Office de la Propriété Intellectuelle du Canada
Un organisme d'Industrie Canada

Canadian Intellectual Property Office
An agency of Industry Canada

CA 2514215 C 2013/10/01

(11)(21) 2 514 215

(12) BREVET CANADIEN
CANADIAN PATENT

(13) C

(22) Date de dépôt/Filing Date: 2005/07/28

(41) Mise à la disp. pub./Open to Public Insp.: 2006/01/28

(45) Date de délivrance/Issue Date: 2013/10/01

(30) Priorités/Priorities: 2004/07/28 (US60/591,694);
2005/03/31 (US11/095,428)

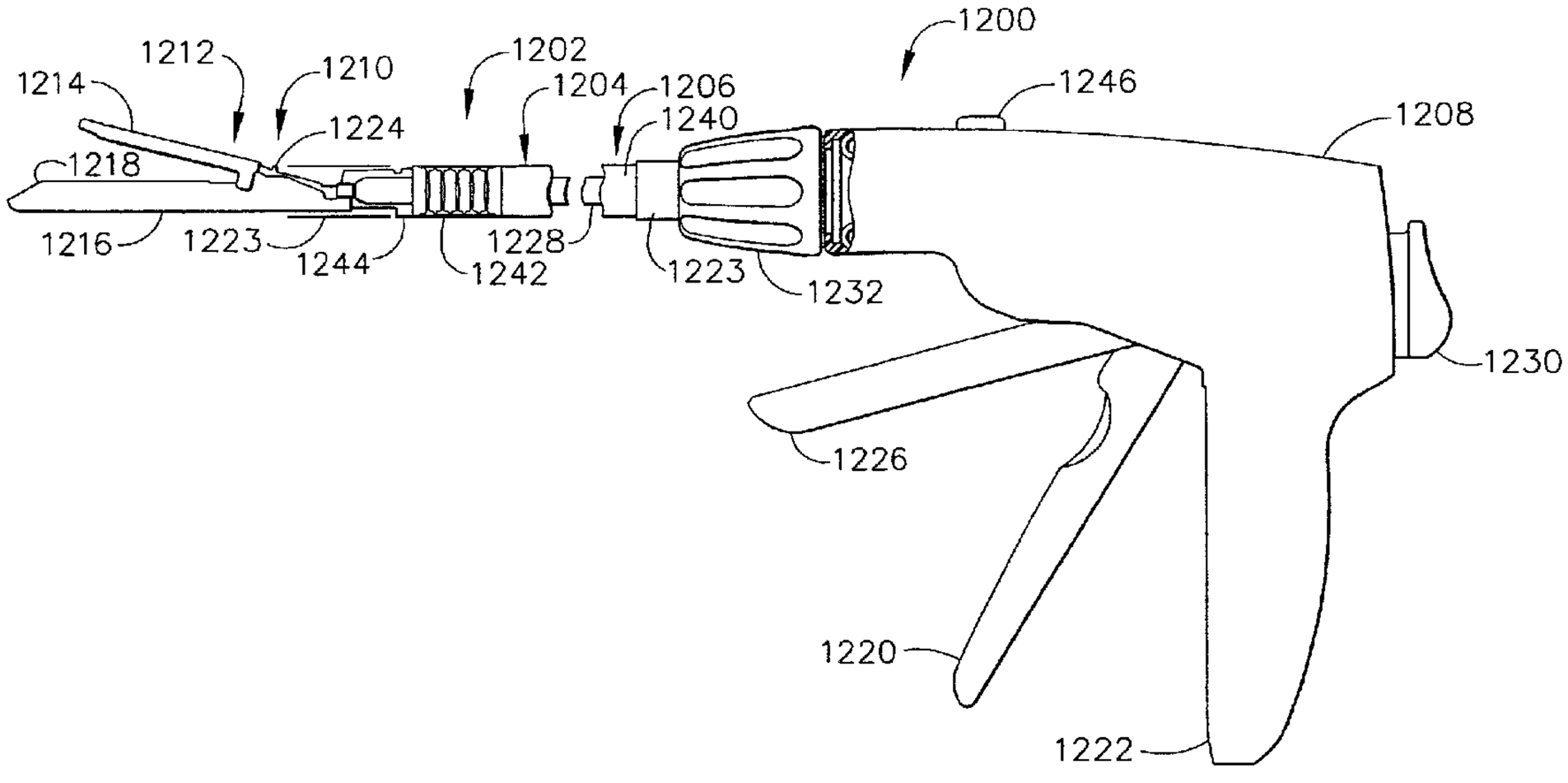
(51) Cl.Int./Int.Cl. *A61B 17/00* (2006.01),
A61B 17/068 (2006.01)

(72) Inventeur/Inventor:
SHELTON, FREDERICK E., IV, US

(73) Propriétaire/Owner:
ETHICON ENDO-SURGERY, INC., US

(74) Agent: NORTON ROSE FULBRIGHT CANADA
LLP/S.E.N.C.R.L., S.R.L.

(54) Titre : INSTRUMENT CHIRURGICAL COMPRENANT UN MECANISME A ARTICULATION ELECTRIQUE
(54) Title: SURGICAL INSTRUMENT INCORPORATING AN ELECTRICALLY ACTUATED ARTICULATION MECHANISM



(57) Abrégé/Abstract:
A surgical instrument particularly suited to endoscopic use articulates an end effector by including an articulation mechanism in an elongate shaft that incorporates an electrically actuated polymer (EAP) actuator for remotely articulating the end effector. In particular, a flexible neck to a frame of the elongate neck may be laterally urged to the left or right by EAP actuators and advantageously locked into an articulated state.

SURGICAL INSTRUMENT INCORPORATING AN ELECTRICALLY ACTUATED ARTICULATION MECHANISM

Abstract of the Invention

A surgical instrument particularly suited to endoscopic use articulates an end effector by including an articulation mechanism in an elongate shaft that incorporates an electrically actuated polymer (EAP) actuator for remotely articulating the end effector. In particular, a flexible neck to a frame of the elongate neck may be laterally urged to the left or right by EAP actuators and advantageously locked into an articulated state.

SURGICAL INSTRUMENT INCORPORATING AN ELECTRICALLY ACTUATED ARTICULATION MECHANISM

Field Of The Invention

[0002] The present invention relates in general to surgical instruments that are suitable for endoscopically inserting an end effector (e.g., endocutter, grasper, cutter, staplers, clip applier, access device, drug/gene therapy delivery device, and an energy device using ultrasound, RF, laser, etc.) to a surgical site, and more particularly to such surgical instruments with an articulating shaft.

Background Of The Invention

[0003] Endoscopic surgical instruments are often preferred over traditional open surgical devices since 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 applier, access device, drug/gene therapy delivery device, and energy device using ultrasound, RF, laser, etc.).

[0004] Positioning the end effector is constrained by the trocar. Generally, these endoscopic surgical instruments include a long shaft between the end effector and a handle portion manipulated by the clinician. This long shaft enables insertion to a desired depth and rotation about the longitudinal axis of the shaft, thereby positioning the end effector to a degree. With judicious placement of the trocar and use of

graspers, for instance, through another trocar, often this amount of positioning is sufficient. Surgical stapling and severing instruments, such as described in U.S. Pat. No. 5,465,895, are an example of an endoscopic surgical instrument that successfully positions an end effector by insertion and rotation.

[0005] More recently. U.S. Pat. Serial No. 10/443,617, "SURGICAL STAPLING INSTRUMENT INCORPORATING AN E-BEAM FIRING MECHANISM" to Shelton et al., filed on 20 May 2003,describes an improved "E-beam" firing bar for severing tissue and actuating staples. Some of the additional advantages include affirmatively spacing the jaws of the end effector, or more specifically a staple applying assembly, even if slightly too much or too little tissue is clamped for optimal staple formation. Moreover, the E-beam firing bar engages the end effector and staple cartridge in a way that enables several beneficial lockouts to be incorporated.

[0006] Depending upon the nature of the operation, it may be desirable to further adjust the positioning of the end effector of an endoscopic surgical instrument. In particular, it is often desirable to orient the end effector at an axis transverse to the longitudinal axis of the shaft of the instrument. The transverse movement of the end effector relative to the instrument shaft is conventionally referred to as "articulation". This is typically accomplished by a pivot (or articulation) joint being placed in the extended shaft just proximal to the staple applying assembly. This allows the surgeon to articulate the staple applying assembly remotely to either side for better surgical placement of the staple lines and easier tissue manipulation and orientation.. This articulated positioning permits the clinician to more easily engage tissue in some instances, such as behind an organ. In addition, articulated positioning advantageously allows an endoscope to be positioned behind the end effector without being blocked by the instrument shaft.

[0007] Approaches to articulating a surgical stapling and severing instrument tend to be complicated by integrating control of the articulation along with the control of closing the end effector to clamp tissue and fire the end effector (i.e., stapling and severing) within the small diameter constraints of an endoscopic instrument. Generally, the three control motions are all transferred through the shaft as longitudinal translations.

For instance, U.S. Pat. No. 5,673,840 discloses an accordion-like articulation mechanism ("flex-neck") that is articulated by selectively drawing back one of two connecting rods through the implement shaft, each rod offset respectively on opposite sides of the shaft centerline. The connecting rods ratchet through a series of discrete positions.

[0008] Another example of longitudinal control of an articulation mechanism is U.S. Pat. No. 5,865,361 that includes an articulation link offset from a camming pivot such that pushing or pulling longitudinal translation of the articulation link effects articulation to a respective side. Similarly, U.S. Pat. No. 5,797,537 discloses a similar rod passing through the shaft to effect articulation.

[0009] In co-pending and commonly owned U.S. Patent Application Ser. No. 10/615,973 "SURGICAL INSTRUMENT INCORPORATING AN ARTICULATION MECHANISM HAVING ROTATION ABOUT THE LONGITUDINAL AXIS" to Frederick E. Shelton IV et al, a rotational motion is used to transfer articulation motion as an alternative to a longitudinal motion.

[0010] While these mechanically communicated articulation motions have successfully enabled an endoscopic surgical stapling and severing instrument to articulate, development trends pose numerous challenges and barriers to entry into the market. Conflicting design objects include a shaft of as small a diameter as possible to reduce the size of the surgical opening yet sufficient strength to perform the several motions (e.g., closing, firing, articulation, rotation, etc.).

[0011] In addition, even though further reduction in cross-sectional size would be desirable, another conflicting desire is to incorporate yet additional functionality at the end effector. For instance, one such additional function is deploying a buttress at the staple site. A buttress is a pair of thin foam or fabric strips that are placed on the anvil and on the cartridge and are stapled into place on either side of the tissue that is transected. It adds structural integrity to the staple line for either extremely thin or thick tissues. Another would be additional enhancements to prevent firing with an improperly closed end effector, empty staple cartridge, missing cartridge, performing a therapeutic or diagnostic treatment by sending energy or fluid to the end effector,

etc. Creating sufficient room in the shaft of the instrument to facilitate such additional function creates an incentive to modify how the end effector is articulated.

[0012] Consequently, a significant need exists for an articulating surgical instrument that incorporates an articulation mechanism that requires less mechanical mechanisms passing through the shaft of the instrument.

Brief Summary of the Invention

[0013] The invention overcomes the above-noted and other deficiencies of the prior art by providing a surgical instrument having an articulating shaft attached between a handle and an end effector. An electroactive polymer (EAP) actuator disposed in an articulation joint of the shaft is responsive to an electrical signal passed through the shaft to effect articulation. Thereby a shaft of advantageously small diameter may be achieved yet with the functionality of remotely controllable actuation.

[0014] In one aspect of the invention, a surgical instrument includes an articulating joint attached between an end effector and a distal end of an elongate shaft. An electrical actuator is positioned to actuate the articulation joint in response to an electrical signal remotely produced in a handle proximally attached to the elongate shaft.

[0015] In another aspect of the invention, a surgical instrument has an elongate shaft having a frame assembly and an encompassing and a longitudinally, slidingly received closure sleeve assembly. A staple applying assembly includes an elongate channel, a staple cartridge engaged in the elongate channel, and an anvil pivotally attached to the elongate channel presenting a staple forming surface to the staple cartridge. An articulation joint is formed in the frame assembly. In particular, a distal frame portion is attached to the elongate channel and a proximal frame portion is pivotally attached to the distal frame portion. A handle attached to a proximal end of the elongate shaft selectively communicates an electrical signal to the elongate shaft to an electroactive polymer actuator connected to the articulation joint that responds thereto to perform articulation of the staple applying assembly. Thus, a surgical stapling and severing instrument is provided that may approach tissue from a desired angle.

[0016] These and other objects and advantages of the present invention shall be made apparent from the accompanying drawings and the description thereof.

Brief Description of the Figures

[0017] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention, and, together with the general description of the invention given above, and the detailed description of the embodiments given below, serve to explain the principles of the present invention.

[0018] FIGURE 1 is a right side view in elevation of a surgical instrument with a closure sleeve assembly cut away to expose an EAP actuated articulation mechanism that articulates a flexible articulating frame ground.

