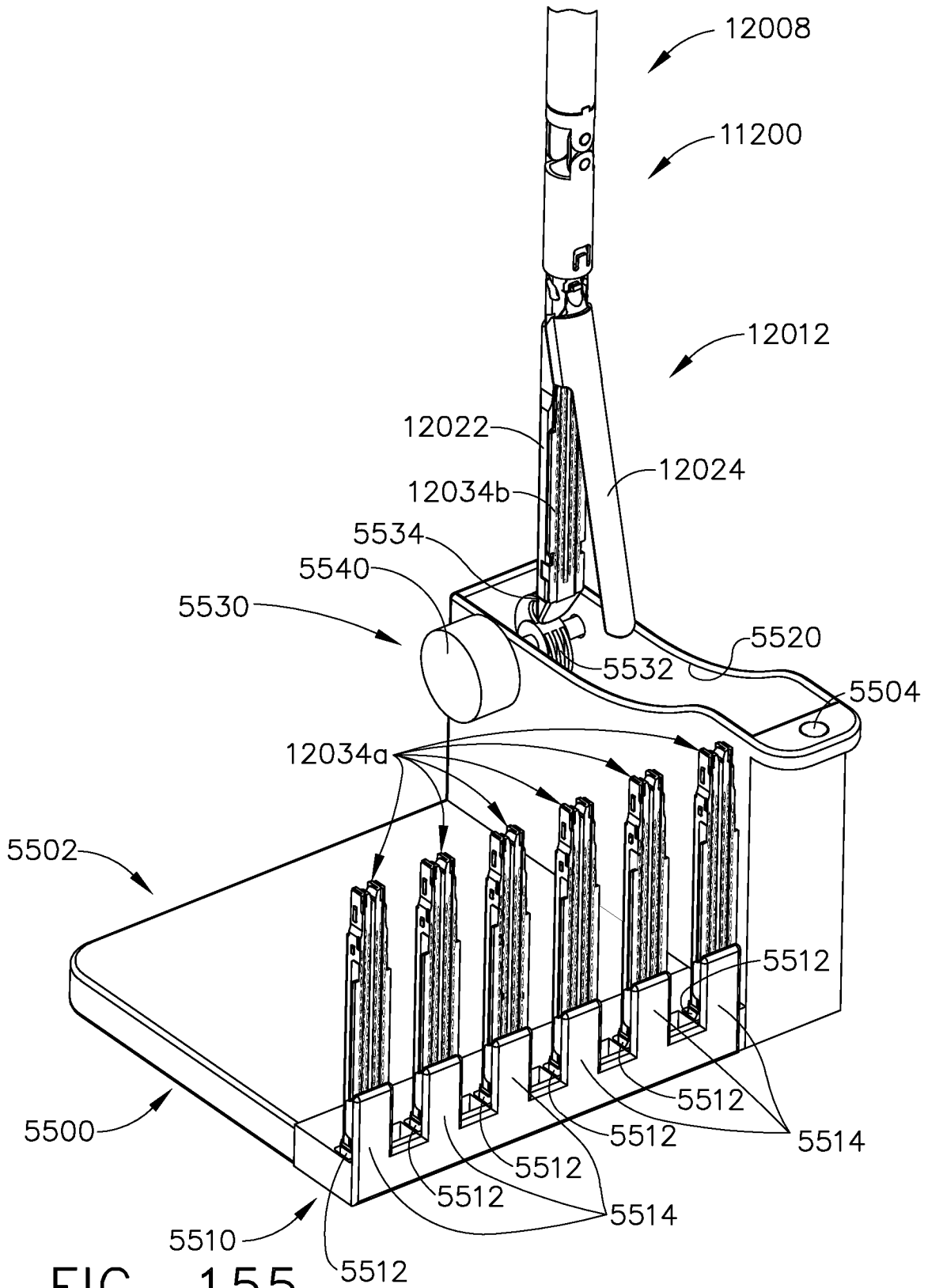


FIG. 155

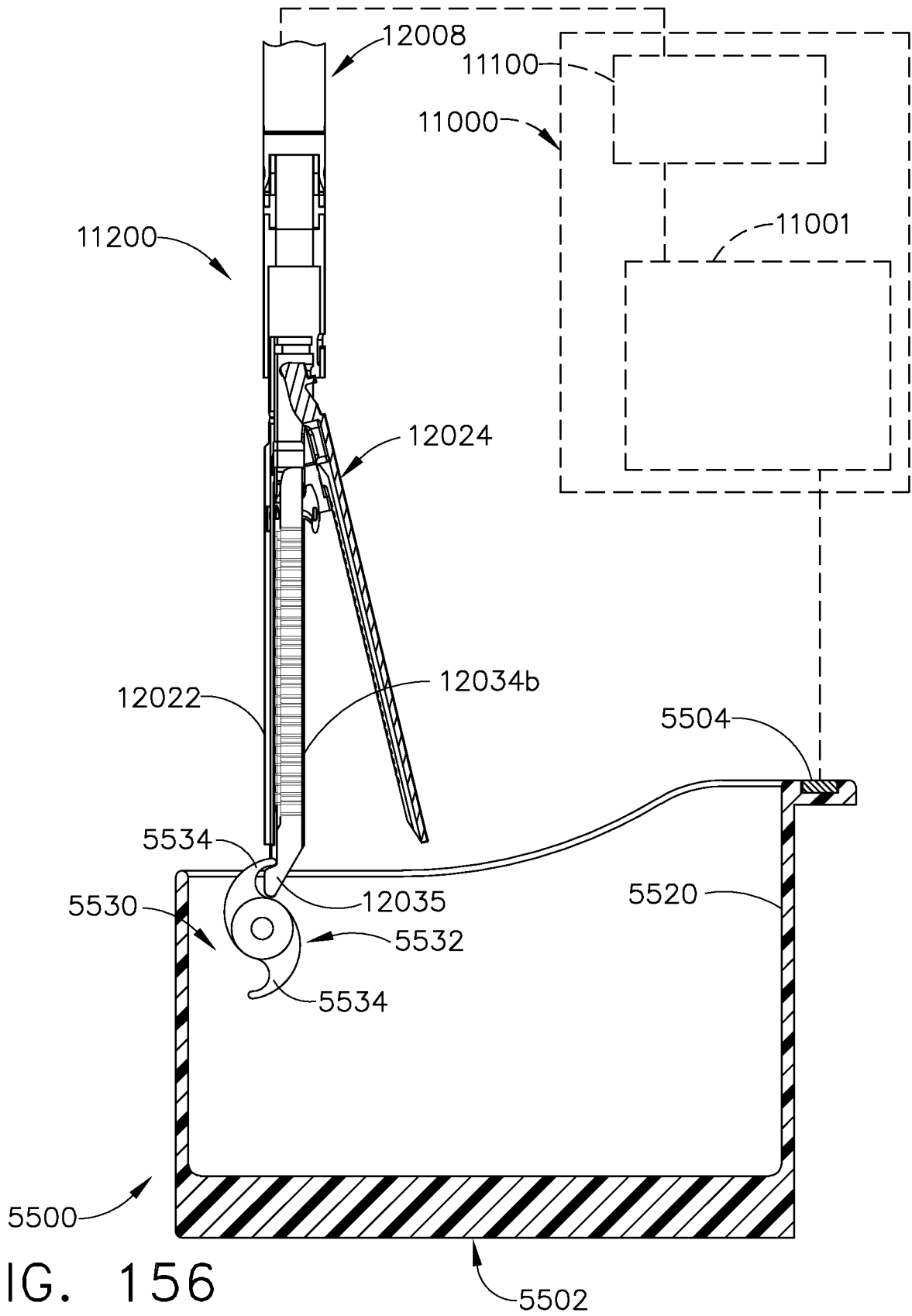


FIG. 156

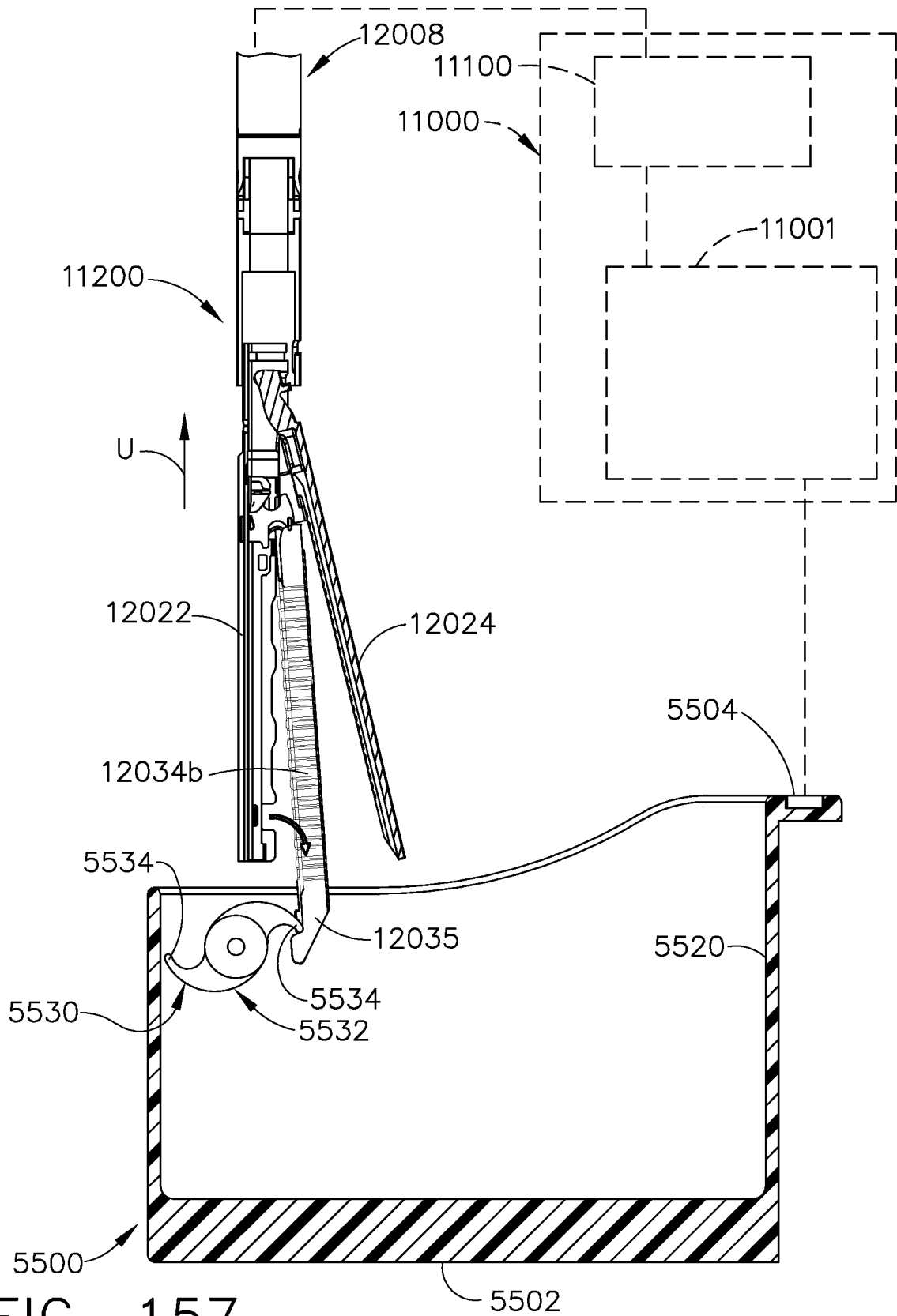


FIG. 157

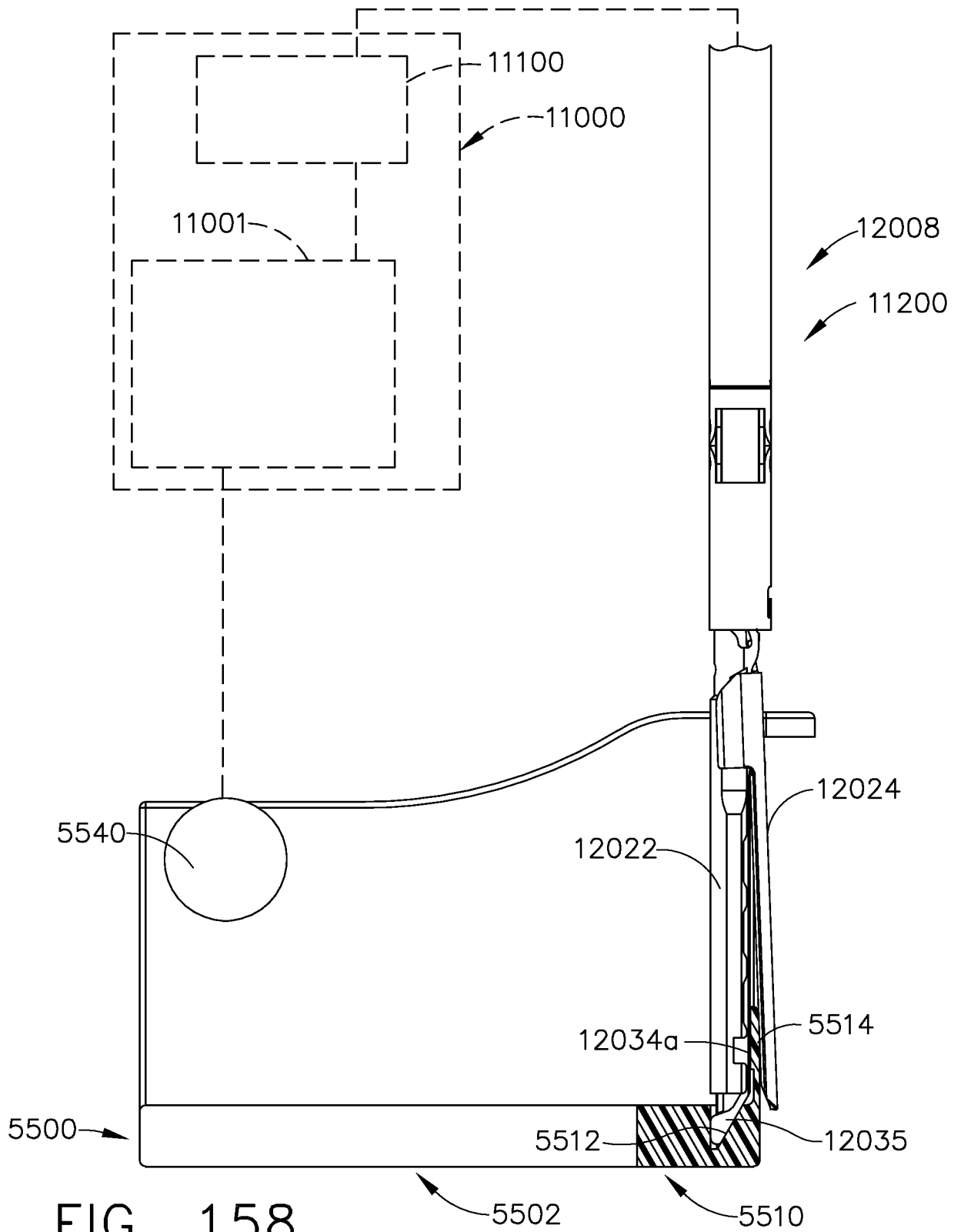


FIG. 158

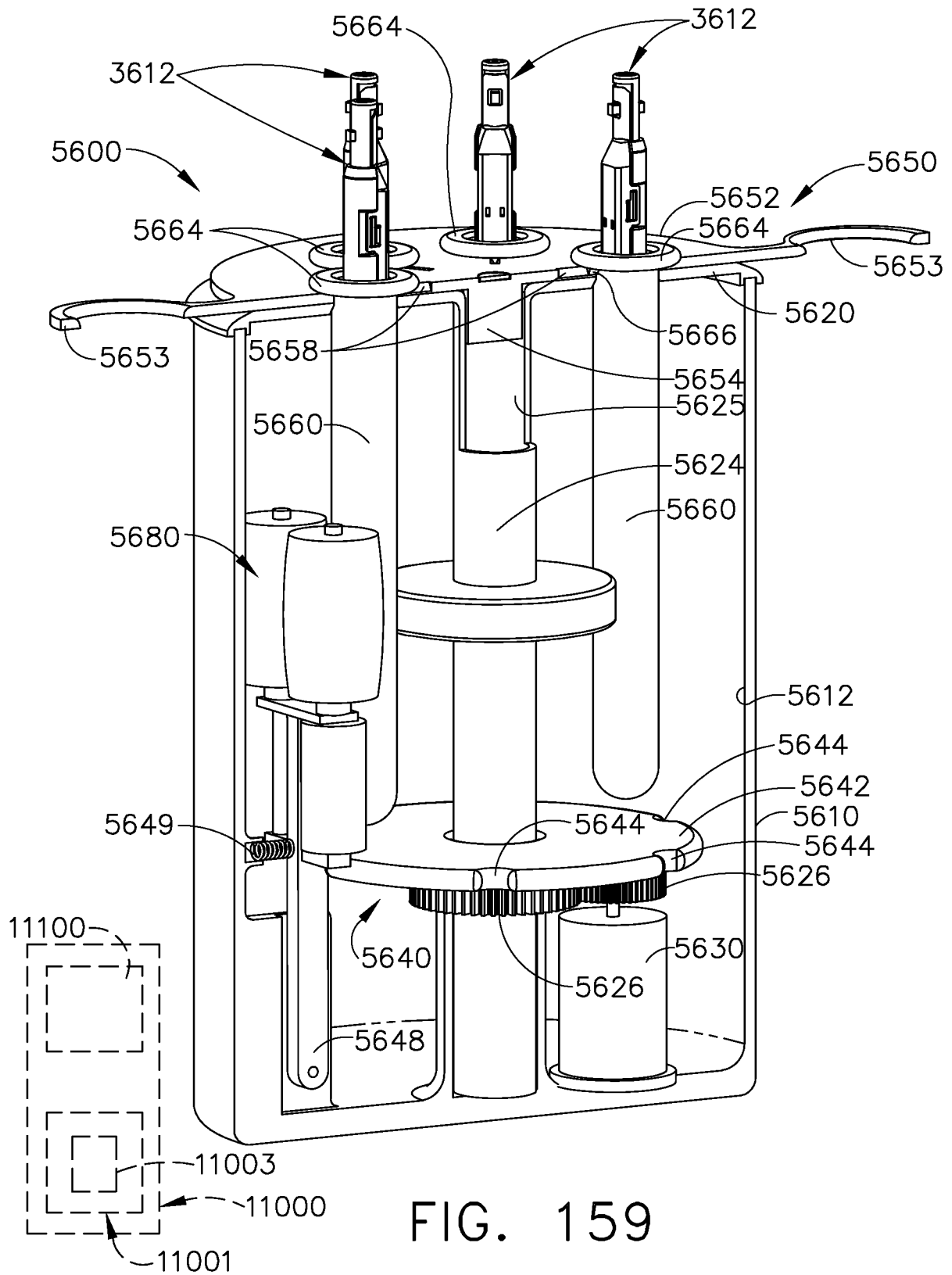


FIG. 159

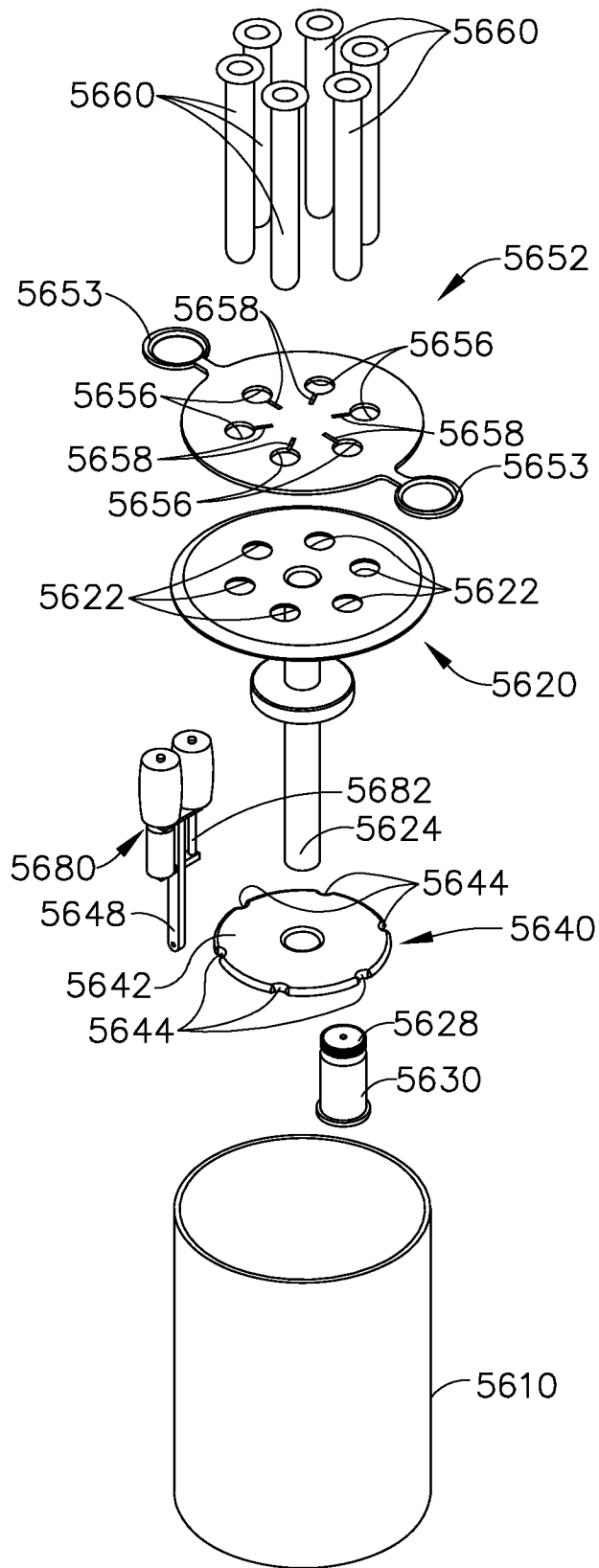


FIG. 160

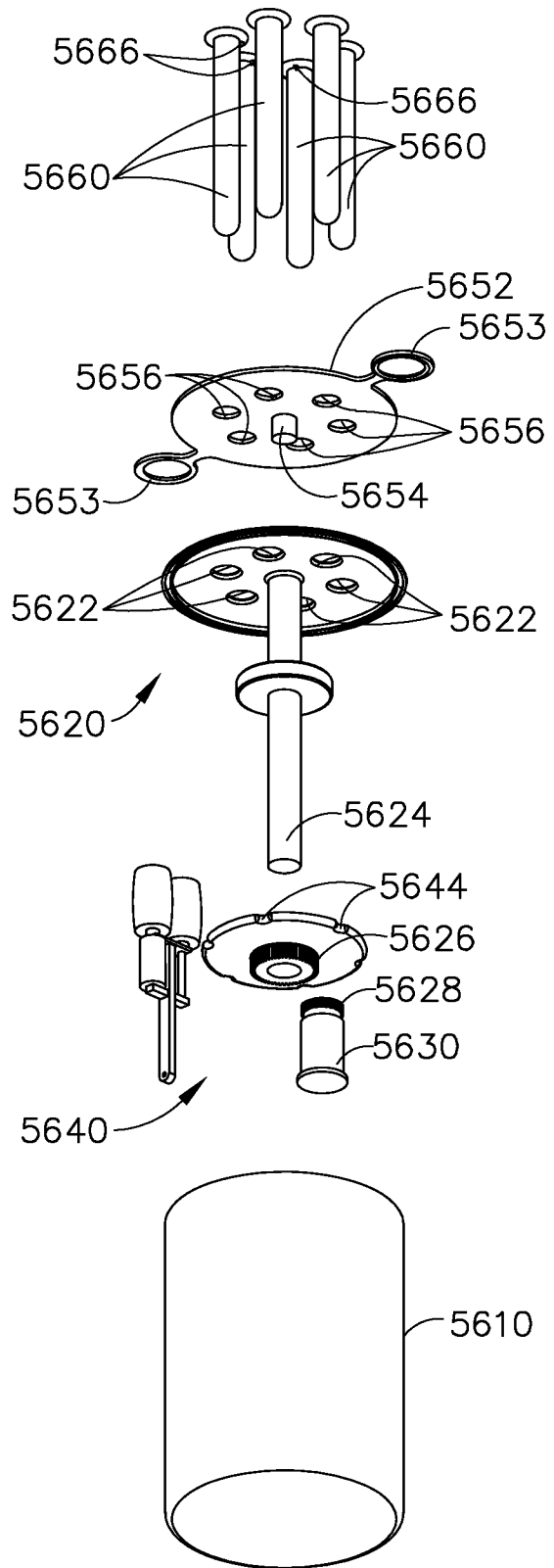


FIG. 161

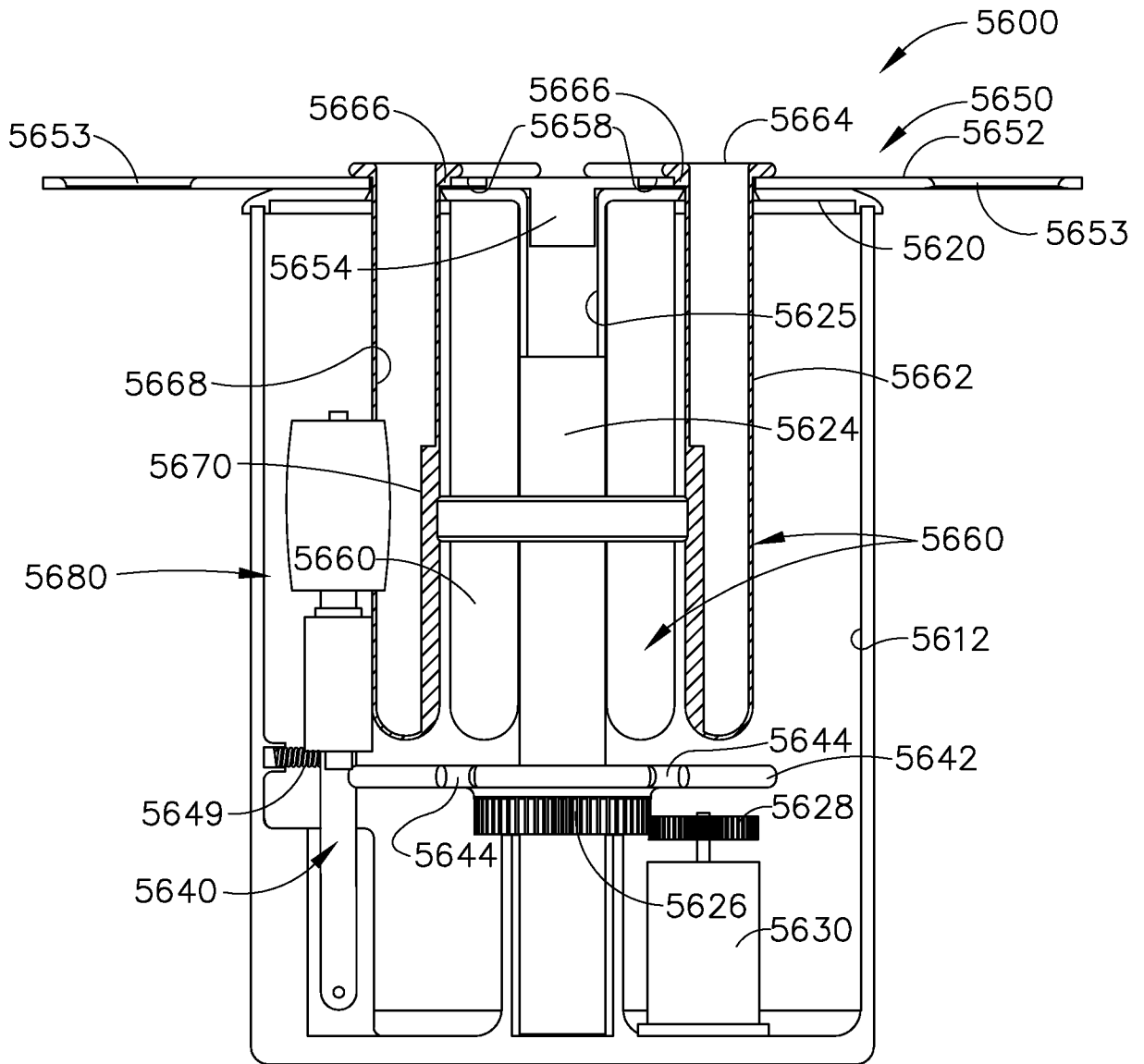


FIG. 162

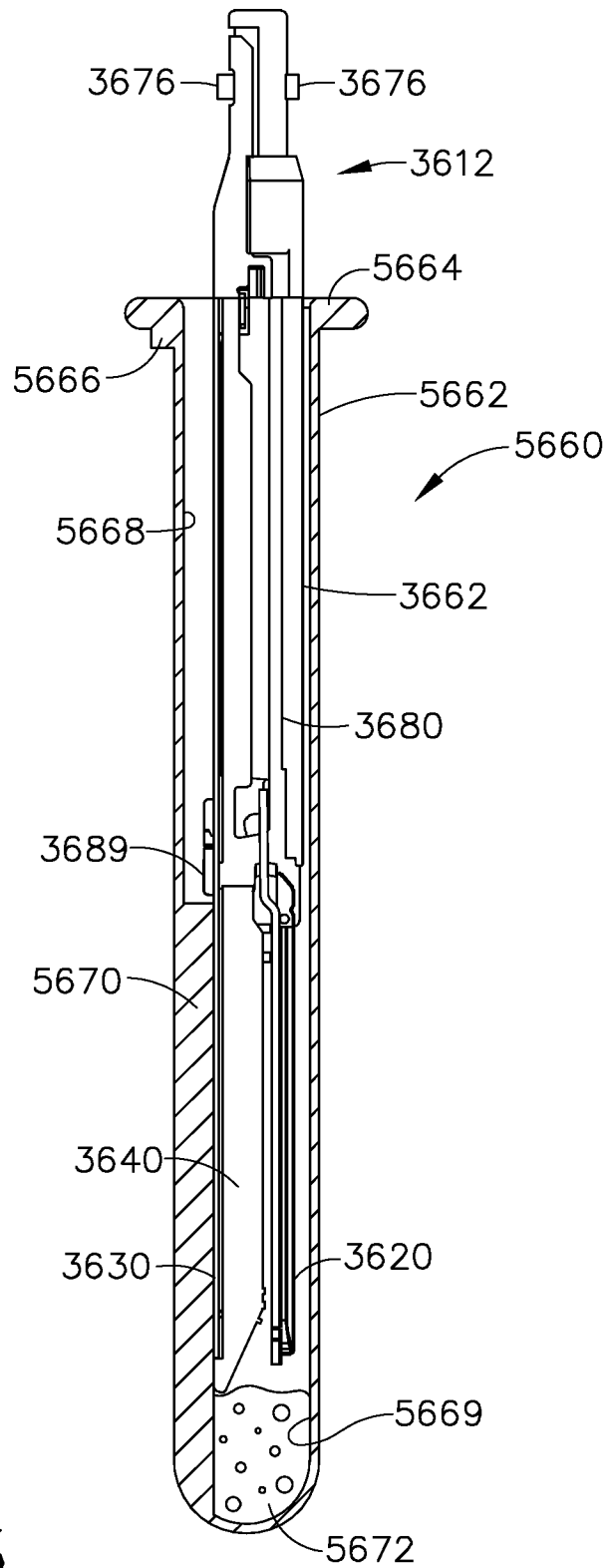


FIG. 163

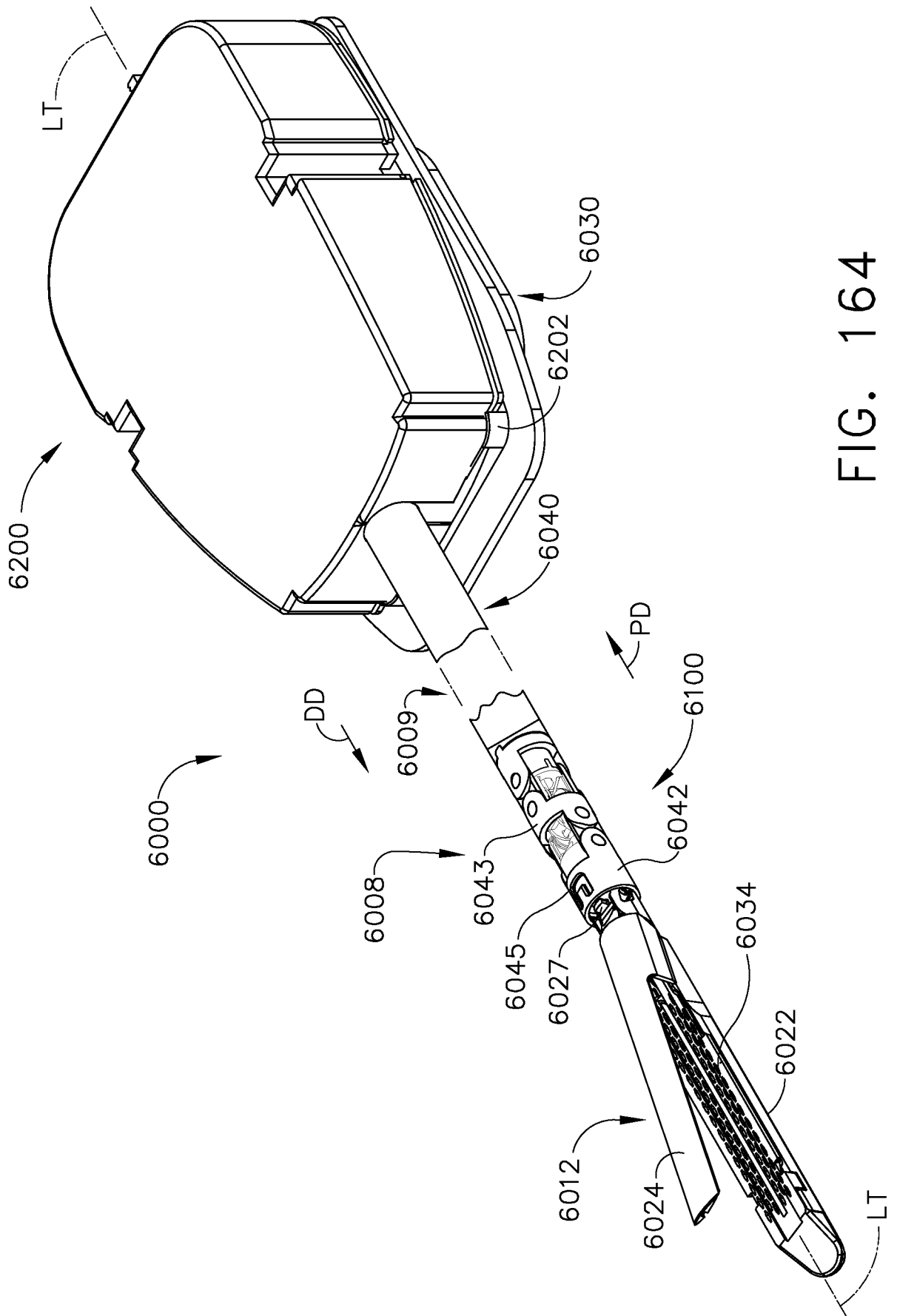


FIG. 164

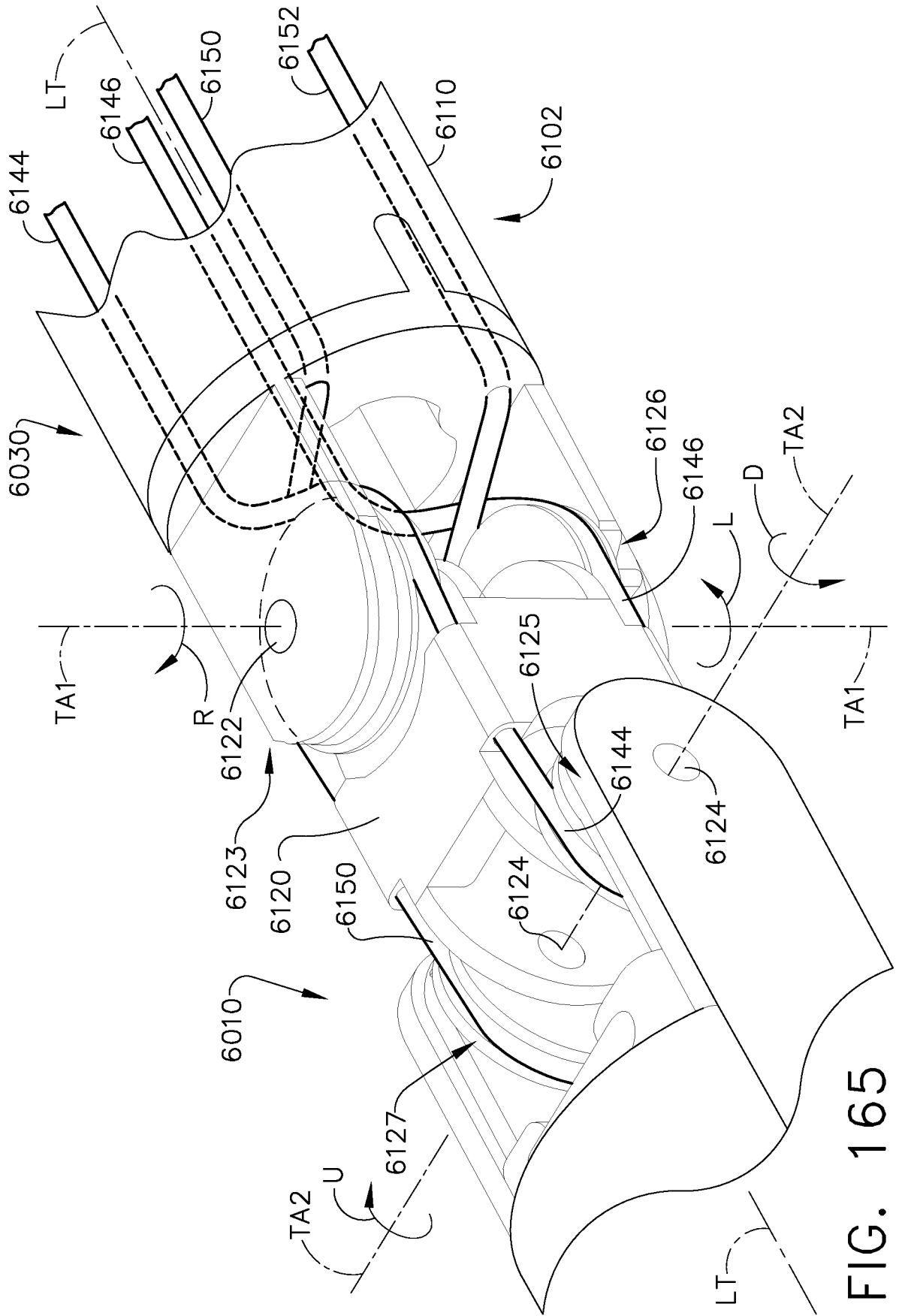


FIG. 165