[0019] FIGURE 1A is a top view of the surgical instrument of FIG. 1 articulating to the left.

[0020] FIGURE 2 is a perspective view of a laminate Electroactive Polymer (EAP) composite.

[0021] FIGURE 3 is a perspective view of an EAP plate actuator formed from a stack formed from an adhesively affixed plurality of laminate EAP composites of FIG. 2.

[0022] FIGURE 4 is a perspective view of a cutaway along a longitudinal axis of a contracting EAP fiber actuator.

[0023] FIGURE 5 is a front view in elevation taken in cross section along lines 5-5 of the contracting EAP fiber actuator of FIG. 4.

[0024] FIGURE 6 is a front right perspective view of an EAP actuated articulation joint for the surgical instrument of FIG. 1 with a laterally flexible closure sleeve assembly and a flexible neck frame assembly and a closed staple applying assembly.

[0025] FIGURE 7 is a front right perspective view of the EAP actuated articulation joint and closed staple applying assembly of FIG. 6 with a flexible closure sleeve assembly removed and a flexible neck frame assembly partially exploded.

[0026] FIGURE 8 is a front right exploded perspective view of the EAP actuated articulation joint and staple applying assembly of FIG. 6.

[0027] FIGURE 9 is a front right perspective view of the articulating frame ground of FIG. 1 that incorporates EAP plate actuators and locking strips.

[0028] FIGURE 10 is a top view of the articulating frame ground of FIG. 1A in a left articulated state with a left EAP locking strip shown in phantom in an unlocked actuated state and a locked relaxed state.

[0029] FIGURE 11 is a top view of the articulating frame ground of FIG. 1A in a left articulated state taken in cross section through the EAP plate actuators and EAP locking strips.

[0030] FIGURE 12 is a front view in elevation of the articulating frame ground of FIG. 10 taken in cross section through lines 12-12 through the lateral guide pins.

[0031] FIGURE 13 is a top view of an alternate articulating frame ground for the surgical instrument of FIG. 1 taken in cross section through a plurality of EAP rib spreader actuators.

[0032] FIGURE 14 is a right perspective partially exploded view of an additional alternative articulating frame ground having a plurality of EAP fiber actuators for the surgical instrument of FIG. 1.

[0033] FIGURE 15 is a front view in elevation of the additional alternative articulating frame ground of FIG. 14 taken in cross section along lines 15-15.

[0034] FIGURE 16 is a top view taken in longitudinal cross section of a firing bar passing through an articulation joint of a surgical instrument with the firing bar advantageously laterally guided by support plates of inwardly actuated EAP plate actuators with one sliding end.

[0035] FIGURE 17 is a top view taken in longitudinal cross section of the firing bar passing through an articulated articulation joint of the surgical instrument of FIG. 16.

[0036] FIGURE 18 is a top view taken in longitudinal cross section of a firing bar passing through an articulated articulation joint of a surgical instrument with the firing bar advantageously laterally guided by support plates of outwardly actuated EAP plate actuators with one sliding end.

[0037] FIGURE 19 is a top view taken in longitudinal cross section of a firing bar passing through an articulation joint of a surgical instrument with the firing bar advantageously laterally guided by outwardly actuated EAP support plates having constrained but longitudinally floating hooked ends.

[0038] FIGURE 20 is a top view taken in longitudinal cross section of a firing bar passing through an articulation joint of a surgical instrument with the firing bar advantageously laterally guided by outwardly actuated EAP support plates each having one fixed hooked end and one end springedly longitudinally constrained.

[0039] FIGURE 21 is a top view taken in longitudinal cross section of a firing bar passing through an articulation joint of a surgical instrument with the firing bar advantageously laterally guided by outwardly actuated EAP support plates with each having both ends springedly longitudinally constrained.

[0040] FIGURE 22 is a top view of a flexible articulation joint incorporating the EAP support plates of FIGS. 43-46.

[0041] FIGURE 23 is a front view in elevation of the flexible articulation joint of FIG. 22 taken through lines 23-23.

[0042] FIGURE 24 is a top view of the flexible articulation joint of FIG. 22 articulated to the left.

[0043] FIGURE 25 is a front right perspective view of a flexible articulation joint incorporating the EAP support plates of FIGS. 16- 19 and also including left and right EAP plate articulation actuators.

Detailed Description of the Invention

Surgical Instrument With EAP Actuated Flexneck Articulation Joint.

[0044] In FIG. 1, a surgical instrument{ XE "1200 surgical instrument" } 1200 advantageously incorporates an EAP actuated articulation joint{ XE "1202 EAP actuated articulation joint" } 1202 that is integral to an articulating frame assembly{ XE "1204 articulating frame assembly" } 1204 of an elongate shaft{ XE "1206 elongate shaft" } 1206 that transfers separate closure and firing motions from a

handle{ XE "1208 handle" } 1208 to an end effector{ XE "1210 end effector" } 1210, depicted as a staple applying assembly{ XE "1212 staple applying assembly" } 1212 having a closeable anvil{ XE "1214 closeable anvil" } 1214 that is pivotally attached to an elongate channel{ XE "1216 elongate channel" } 1216 that holds a replaceable staple cartridge{ XE "1218 replaceable staple cartridge" } 1218. The handle 1208 includes a closure trigger{ XE "1220 closure trigger" } 1220 that is squeezed proximally toward a pistol grip{ XE "1222 pistol grip" } 1222 to effect closure of the anvil 1214. It should be appreciated that a closure sleeve assembly{ XE "1223 closure sleeve assembly" } 1223 or other closure means (e.g., EAP actuated anvil, internal longitudinally translating member, etc.) that is not shown acts upon an anvil closure feature{ XE "1224 anvil closure feature" } 1224 to effect opening and closing of the anvil 1214. Once closed and clamped, a more distal firing trigger{ XE "1226 more distal firing trigger" } 1226 is squeezed toward the pistol grip 1222 to effect firing of a firing member{ XE "1228 firing member (firing bar)" } 1228 longitudinally down the elongate shaft 1206 to cause severing of tissue and stapling of the severed ends. Once the firing trigger 1226 is released, a closure release button{ XE "1230 closure release button" } 1230 is depressed along with a slight depression of the closure trigger 1220 to release clamping components followed by release of the closure trigger 1220 to open the anvil 1214 and allow release of the stapled and severed tissue. A rotation knob{ XE "1232 rotation knob" } 1232 allows selective rotation about a longitudinal axis of the elongate shaft 1206.

[0045] The articulating frame assembly 1204 includes a proximal frame ground{ XE "1240 proximal frame ground" } 1240 proximally and rotatably attached to the handle 1208 and that is distally attached to an articulating frame ground{ XE "1242 articulating frame ground" } 1242 that in turn is attached to a distal frame ground{ XE "1244 distal frame ground" } 1244 that supports the end effector 1210. An articulation control{ XE "1246 articulation control" } 1246 on the handle 1208 advantageously allows the selection of articulating the articulating frame ground 1242 by activating appropriate electrical signals thereto, such as depicted in FIG. 1A when a leftward articulation has been selected by articulation control 1246. It should be appreciated that the articulation control 1246 may advantageously include manual and/or

automatic disengagement of an articulation lock for the articulating frame ground 1242.

Handle.

[0046] In FIG. 1, the staple applying assembly 12 accomplishes the functions of clamping onto tissue, driving staples and severing tissue by two distinct motions transferred longitudinally down the shaft 1206 over a shaft frame (not shown in FIG. 1 but described below regarding FIG. 7). This shaft frame assembly is proximally attached to the handle 14 and coupled for rotation with the rotation knob 30. An illustrative multi-stroke handle 14 for the surgical stapling and severing instrument 10 of FIG. 1 is described in greater detail in the co-pending and co-owned U.S. patent applications entitled "SURGICAL STAPLING INSTRUMENT INCORPORATING A MULTISTROKE FIRING POSITION INDICATOR AND RETRACTION MECHANISM" to Swayze and Shelton, Ser. No. 10/674,026, and entitled "SURGICAL STAPLING INSTRUMENT INCORPORATING A MULTI-STROKE FIRING MECHANISM WITH AUTOMATIC END OF FIRING TRAVEL RETRACTION", Ser. No. 11/052,632, filed on February 7, 2005 to Kevin Doll, Jeffrey S. Swayze, Frederick E. Shelton IV, Douglas Hoffman, and Michael Setser, with additional features and variation as described herein.

[0047] While a multi-stroke handle 14 advantageously supports applications with high firing forces over a long distance, applications consistent with the present invention may incorporate a single firing stroke, such as described in co-pending and commonly owned U.S. patent application "SURGICAL STAPLING INSTRUMENT HAVING SEPARATE DISTINCT CLOSING AND FIRING SYSTEMS" to Frederick E. Shelton IV, Michael E. Setser, and Brian J. Hemmelgarn, Ser. No. 10/441,632.

Electroactive Polymers.

[0048] Electroactive polymers (EAPs) are a set of conductive doped polymers that change shape when an electrical voltage is applied. In essence, the conductive polymer is paired to some form of ionic fluid or gel and electrodes. Flow of the ions

from the fluid/gel into or out of the conductive polymer is induced by the voltage potential applied and this flow induces the shape change of the polymer. The voltage potential range from 1V to 4kV depends on the polymer and ionic fluid used. Some of the EAPs contract when voltage is applied and some expand. The EAPs may be paired to mechanical means such as springs or flexible plates to change the effect that is caused when the voltage is applied.

[0049] There are two basic types and multiple configurations of each type. The two basic types are a fiber bundle and a laminate version. The fiber bundle consists of fibers around 30-50 microns. These fibers may be woven into a bundle much like textiles and are often called EAP yarn because of this. This type of EAP contracts when voltage is applied. The electrodes are usually a central wire core and a conductive outer sheath, which also serve to contain the ionic fluid that surrounds the fiber bundles. An example of a commercially available fiber EAP material is manufactured by Santa Fe Science and Technology, is sold as PANION™ fiber and is described in U.S. Pat. No. 6,667,825.

[0050] The other type is a laminate structure. It consists of a layer of EAP polymer, a layer of ionic gel and two flexible plates that are attached to either side of the laminate. When a voltage is applied, the square laminate plate expands in one direction and contracts in the perpendicular direction. An example of a commercially available laminate (plate) EAP material is manufactured by Artificial Muscle Inc, a division of SRI Laboratories. Plate EAP material is also available from EAMEX of Japan and referred to as thin film EAP.

[0051] It should be noted that EAPs do not change volume when energized, they merely expand or contract in one direction while doing the opposite in the transverse direction. The laminate version may be used in its basic form by containing one side against a rigid structure and using the other much like a piston. It may also be adhered to either side of a flexible plate. When one side of the flexible plate EAP is energized, it would expand, flexing the plate in the opposite direction. This allows the plate to be flexed in either direction, depending on which side is energized.

[0052] An EAP actuator usually is made up of numerous layers or fibers bundled together to work in cooperation. The mechanical configuration of the EAP determines the EAP

actuator and its capabilities for motion. The EAP may be formed into long stands and wrapped around a single central electrode. A flexible exterior outer sleeve will form the other electrode for the actuator as well as contain the ionic fluid necessary for the function of the device. In this configuration, when the electrical filed is applied to the electrodes, the strands of EAP would shorten. This configuration of EAP actuator is called a fiber EAP actuator. Likewise, the laminate configuration may be placed in numerous layers on either side of a flexible plate or merely in layers on itself to increase its capabilities. Typical fiber structures have an effective strain of 2-4% where the typical laminate version achieves 20-30% utilizing much higher voltages.

[0053] In FIG. 2, a laminate EAP composite{ XE "0100 laminate EAP composite" } 100 is depicted as being formed from a positive plate electrode layer{ XE "0102 positive plate electrode later" } 1302 attached to an EAP layer{ XE "0104 EAP layer" } 104, which in turn is attached to an ionic cell layer{ XE "0106 ionic cell layer" } 106, which in turn is attached to a negative plate electrode layer{ XE "0108 negative plate electrode layer" } 108. In FIG. 3, a plurality of five laminate EAP composites 100 are affixed in a stack by adhesive layers{ XE "0110 adhesive layers" } 110 therebetween to form an EAP plate actuator{ XE "0120 EAP plate actuator" } 120. It should be appreciated that opposing EAP actuators 120 may be formed that can be selected to bend in either direction.

[0054] In FIGS. 4-5, a contracting EAP fiber actuator{ XE "0140 contracting EAP fiber actuator" } 140 includes a longitudinal platinum cathode wire{ XE "0142 longitudinal platinum cathode wire" } 142 that passes through an insulative polymer proximal end cap{ XE "0144 insulative polymer proximal end cap" } 144 through an elongate cylindrical cavity{ XE "0146 elongate cylindrical cavity" } 146 formed within a plastic cylinder wall{ XE "0148 plastic cylinder wall (anode)" } 148 that is conductively doped to serve as a positive anode. A distal end of the platinum cathode wire 142 is embedded into an insulative polymer distal end cap{ XE "0150 insulative polymer distal end cap" } 150. A plurality of contracting polymer fibers{ XE "0152 contracting polymer fibers" } 152 are arranged parallel with and surrounding the cathode wire 142 and have their ends embedded into respective end caps 144, 150. The plastic cylinder wall 148 is peripherally attached around respective end caps 144, 150 to enclose the cylindrical cavity 146 to seal in ionic fluid or gel{ XE "0154 ionic

fluid or gel" } 154 that fills the space between contracting polymer fibers 152 and cathode wire 142. When a voltage is applied across the plastic cylinder wall (anode) 148 and cathode wire 142, ionic fluid enters the contracting polymer fibers 152, causing their outer diameter to swell with a corresponding contraction in length, thereby drawing the end caps 144, 150 toward one another.

EAP Actuated Articulation Joint.

[0055] In FIGS. 6-7, a surgical severing and stapling instrument{ XE "0200 surgical severing and stapling instrument" } 200 includes an EAP actuated articulation joint{ XE "0202 EAP actuated articulation joint" } 202 that is formed in its elongate shaft{ XE "0204 elongate shaft" } 204 proximate to the end effector, which is illustrated by the surgical stapling and severing assembly 12 that advantageously responds to separate closure and firing motions that are transferred longitudinally by the elongate shaft 204. The EAP actuated articulation joint 202 advantageously adds the desirable clinical flexibility of articulating the staple applying assembly 12.

[0056] In the illustrative version of FIGS. 6-8, the EAP actuated articulation joint 202 is more particularly a flexible closure and pivoting frame articulation joint{ XE "0210 flexible closure and pivoting frame articulation joint" } 210, which in FIG. 6 is shown to include a flexible closure sleeve assembly{ XE "0212 flexible closure sleeve assembly" } 212 having a proximal closure tube{ XE "0214 proximal closure tube" } 214 and distal closure ring{ XE "0216 distal closure ring" } 216 connected by a flexible closure tube{ XE "0218 flexible closure tube" } 218. Left and right longitudinal rows of vertical slits{ XE "0220, 0222 left and right longitudinal rows of vertical slits" } 220, 222 formed in the flexible closure tube 218 allow flexing to the right or to the left for articulation, yet an uninterrupted top longitudinal band{ XE "0224 uninterrupted top longitudinal band" } 224 and bottom longitudinal band (not shown) transfer a longitudinal closure motion regardless of an amount of such flexing. In particular, a top portion of the distal closure ring 216 includes a horseshoe aperture{ XE "0226 horseshoe aperture" } 226 that engages an anvil closure feature{ XE "0228 anvil closure feature" } 228 of the anvil 22. In FIGS. 7-8, the anvil 22 includes laterally projecting pivot pins{ XE "0230 laterally projecting pivot pins" } 230 at its proximal end that pivotally engage pivot apertures{ XE "0232 pivot

apertures" } 232 formed near the proximal end of the elongate channel 18. The slightly more distal anvil closure feature 228 thus imparts a closing motion when the flexible closure sleeve assembly 212 moves distally and imparts an opening motion when moving proximally. The flexible closure tube 218 may bend along the length of the left and right longitudinal rows of vertical slits 220, 222, thus accommodating an encompassed laterally flexible frame assembly{ XE "0234 single pivot frame assembly" } 234 of the flexible closure and pivoting frame articulation joint 210 when articulated.

[0057] In FIGS. 6-8, the laterally flexible frame assembly 234 includes a proximal frame ground 236 that includes a distally open cylindrical end 237 with top slot 238 that engages a top key tab 239 on a proximal end of a flexible frame member 240. A distal end of the flexible frame member 240 in turn has a distally presented top key tab 241 that is received within a top slot 242 in a proximally open cylindrical end 243 of a distal frame ground 250. Left and right vertical slots 244, 245 in the flexible frame member 240 allow for EAP actuators 245 that are inserted into these slots 244, 245 to assert an articulation motion to the flexible frame assembly 234.

[0058] In FIG. 8, an implement portion{ XE "0260 implement portion" } 260 of the surgical instrument 200, formed by the elongate shaft 16 and staple applying assembly 12, further includes a firing bar{ XE "0270 firing bar" } 270 that longitudinally translates through the proximal frame ground 218, through the flexible closure and pivoting frame articulation joint 210, and through a firing slot{ XE "0272 firing slot in distal frame ground" } 272 in the distal frame ground 250 into the staple applying assembly 12. Distal and proximal square apertures{ XE "0274, 2076 distal and proximal square apertures" } 274, 276, formed on top of the distal frame ground 250, define a clip bar{ XE "0278 clip bar" } 278 therebetween that receives a top arm{ XE "0280 top arm of spring clip" } 280 of a clip spring{ XE "0282 clip spring" } 282 whose lower, distally extended arm{ XE "0284 lower, distally extended arm" } 284 asserts a downward pressure on a raised portion{ XE "0286 raised portion of firing bar" } 286 along an upper portion of the firing bar 270 corresponding to the empty/missing cartridge lockout portion of firing travel.

[0059] With particular reference to FIG. 8, a distally projecting end of the firing bar 270 is attached to an E-beam{ XE "0288 E-beam" } 288 that assists in spacing the anvil 22 from the staple cartridge 20, severs tissue, and actuates the staple cartridge 20. The staple cartridge 20 includes a molded cartridge body{ XE "0290 molded cartridge body" } 290 that holds a plurality of staples resting upon staple drivers{ XE "0292 staple drivers" } 292 within respective upwardly open staple apertures{ XE "0294 upwardly open staple apertures" } 294. A wedge sled{ XE "0296 wedge sled" } 296 is driven distally by the E-beam 288, sliding upon a cartridge tray{ XE "0298 cartridge tray" } 298 that holds together the various components of the replaceable staple cartridge 20. The wedge sled 296 upwardly cams the staple drivers 292 to force out the staples into deforming contact with the anvil 22 while a cutting surface{ XE "0300 cutting surface" } 300 of the E-beam 288 severs clamped tissue. It should be appreciated that upper pins{ XE "0302 upper pins" } 302 of the E-beam 288 engage the anvil 22 during firing while middle pins{ XE "0304 middle pins" } 304 and a bottom foot{ XE "0306 bottom foot" } 306 engage the respective top and bottom surfaces of a longitudinal slot{ XE "0308 longitudinal slot in channel" } 308 formed in the elongate channel 18, with a corresponding longitudinal opening{ XE "0310 longitudinal opening in tray" } 310 in the cartridge tray 298 and a rearwardly open vertical slot{ XE "0312 rearwardly open vertical slot" } 312 in the cartridge body 290. Thereafter, the firing bar 270 is retracted proximally, retracting as well the E-beam 288, allowing the anvil 22 to be opened to release the two stapled and severed tissue portions (not shown).

[0060] The staple applying assembly 12 is described in greater detail in co-pending and commonly-owned U.S. Patent Application Ser. No. 10/955,042, "ARTICULATING SURGICAL STAPLING INSTRUMENT INCORPORATING A TWO-PIECE E-BEAM FIRING MECHANISM" to Frederick E. Shelton IV, et al., filed 30 September 2004.

[0061] As an alternative to the flexible frame assembly 234, in FIGS. 9-12, the articulating frame ground 1242 incorporates an EAP actuating system{ XE "1300 EAP actuating system" } 1300 that uses left and right EAP plate actuators{ XE "1302, 1304 left and right EAP plate actuators" } 1302, 1304 that pass through respective left

and rectangular actuator recesses{ XE "1306, 1308 left and rectangular actuator recesses" } 1306, 1308 (FIGS. 11-12) in each lateral side of a generally cylindrical resilient frame body{ XE "1310 generally cylindrical resilient frame body" } 1310. A rectangular knife slot{ XE "1312 rectangular knife slot" } 1312 is formed in the resilient frame body 1310 aligned between the left and right rectangular actuator recesses 1306, 1308 for guiding a firing bar{ XE "1314 firing bar" } 1314 that is a distal portion of the firing member 1228.

[0062] Continuous top and bottom longitudinal bands{ XE "1320 continuous top and bottom longitudinal bands" } 1320 (FIGS. 9-10) of the resilient frame body 1310 maintain a longitudinal amount of travel for the firing bar 1314 when the articulating frame ground 1242 is either straight or articulated. To advantageously allow forming of the resilient frame body 1310 from a homogenous material that does not significantly compress along its longitudinal axis, left and right pluralities of longitudinally aligned vertical recesses{ XE "1322, 1324 left and right pluralities of longitudinally aligned vertical recesses" } 1322, 1324 intersect respectively with the left and right EAP actuator recesses 1306, 1308. Each vertical recess 1322, 1324 includes a rectangular through hole{ XE "1326 rectangular through hole" } 1326 that passes from top to bottom through the resilient frame body 1310 parallel with and laterally offset from both the rectangular knife slot 1312 and the appropriate one of either the left or right rectangular actuator recess 1306, 1308. Each rectangular through hole 1326 communicates laterally with a narrowed lateral gap{ XE "1328 narrowed lateral gap" } 1328. Adjacent vertical recesses 1322, 1324 define therebetween a rib{ XE "1330 rib" } 1330 that has a narrow inner wall{ XE "1332 narrow inner wall" } 1332, which allows lateral bending of the continuous top and bottom longitudinal bands 1320, and a thicker curved outer slice{ XE "1334 thicker curved outer slice" } 1334 that supports the respective one of the EAP plate actuators 1302, 1304 and limits the amount of articulation that may be achieved in that direction before the narrowed lateral gaps 1328 collapse fully as one or both EAP plate actuators 1302, 1304 are activated to bend in a selected direction. In FIG. 10, for instance, the left EAP plate actuator 1302 is activated to actuate to the left with the right EAP plate actuator 1304 stretching in response. It should be appreciated that the left and right EAP plate actuators 1302, 1304 may alternatively contract or expand

when electrically activated to create a pull or a push respectively within the left and right rectangular actuator recesses 1306, 1308.

[0063] In FIGS. 11-12, the articulating frame ground 1242 advantageously includes an EAP articulation locking mechanism{ XE "1350 EAP articulation locking mechanism" } 1350 that selectively holds the resilient frame body 1310 in an articulated left or an articulated right condition. To that end, a left locking passage{ XE "1352 left locking passage" } 1352 is defined passing through the left plurality of rectangular through holes 1326 proximate to their leftmost outer portion, allowing a left ridged EAP locking strip{ XE "1354 left ridged EAP locking strip" } 1354 to pass therethrough. Similarly, a right locking passage{ XE "1356 right locking passage" } 1356 is defined passing through the right plurality of rectangular through holes 1326 proximate to their rightmost outer portion, allowing a right ridged EAP locking strip{ XE "1358 right ridged EAP locking strip" } 1358. Along their respective outermost surface{ XE "1360 outermost surface" } 1360 of both the left and right ridged EAP locking strips 1354, 1358, a plurality of longitudinally spaced vertical blocking ridges{ XE "1362 longitudinally spaced vertical blocking ridges" } 1362 are longitudinally spaced and sized to define, in conjunction with the geometry of the ribs 1330, to lock at a desired articulation amount. In particular, when the flexible frame ground 1242 articulates toward the opposite side of a respective ridged EAP locking strip 1354, 1358, the ribs 1330 on that side arc away from one another, as depicted in FIG. 11 in articulating to the left. Once the ribs 1330 have reached a spacing sufficient for locking (i.e., wider than the longitudinal width of the vertical blocking ridges 1362), the right ridged EAP locking strip 1358 is biased outwardly to snap its ridges 1362 between adjacent thickened curved outer slices 1334 of adjacent ribs 1330. Activating the right ridged EAP locking strip 1358 causes contraction that unlocks the right ridged EAP locking strip 1358. In FIG. 12, lateral upper and lower guide pins{ XE "1370, 1372 lateral upper and lower guide pins" } 1370, 1372 pass above and below the rectangular knife slot 1312 to preserve lateral alignment.

[0064] In FIG 13, the articulating frame ground 1242 incorporates an EAP actuating system{ XE "1400 EAP actuating system" } 1400 that uses a left plurality left and right EAP rib spreader plate actuator{ XE "1402 EAP rib spreader actuators" } 1402 that resides between an opposing pair of distally and proximally open rectangular

recesses{ XE "1404, 1406 opposing pair of distally and proximally open rectangular recesses" } of a resilient frame body{ XE "1408 resilient frame body" } 1408. Each opposing pair of distally and proximally open rectangular actuator recesses 1404, 1406 respectively are formed in an adjacent pair (proximal/distal) of laterally defined ribs{ XE "1410 laterally defined ribs" } 1410. Each rib 1410 includes a vertical slot{ XE "1412 vertical slot" } 1412 that is open outwardly laterally along its height with a wider rectangular through hole{ XE "1414 wider rectangular through hole" } 1414 more inwardly positioned that narrows into an outer vertical slot{ XE "1416 outer vertical slot" } 1416. Each rib 1410 thus includes a thin inner wall{ XE "1418 thin inner wall" } 1418 that connects to upper and lower longitudinal continuous bands{ XE "1420 upper and lower longitudinal continuous bands" } 1420. A rectangular knife slot{ XE "1422 rectangular knife slot" } 1422 is formed laterally along the longitudinal centerline. Left and right ridged EAP locking strips 1354, 1358 as described above advantageously relax to an expanded curved shape on the expanded side of the articulating frame ground 1242 to lock, with longitudinal alignment maintained by lateral guide pins 1370.