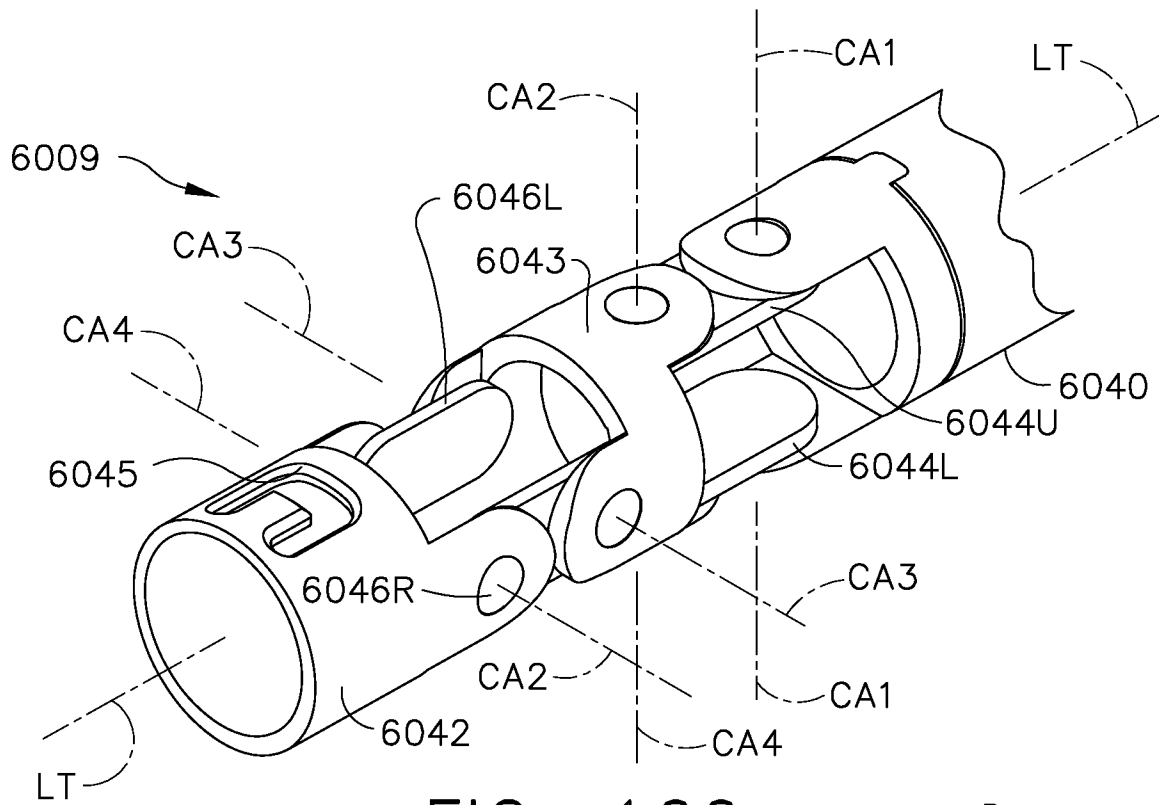


FIG. 166

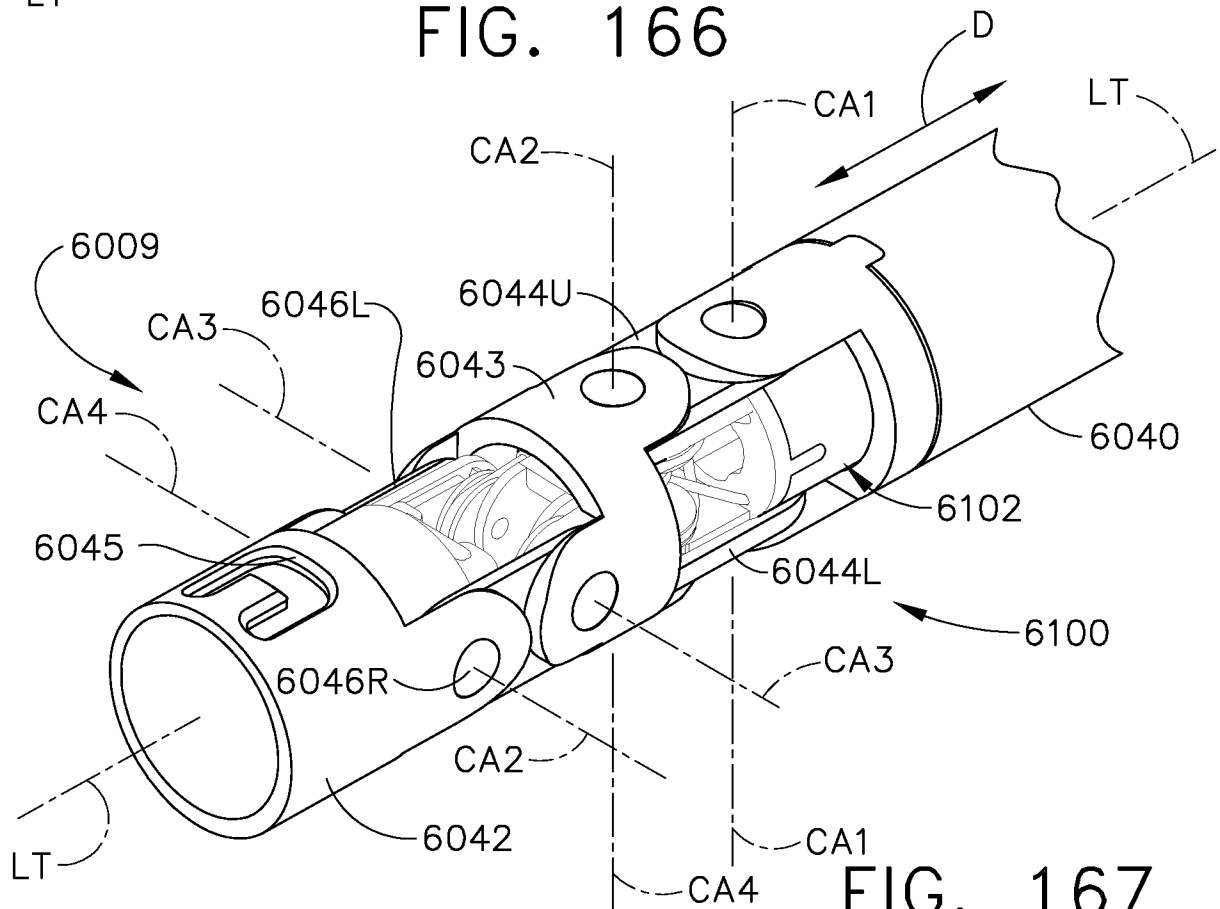


FIG. 167

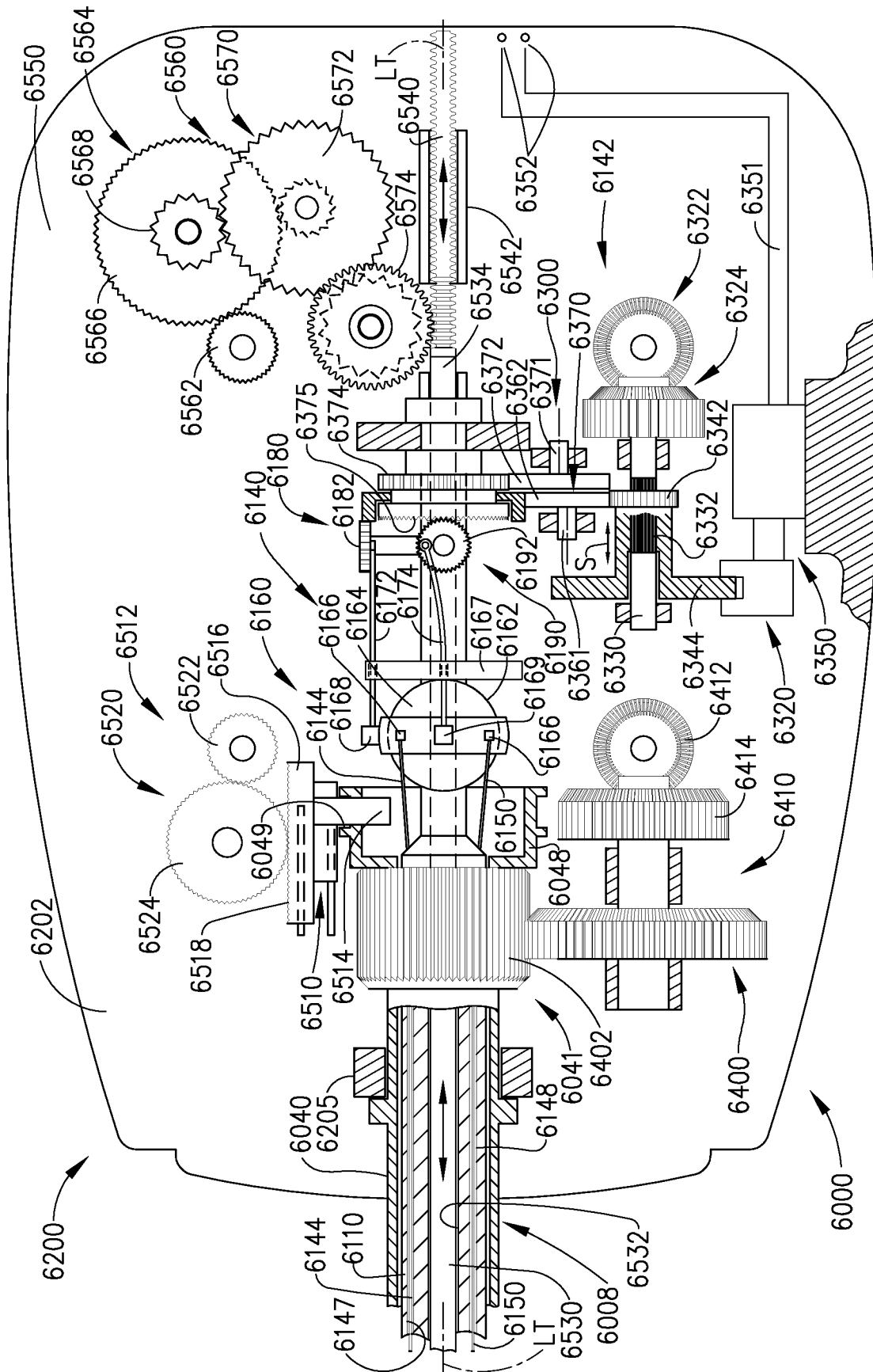


FIG. 168

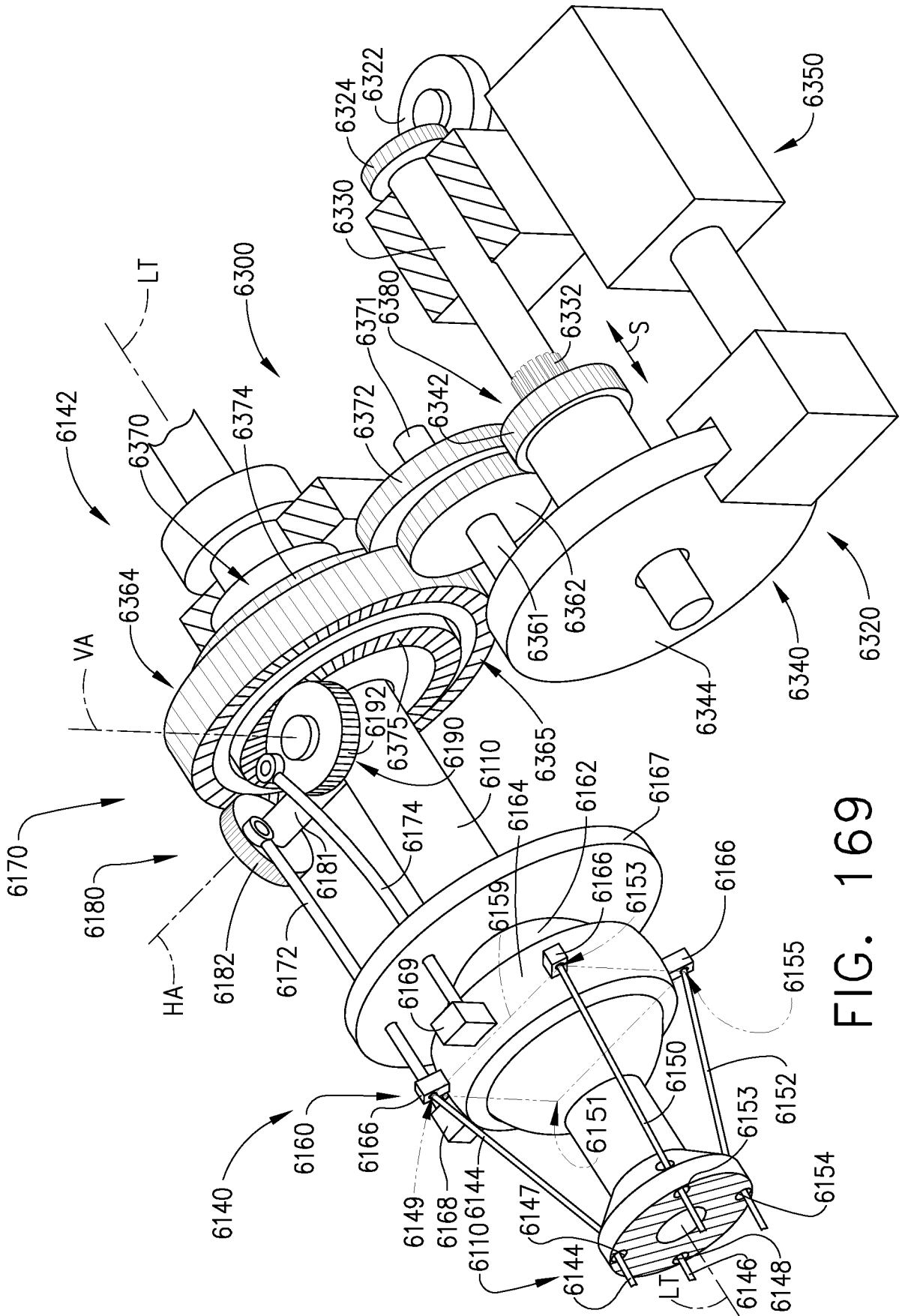


FIG. 169

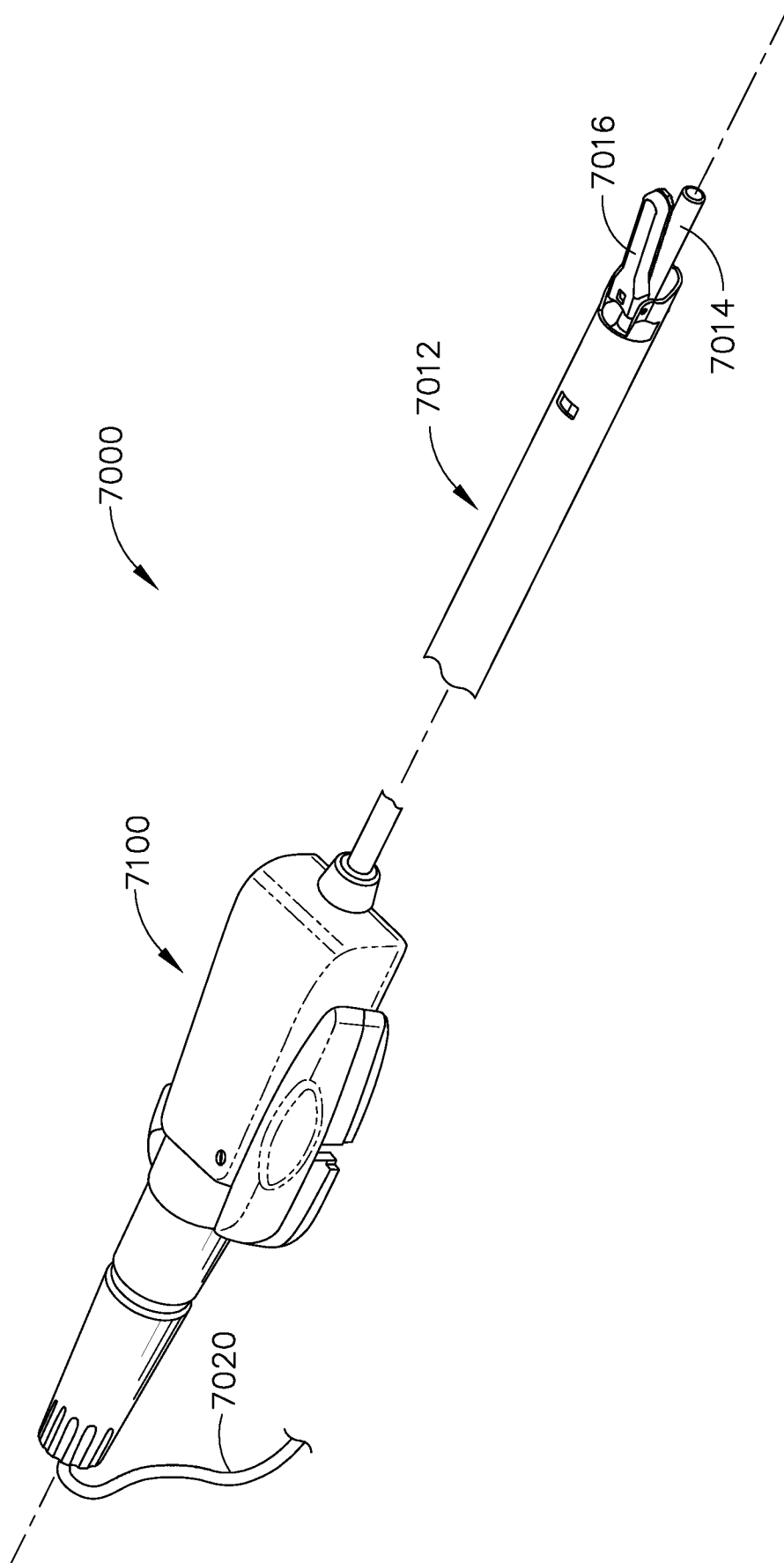


FIG. 170

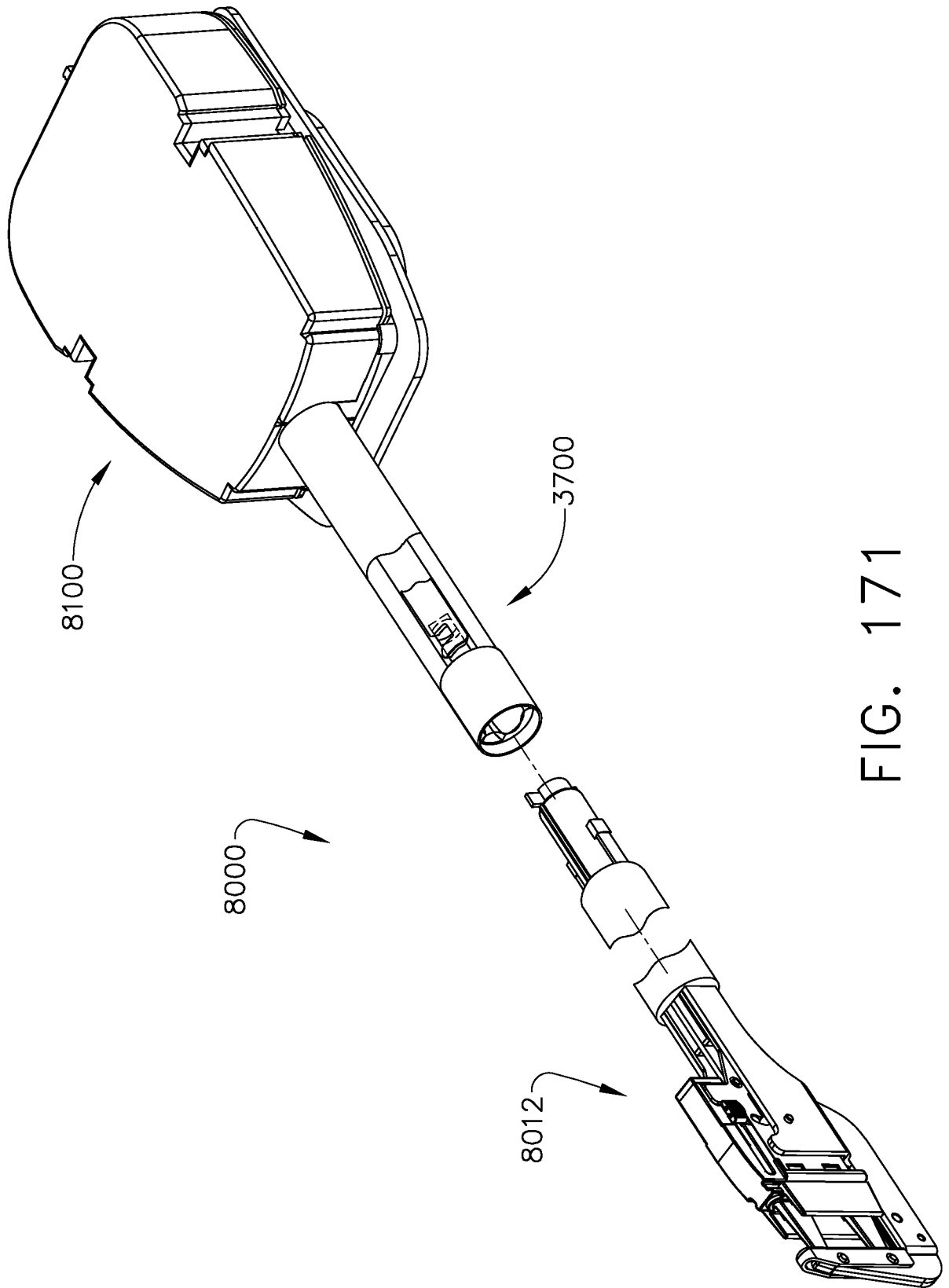


FIG. 171

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/039141

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B17/072
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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| X | US 5 383 880 A (HOOVEN MICHAEL D [US]) 24 January 1995 (1995-01-24) cited in the application the whole document ----- -/-- | 1-16 |

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See patent family annex.

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| Date of the actual completion of the international search 11 October 2012 | Date of mailing of the international search report 19/10/2012 |
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| Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016 | Authorized officer Strazdauskas, Gedas |
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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2012/039141

| C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT | | |
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| A | EP 0 699 418 A1 (UNITED STATES SURGICAL CORP [US]) 6 March 1996 (1996-03-06) paragraph [0019] - paragraph [0020]; figure 3 ----- | 1-17 |

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Information on patent family members

International application No

PCT/US2012/039141

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date | |
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