[0065] In FIGS. 14-15, the articulating frame ground 1242 incorporates a further alternative EAP actuating system{ XE "1500 alternative EAP actuating system" } 1500 into a resilient frame body{ XE "1502 resilient frame body" } 1502 that includes longitudinally aligned EAP fiber actuators{ XE "1504 longitudinally aligned EAP fiber actuators" } 1504 arranged in left and right vertical stacks{ XE "1506, 1508 left and right vertical stacks" } 1506, 1508 that pass through a respectively left and right plurality of lateral ribs{ XE "1510 left and right plurality of lateral ribs" } 1510 each having a thin inner vertical wall{ XE "1512 thin inner vertical wall" } 1512 that connects to continuous longitudinal top and bottom bands{ XE "1514 continuous longitudinal top and bottom bands" } 1514 to facilitate lateral bending thereof. Each rib 1510 widens laterally to a thick outer slice{ XE "1516 thick outer slice" } 1516 that is dimensioned for the limitation of articulation to that side. Each thick outer slice 1516 includes vertical aligned longitudinal through holes{ XE "1518 vertical aligned longitudinal through holes " } 1518 for allowing the EAP fiber actuators 1504 to pass through. Distal and proximal lateral covers{ XE "1522, 1524 distal and proximal lateral covers" } 1520, 1522 longitudinally flank the ribs 1510 to cover respective

termination ends of the EAP fiber actuators 1504. A laterally centered knife slot{ XE "1524 laterally centered knife slot" } 1524 is formed in the resilient frame body 1502 for the firing bar 1314. Contracting a selected vertical stack 1506, 1508 of EAP fiber actuators 1504 causes articulation to that side with the nonactuated vertical stack 1506, 1508 passively elongating in response thereto.

EAP Support Plates For Firing Bar.

[0066] In FIG. 16, an articulation joint{ XE "2000 articulation joint" } 2000 for a surgical instrument{ XE "2002 surgical instrument" } 2002 includes a pair of EAP support plates{ XE "2004, 2006 EAP support plates" } 2004, 2006 that laterally support a firing bar{ XE "2008 firing bar" } 2008 to minimize binding and buckling when articulated. Each support plate 2004, 2006 includes a structural member{ XE "2010 structural member" } 2010 (e.g., rigid polymer, metal) that includes a laterally widened end{ XE "2012 laterally widened end" } 2012 that is captured within a correspondingly sized recess{ XE "2014 correspondingly sized recess" } 2014 in a first frame ground{ XE "2016 first frame ground" } 2016 and a straight end{ XE "2018 straight end" } 2018 that is slidingly received within a second frame ground{ XE "2020 second frame ground" } 2020. A longitudinally expansive EAP laminate{ XE "2022 longitudinally expansive EAP laminate" } 2022 covers an internal surface of each support plate 2004, 2006.

[0067] In FIG. 17, the articulation joint 2000 is articulated to one lateral side, causing the firing bar 2008 to overshoot an articulated longitudinal axis{ XE "2024 articulated longitudinal axis" } 2024 and come into contact with support plate 2006. Lateral support therefrom prevents a blow out of the firing bar 2008 out of the articulation joint 2000 and/or allows fabrication of a more flexible firing bar 2008 with thus reduced force to articulate. In addition, the EAP laminates 2022 on each support plate 2004, 2006 are activated as necessary to control the amount of curvature of both to preserve a desired spacing therebetween for the firing bar 2008. The straight ends 2018 slide in the second frame ground portion 2020 to accommodate the reduced travel required of the inner support plate 2004 as compared to the outer support plate 2006. The EAP laminate 2022 may further provide cushioning and low surface friction characteristics that assist in laterally guiding the firing bar 2008.

[0068] In FIG. 18, an alternative articulation joint{ XE "2100 articulation joint" } 2100 for a surgical instrument{ XE "2102 surgical instrument" } 2102 includes a pair of EAP support plates{ XE "2104, 2106 EAP support plates" } 2104, 2106 that laterally support a firing bar{ XE "2108 firing bar" } 2108 to minimize binding and buckling when articulated. Each support plate 2104, 2106 includes a structural member{ XE "2110 structural member" } 2110 (e.g., rigid polymer, metal) that includes a laterally widened end{ XE "2112 laterally widened end" } 2112 that is captured within a correspondingly sized recess{ XE "2114 correspondingly sized recess" } 2114 in a first frame ground{ XE "2116 first frame ground" } 2116 and a straight end{ XE "2118 straight end" } 2118 that is slidingly received within a second frame ground{ XE "2120 second frame ground" } 2120. A longitudinally expansive EAP laminate{ XE "2122 longitudinally expansive EAP laminate" } 2122 covers an outer surface of each support plate 2104, 2106. The articulation joint 2100 is articulated to one lateral side, causing the firing bar 2108 to overshoot an articulated longitudinal axis{ XE "2124 articulated longitudinal axis" } 2124 and come into contact with support plate 2106. Lateral support therefrom prevents a blow out of the firing bar 2108 out of the articulation joint 2100 and/or allows fabrication of a more flexible firing bar 2108 with thus reduced force to articulate. In addition, the EAP laminates 2122 on each support plate 2104, 2106 are activated as necessary to control the amount of curvature of both to preserve a desired spacing therebetween for the firing bar 2108. The straight ends 2118 slide in the second frame ground portion 2120 to accommodate the reduced travel required of the inner support plate 2104 as compared to the outer support plate 2106. Placement of the EAP laminates 2122 away from contact from the firing bar 2108 may have advantages such as reducing wear to the EAP laminates 2122.

[0069] In FIG. 19, an additional alternative articulation joint{ XE "2200 articulation joint" } 2200 for a surgical instrument{ XE "2202 surgical instrument" } 2202 includes a pair of EAP support plates{ XE "2204, 2206 EAP support plates" } 2204, 2206 that laterally support a firing bar{ XE "2208 firing bar" } 2208 to minimize binding and buckling when articulated. Each support plate 2204, 2206 includes a structural member{ XE "2210 structural member" } 2210 (e.g., metal) that includes a first outwardly tabbed end{ XE "2212 outwardly tabbed end" } 2212 that is

constrained and longitudinally free floating within a first inwardly open recess{ XE "2214 first inwardly recess" } 2214 in a first frame ground{ XE "2216 first frame ground" } 2216 and a second outwardly tabbed end{ XE "2218 second outwardly tabbed end" } 2218 that is constrained and longitudinally free floating within a second inwardly open recess{ XE "2220 second inwardly open recess" } 2220 of a second frame ground{ XE "2222 second frame ground" } 2222. A longitudinally expansive EAP laminate{ XE "2224 longitudinally expansive EAP laminate" } 2224 covers an inner surface of each support plate 2204, 2206.

[0070] In FIG. 20, yet an additional alternative articulation joint{ XE "2300 articulation joint" } 2300 for a surgical instrument{ XE "2302 surgical instrument" } 2302 includes a pair of EAP support plates{ XE "2304, 2306 EAP support plates" } 2304, 2306 that laterally support a firing bar{ XE "2308 firing bar" } 2308 to minimize binding and buckling when articulated. Each support plate 2304, 2306 includes a structural member{ XE "2310 structural member" } 2310 (e.g., metal) that includes a first outwardly tabbed end{ XE "2312 outwardly tabbed end" } 2312 that is fixed with an inwardly open slot{ XE "2314 inwardly open slot" } 2314 in a first frame ground{ XE "2316 first frame ground" } 2316 and a second outwardly tabbed end{ XE "2318 second outwardly tabbed end" } 2318 that is constrained and longitudinally free floating within an inwardly open recess{ XE "2320 inwardly open recess" } 2320 of a second frame ground{ XE "2322 second frame ground" } 2322. A longitudinally expansive EAP laminate{ XE "2324 longitudinally expansive EAP laminate" } 2324 covers an inner surface of each support plate 2304, 2306. A pair of compression springs{ XE "2326, 2328 compression springs" } 2326, 2328 are longitudinally aligned within the inwardly open recess 2320 biasing the second outwardly tabbed end 2318 of each support plate 2304, 2306 to a neutral position therein.

[0071] In FIG. 21, yet a further alternative articulation joint{ XE "2400 articulation joint" } 2400 for a surgical instrument{ XE "2402 surgical instrument" } 2402 includes a pair of EAP support plates{ XE "2404, 2406 EAP support plates" } 2404, 2406 that laterally support a firing bar{ XE "2408 firing bar" } 2408 to minimize binding and buckling when articulated. Each support plate 2404, 2406 includes a structural member{ XE "2410 structural member" } 2410 (e.g., metal) that includes a first outwardly tabbed end{ XE "2412 first outwardly tabbed end" } 2412 that is

constrained but longitudinally free floating with a first inwardly open recess{ XE "2414 first inwardly open recess" } 2414 in a first frame ground{ XE "2416 first frame ground" } 2416 and a second outwardly tabbed end{ XE "2418 second outwardly tabbed end" } 2418 that is constrained and longitudinally free floating within a second inwardly open recess{ XE "2420 second inwardly open recess" } 2420 of a second frame ground{ XE "2422 second frame ground" } 2422. A longitudinally expansive EAP laminate{ XE "2424 longitudinally expansive EAP laminate" } 2424 covers an inner surface of each support plate 2404, 2406. A pair of compression springs{ XE "2426, 2428 compression springs" } 2426, 2428 are longitudinally aligned within the first inwardly open recess 2414 biasing the first outwardly tabbed end 2412 of each support plate 2404, 2406 to a neutral position therein. Another pair of compression springs{ XE "2430, 2432 compression springs" } 2430, 2432 are longitudinally aligned within the second inwardly open recess 2420 biasing the second outwardly tabbed end 2418 of each support plate 2404, 2406 to a neutral position therein.

[0072] In FIGS. 22-25, yet a further alternative articulation joint{ XE "2500 further alternative articulation joint" } 2500 for a surgical instrument{ XE "2502 surgical instrument" } 2502 that incorporates EAP support plates{ XE "2504, ,2506 EAP support plates" } 2504, 2506 resides on each lateral side of a firing bar{ XE "2508 firing bar" } 2508 in a knife slot{ XE "2510 knife slot" } 2510 of a resilient frame body{ XE "2512 resilient frame body" } 2512 of an articulating frame ground{ XE "2514 articulating frame ground" } 2514 and is proximally coupled to a proximal frame ground{ XE "2516 proximal frame ground" } 2516 and distally coupled to a distal frame ground{ XE "2518 distal frame ground" } 2518. A left EAP plate actuator{ XE "2520 left EAP plate actuator" } 2520 passes through a left plurality of lateral ribs{ XE "2522 left plurality of lateral ribs" } 2522 formed in the resilient frame body 2512. A right EAP plate actuator{ XE "2524 right EAP plate actuator" } 2524 passes through a right plurality of lateral ribs{ XE "2526 right plurality of lateral ribs" } 2526. Each EAP plate actuator 2520, 2524 extends proximally into the proximal frame ground 2516, includes an outer EAP laminate layer{ XE "2528 outer EAP laminate layer" } 2528 attached to an inner plate{ XE "2530 inner plate" } 2530 and is configured to actuate when electrically energized to bend the distal frame round 2518 toward the other side. The resilient frame body 2512 includes proximal inwardly

open recesses{ XE "2532 proximal inwardly open recesses" } 2532 that grip proximal, outwardly curved ends{ XE "2534 proximal, outwardly curved ends" } 2534 of each support plate 2504, 2506. Distal straight ends 2536{ XE "2536 distal straight ends 2536" } of each support plate 2504, 2506 are allowed to slide out of the knife slot 2510 to adjust for changes in travel for articulation, as depicted in FIG. 24.

[0073] 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.

[0074] What is claimed is:

Claims

1. A surgical instrument, comprising:

an end effector;

an elongate shaft;

an articulation joint comprising an upper band and a lower band each formed of a flexible and longitudinally incompressible material and a plurality of left vertical ribs and a plurality of right vertical ribs, each rib connected on a respective lateral side between the upper and lower bands;

at least one right electroactive polymer actuator attached to the right plurality of vertical ribs and at least one left electroactive polymer actuator attached to the left plurality of vertical ribs, each responsive to an electrical signal to actuate; and

a handle portion attached to a proximal end of the elongate shaft and containing control circuitry operatively configured to produce the electrical signal.

2. The surgical instrument of claim 1, wherein the left plurality of ribs includes a left longitudinal actuator recess that receives the left electroactive polymer actuator, the right plurality of ribs including a right longitudinal actuator recess that receives the right electroactive polymer actuator.

3. The surgical instrument of claim 2, wherein the left and right electroactive polymer actuators each comprise a plate actuator operably configured to bend in at least one lateral direction when energized.

4. The surgical instrument of claim 2, wherein the left and right electroactive polymer actuators each comprise at least one electroactive polymer fiber actuator operably configured to longitudinally contract when activated, the respective distal and proximal ends of the left and right electroactive polymer fiber actuators being attached to respective distal and proximal ends of the articulation joint.

5. The surgical instrument of claim 1, further comprising a plurality of left electroactive polymer stack actuators, each positioned between adjacent ones of the plurality of left vertical ribs and comprising a plurality of right electroactive polymer stack actuators, each positioned between adjacent ones of the plurality of right vertical ribs.

6. The surgical instrument of claim 5, wherein the pluralities of left and right electroactive polymer stack actuators are operatively configured to longitudinally expand upon activation to urge the adjacent ribs apart and to resiliently compress upon deactivation.

7. The surgical instrument of claim 5, wherein the pluralities of left and right electroactive polymer stack actuators are operatively configured to longitudinally contract upon activation to urge the adjacent ribs together and to resiliently expand upon deactivation.

8. The surgical instrument of claim 1, wherein each plurality of left and right vertical ribs includes a locking recess, the articulation joint further comprising a left locking band and a right locking band, each positioned in the respective left and right locking recess, each locking band including an electroactive polymer locking actuator operably configured to change the longitudinal length of the locking band and including a plurality of locking projections longitudinally registered for insertion between adjacent ribs when both the adjacent ribs and the locking band are in a longitudinally expanded state to thereby maintain the ribs in the expanded spacing.

9. The surgical instrument of claim 1, wherein the end effector comprises a lower jaw and a pivotally attached upper jaw.

10. The surgical instrument of claim 9, wherein the end effector further comprises a stapling and severing assembly actuated by a firing bar, the handle portion proximally attached to the firing bar and operably configured to impart longitudinal firing motion to the firing bar, the elongate shaft and articulating joint further comprising a firing bar guide supporting the firing bar through the articulation joint.

11. The surgical instrument of claim 10, wherein the lower jaw comprises an elongate channel containing a staple cartridge and the pivotally attached upper jaw comprises an anvil presenting a staple forming surface.

12. The surgical instrument of claim 11, wherein the elongate shaft further comprises:

a frame assembly comprising a proximal frame portion attached between the handle portion and the articulation joint and a distal frame portion attached between the articulation joint and the elongate channel; and

a closure sleeve assembly encompassing the frame assembly and articulation joint, comprising a distal closure tube portion engaged to the anvil, a proximal closure tube portion coupled to the handle portion, and a laterally flexible closure sleeve attached therebetween encompassing the articulation joint;

wherein the handle portion is operably configured to longitudinally translate the closure sleeve assembly to effect closure of the anvil.

13. The surgical instrument of claim 12, wherein the flexible closure sleeve comprises a cylindrical sleeve formed of a resilient material and including left and right rows of vertical slits.

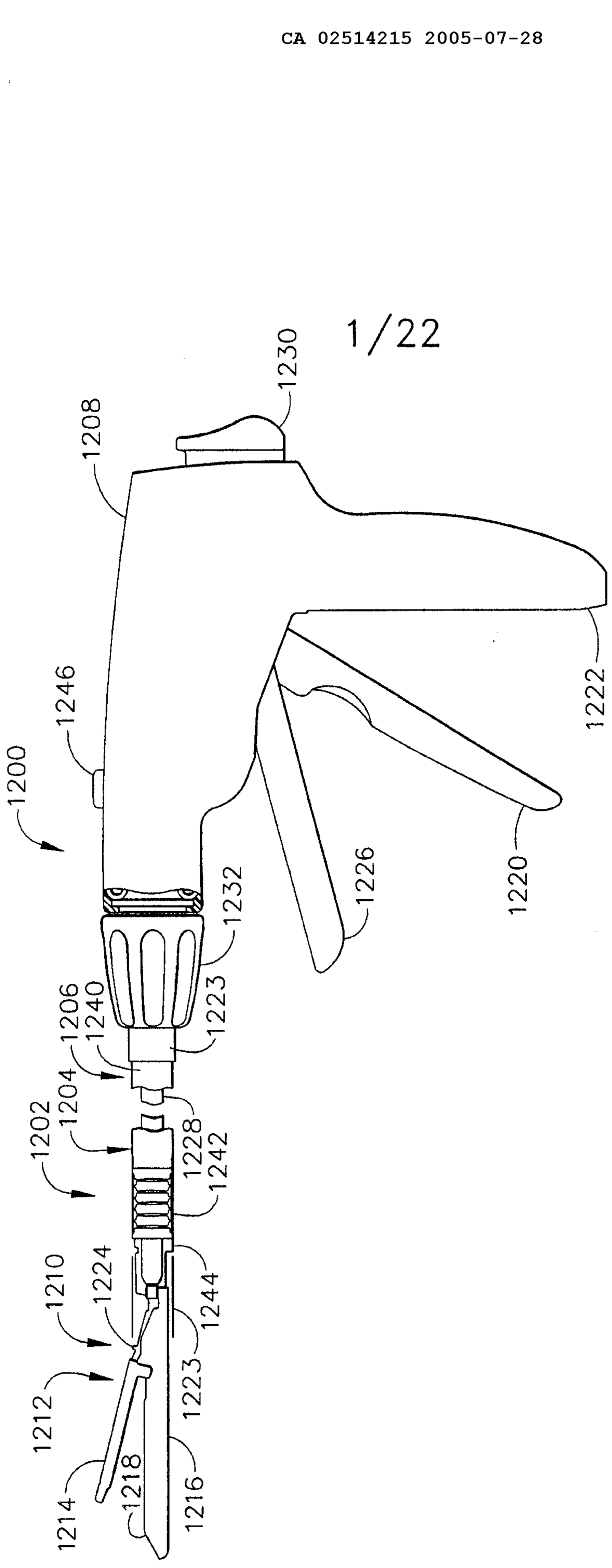

1200
1246
1208
1230
1222
1220
1226
1232
1206
1240
1223
1204
1202
1228
1242
1210
1224
1244
1212
1214
1218
1216
1223

FIG. 1

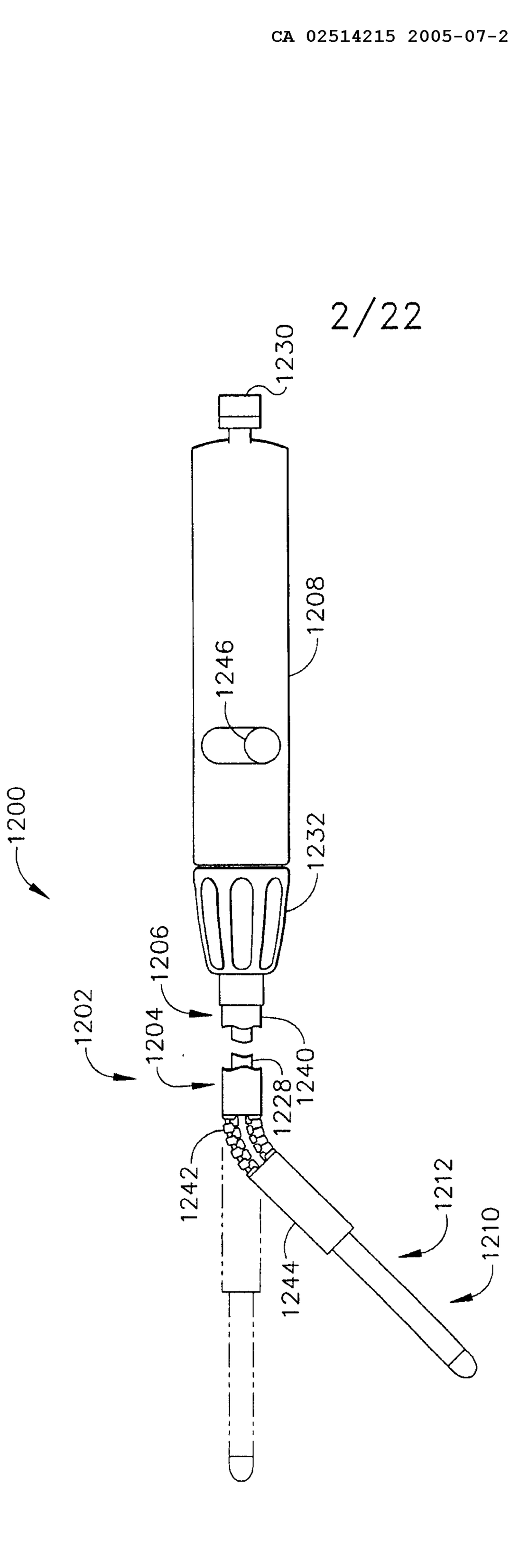

1200
1202
1204
1206
1208
1210
1212
1230
1232
1240
1242
1244
1246
1228

FIG. 1A

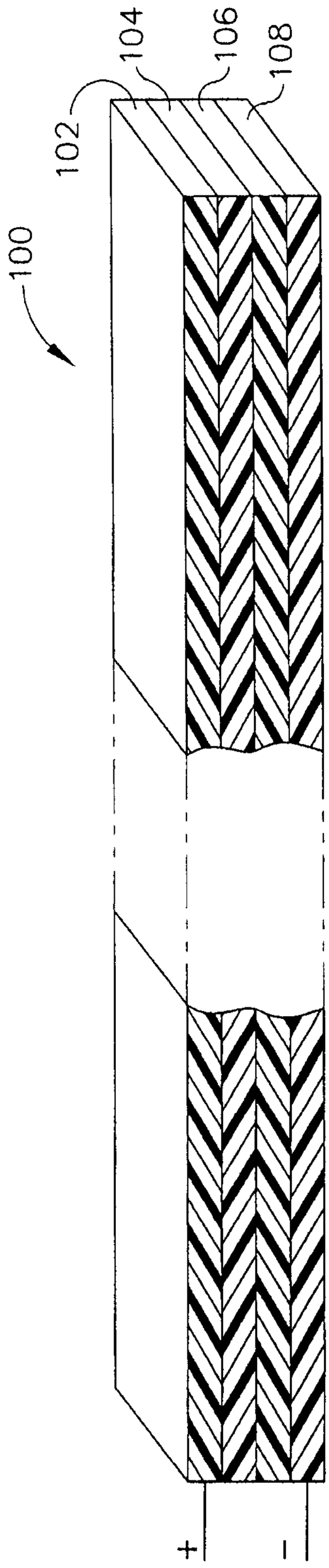


FIG. 2

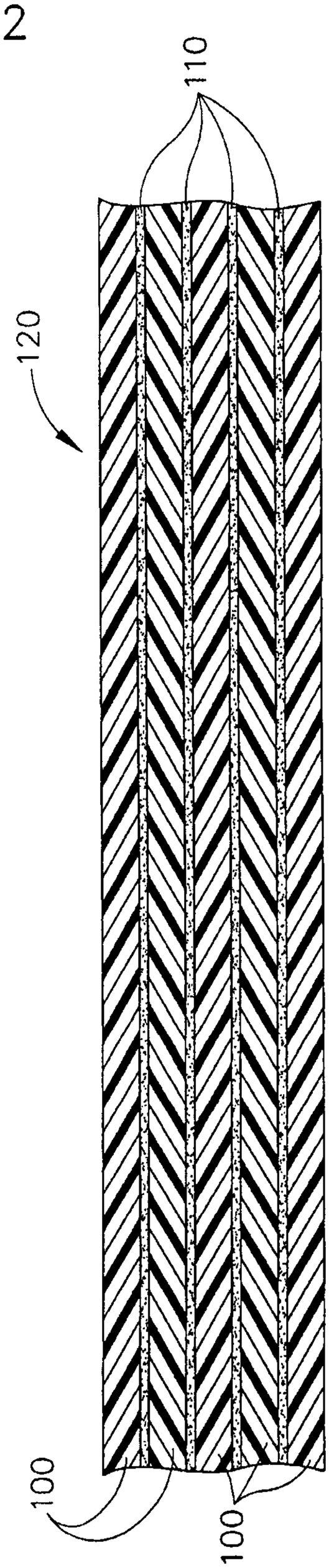


FIG. 3

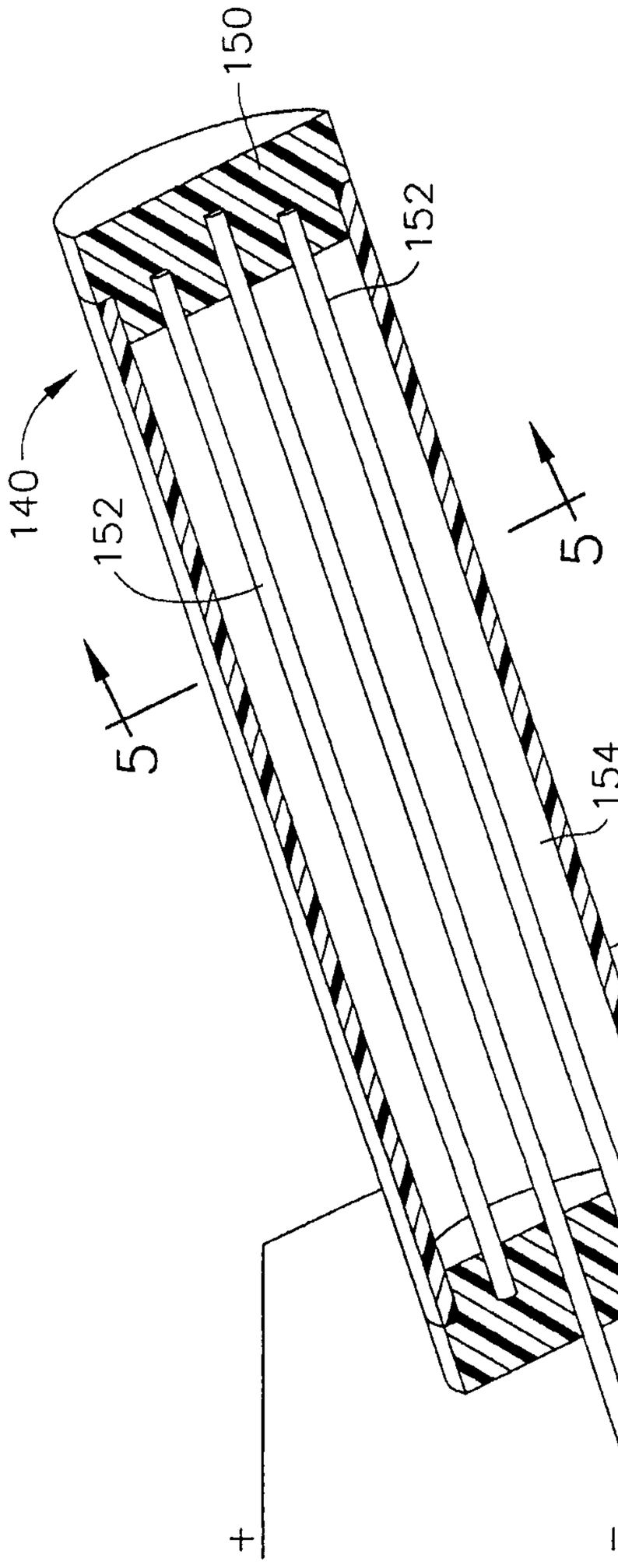


FIG. 4

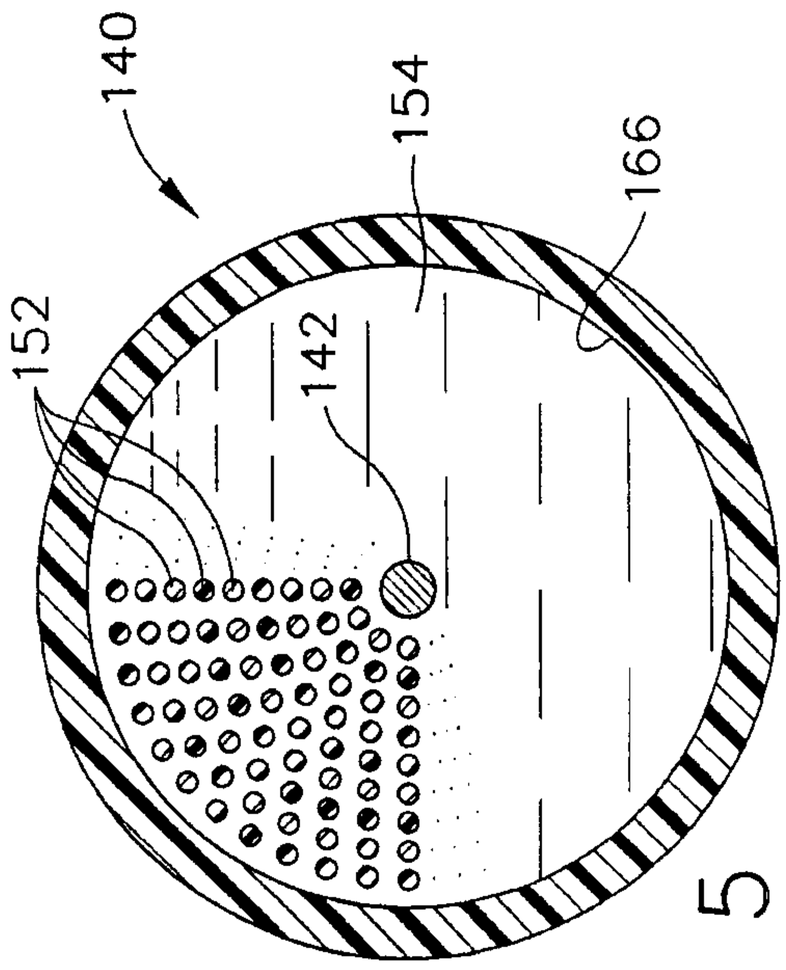


FIG. 5

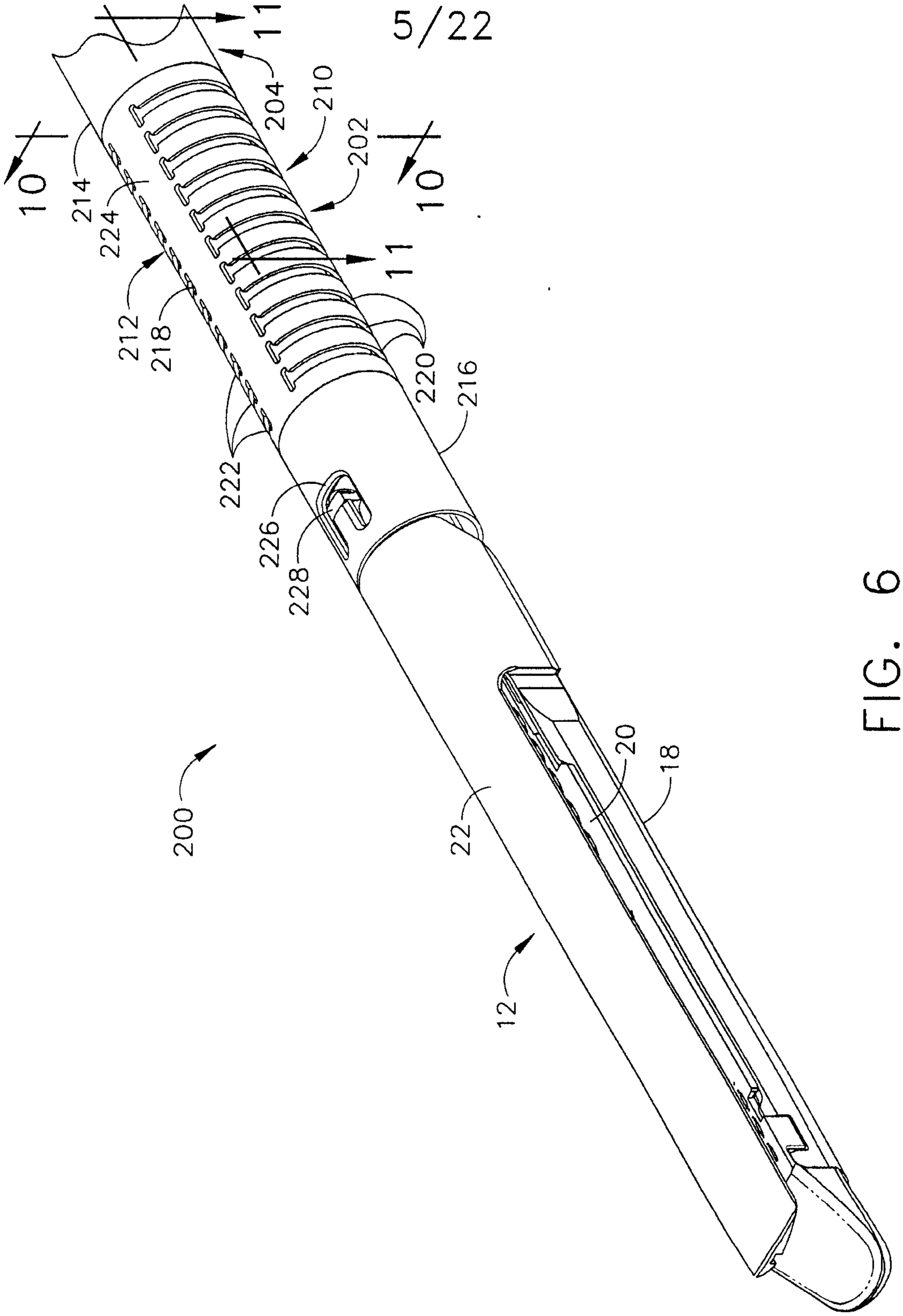

11
10
214
224
212
218
222
226
228
204
210
202
10
11
220
216
200
22
12
20
18

FIG. 6

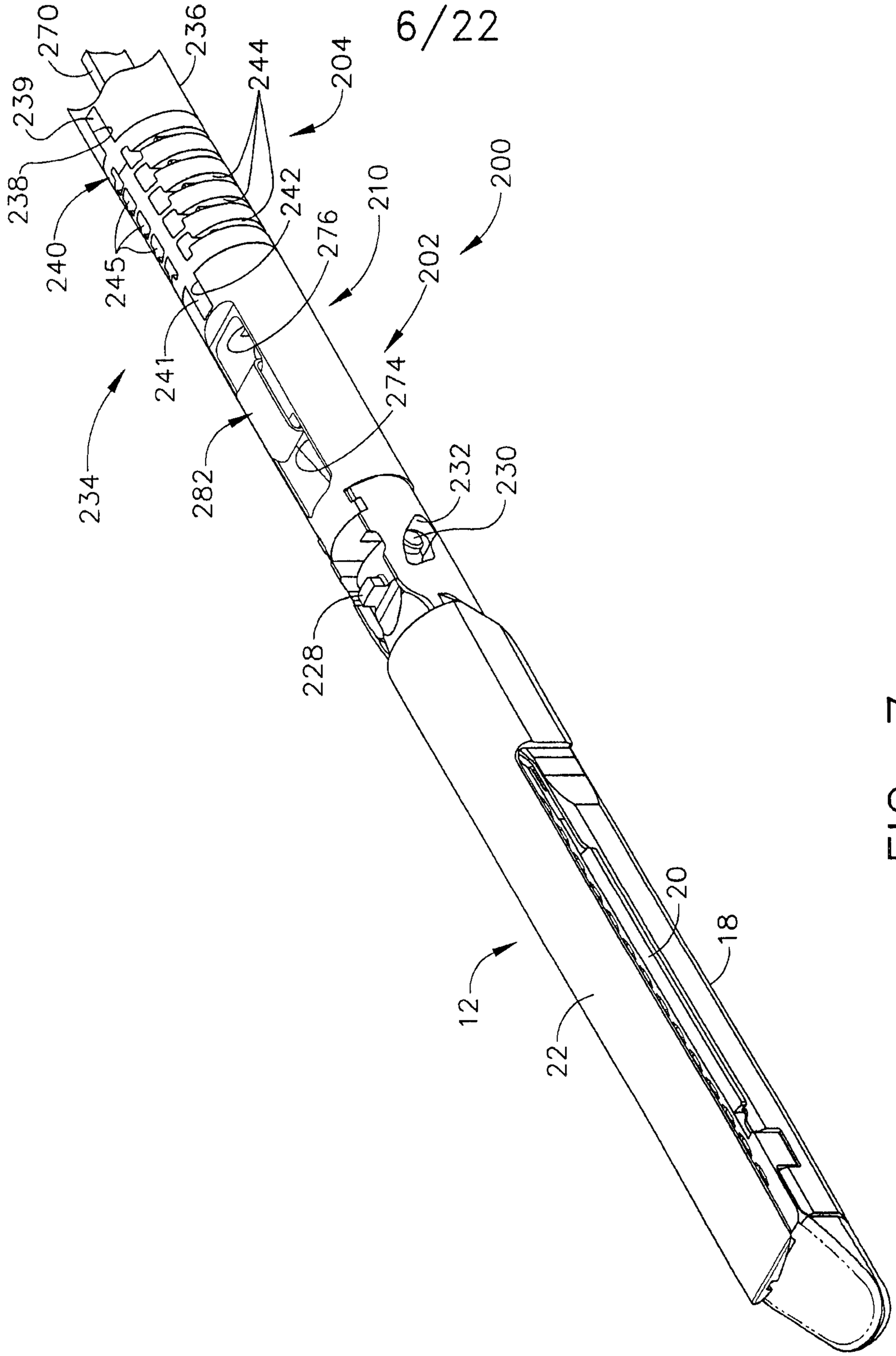

270
236
239
238
240
245
242
244
204
210
200
202
276
241
274
234
282
232
230
228
12
22
20
18

FIG. 7

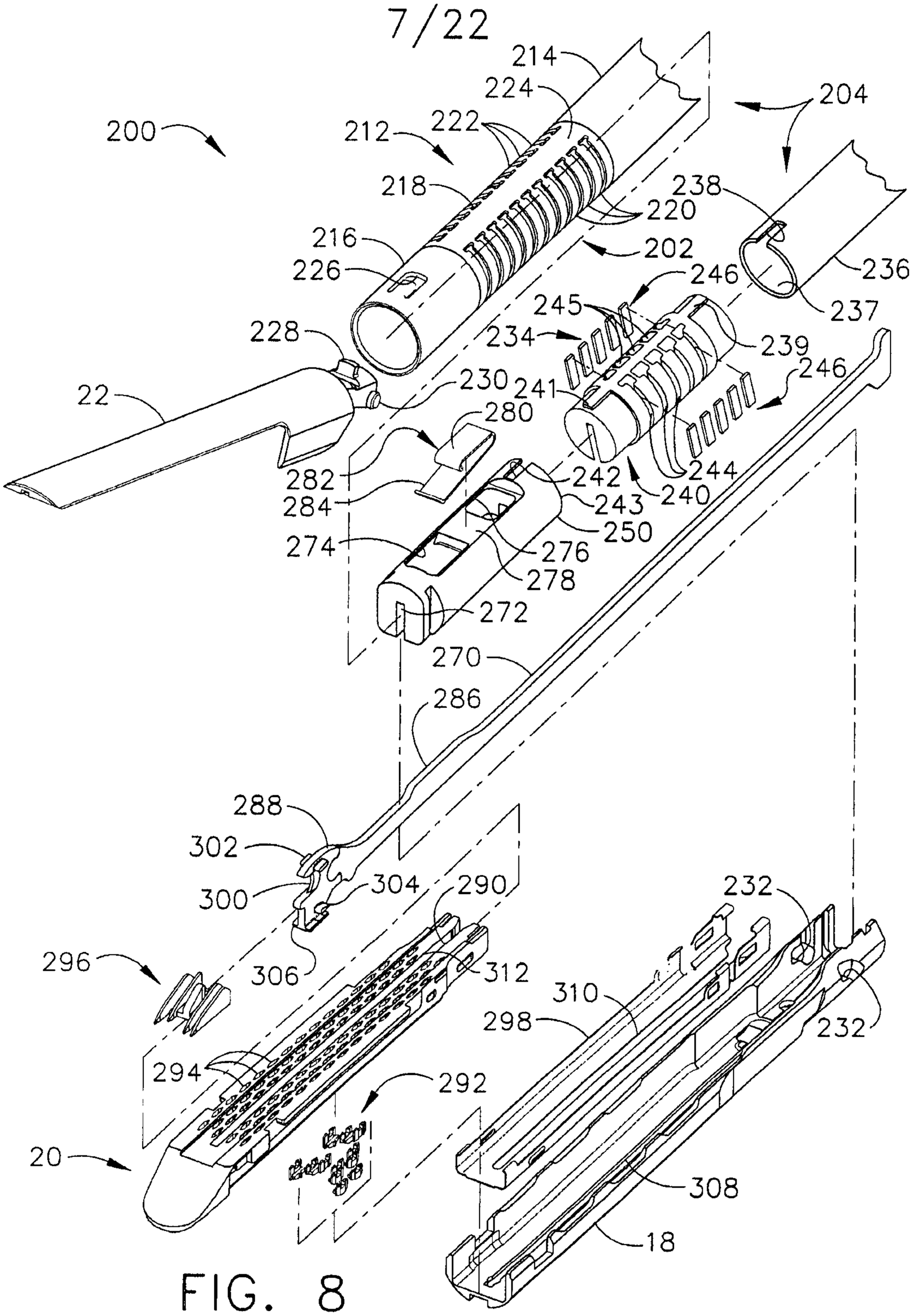

214
224
204
222
200
212
218
238
220
216
202
226
246
236
245
237
228
234
239
246
230
241
22
280
282
242
244
284
243
240
250
274
276
278
272
270
286
288
302
304
290
300
232
296
306
312
310
298
294
292
232
20
308
18

FIG. 8

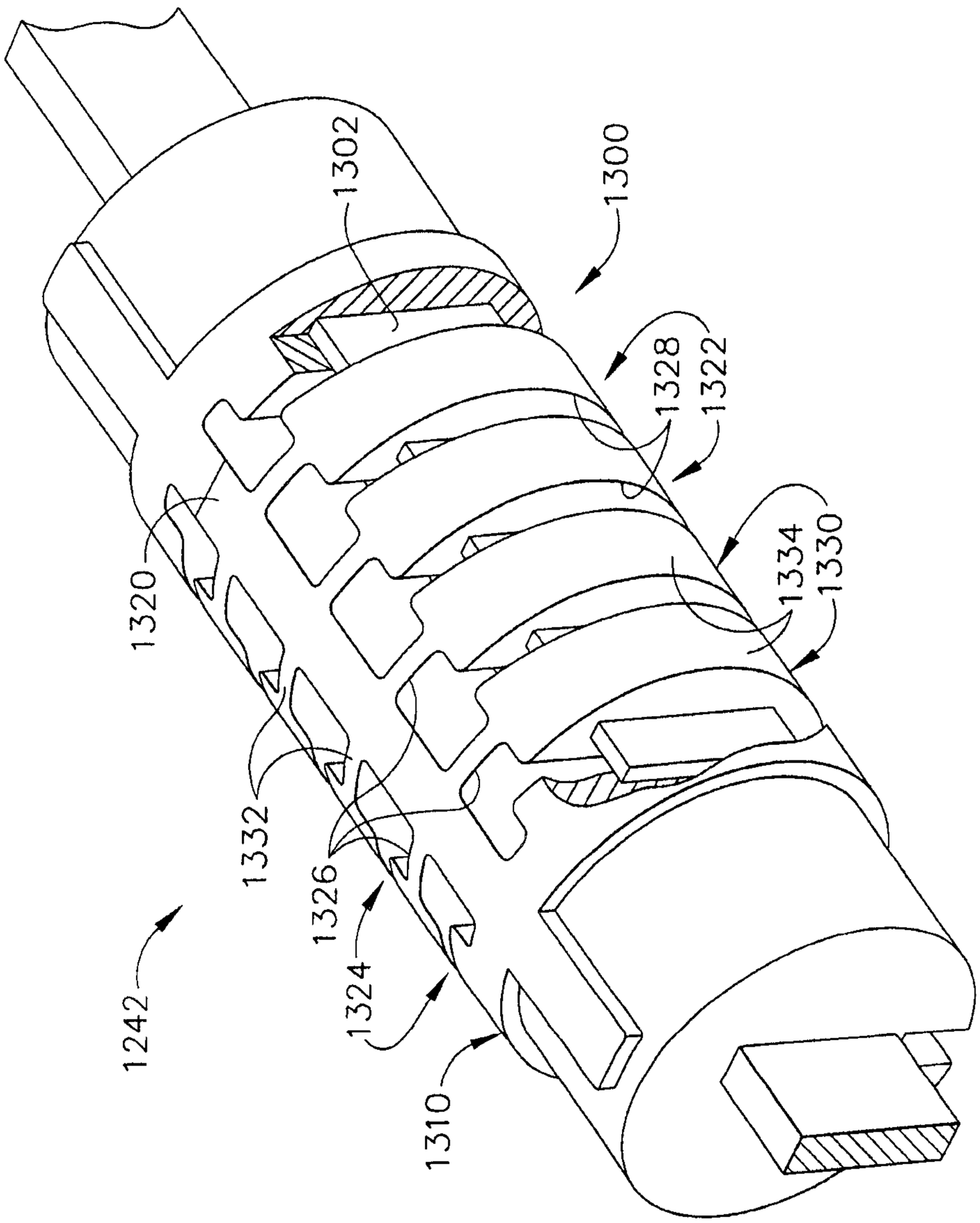


FIG. 9

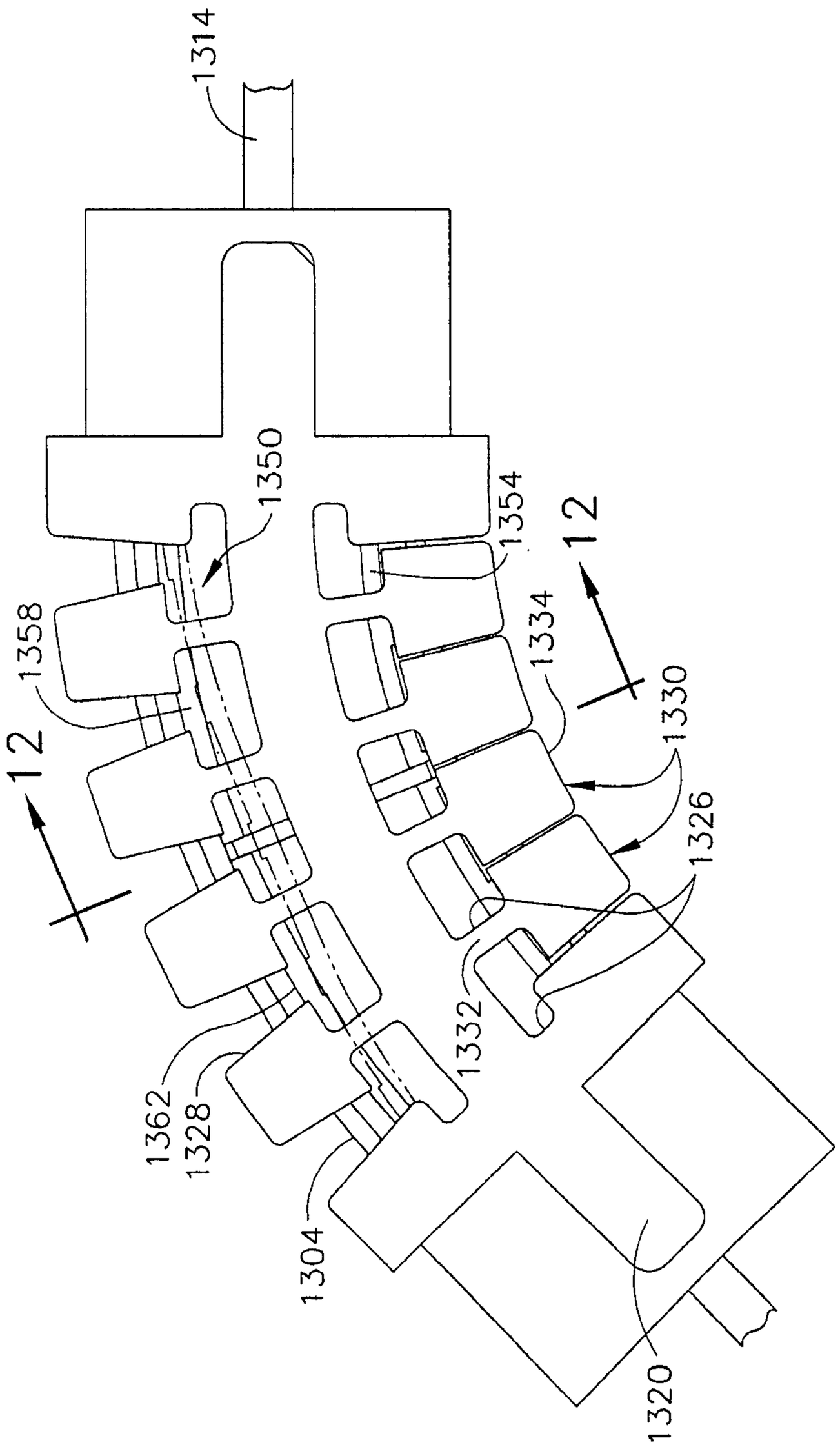

1314
1350
1354
1358
12
1334
1330
1326
1362
1328
1332
1304
1320

FIG. 10

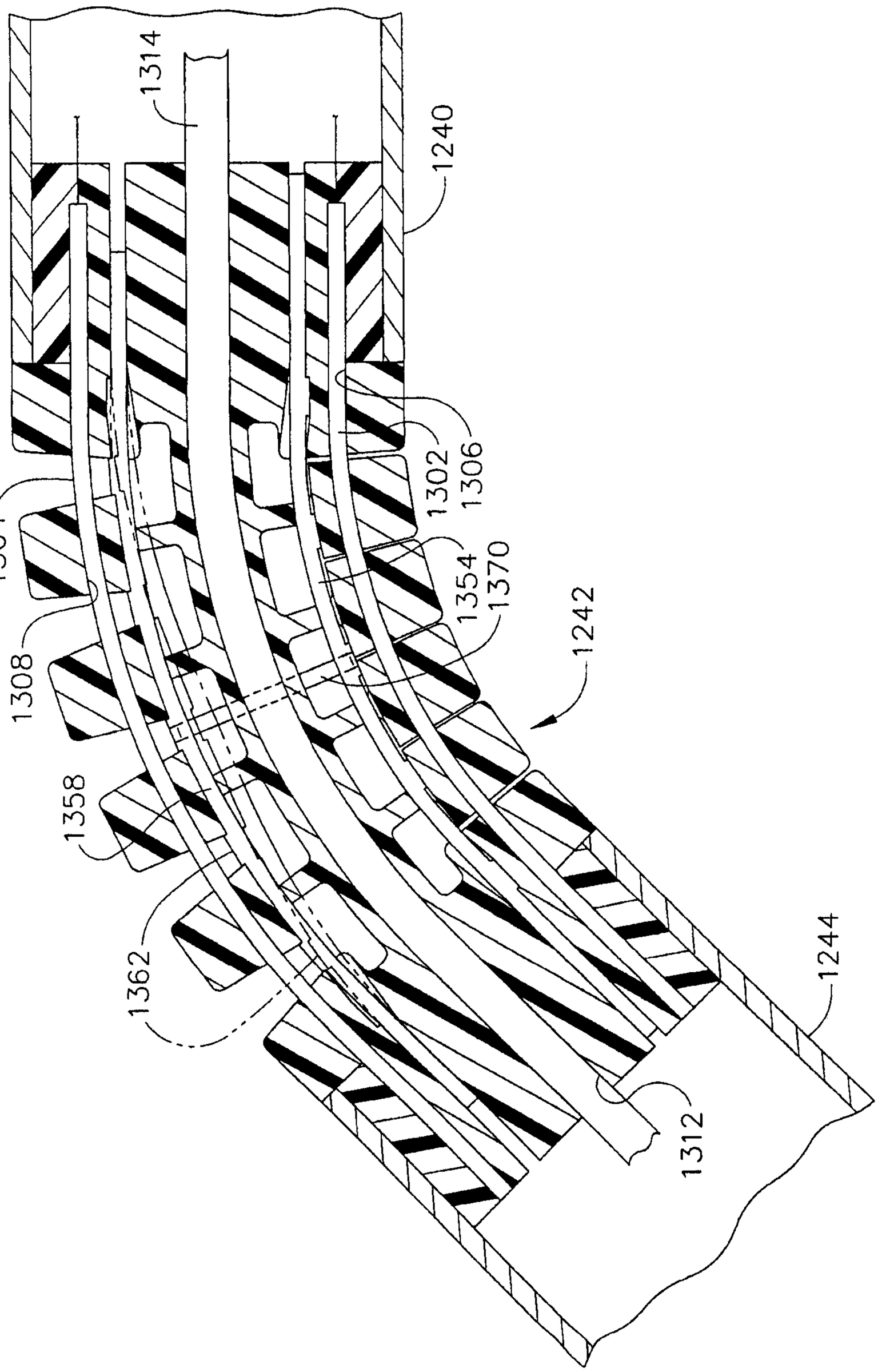

1314
1240
1304
1302
1306
1308
1354
1370
1242
1358
1362
1244
1312

FIG. 11

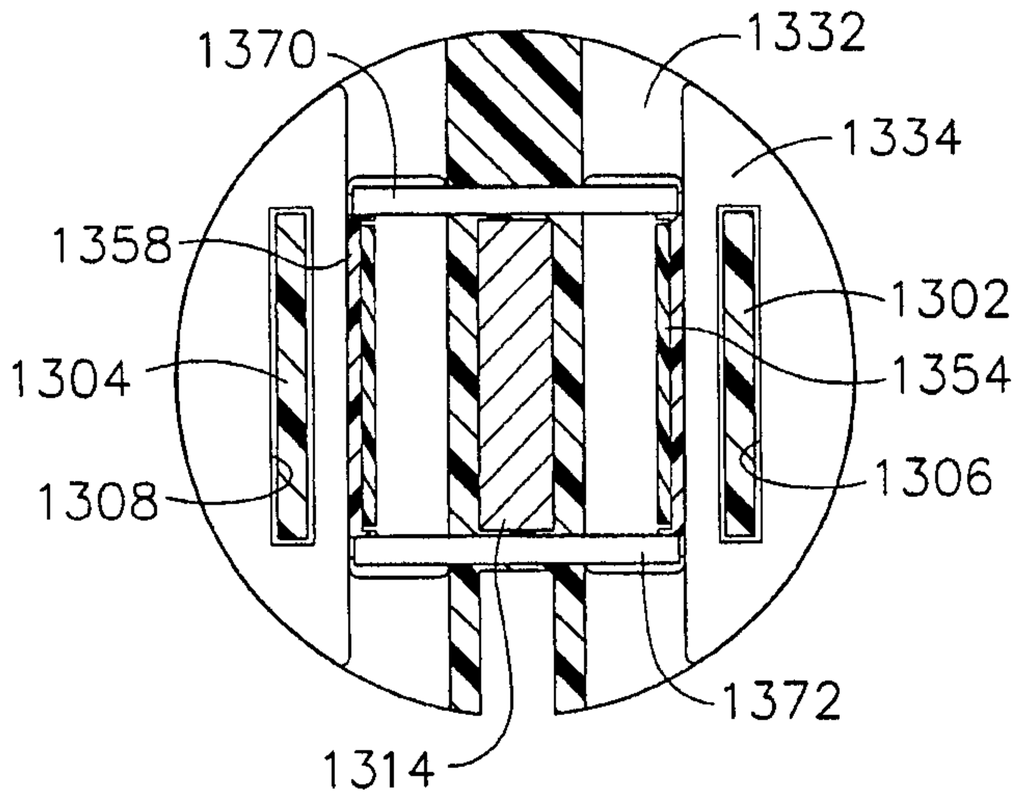

1370
1332
1334
1358
1302
1304
1354
1306
1308
1372
1314

FIG. 12

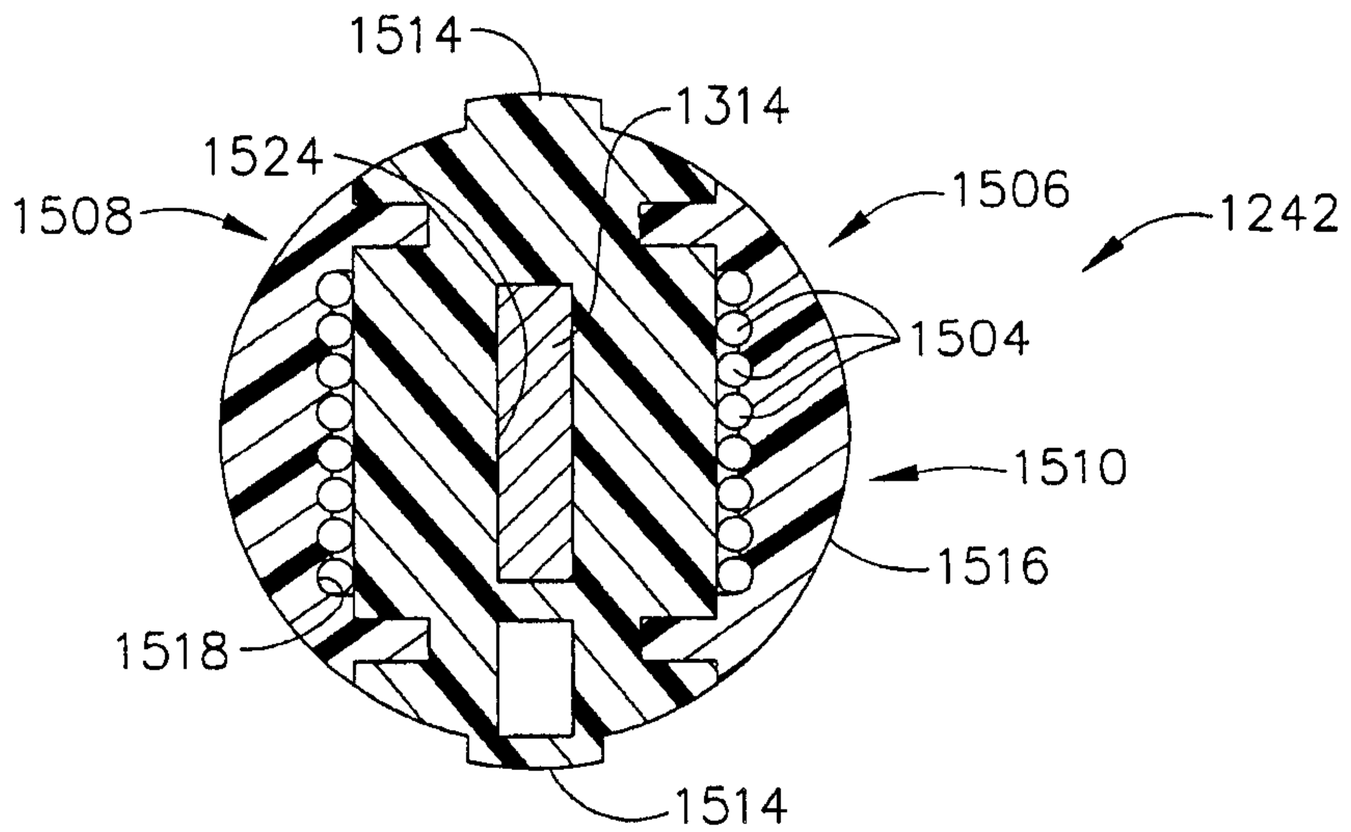

1514
1314
1524
1508
1506
1242
1504
1510
1516
1518
1514

FIG. 15

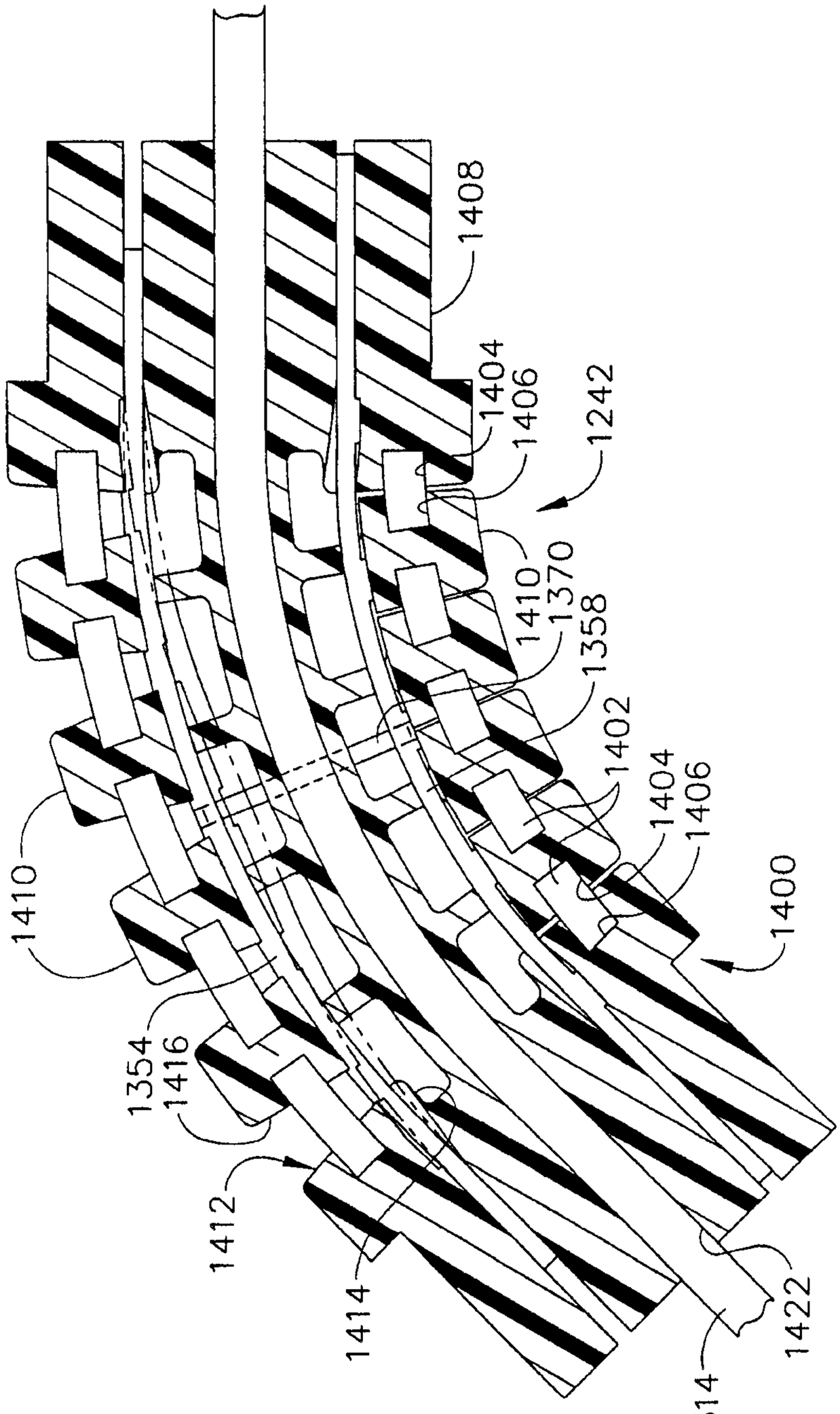

1408
1404
1406
1242
1410
1370
1358
1402
1404
1406
1400
1422
1314
1354
1416
1412
1414
1410

FIG. 13

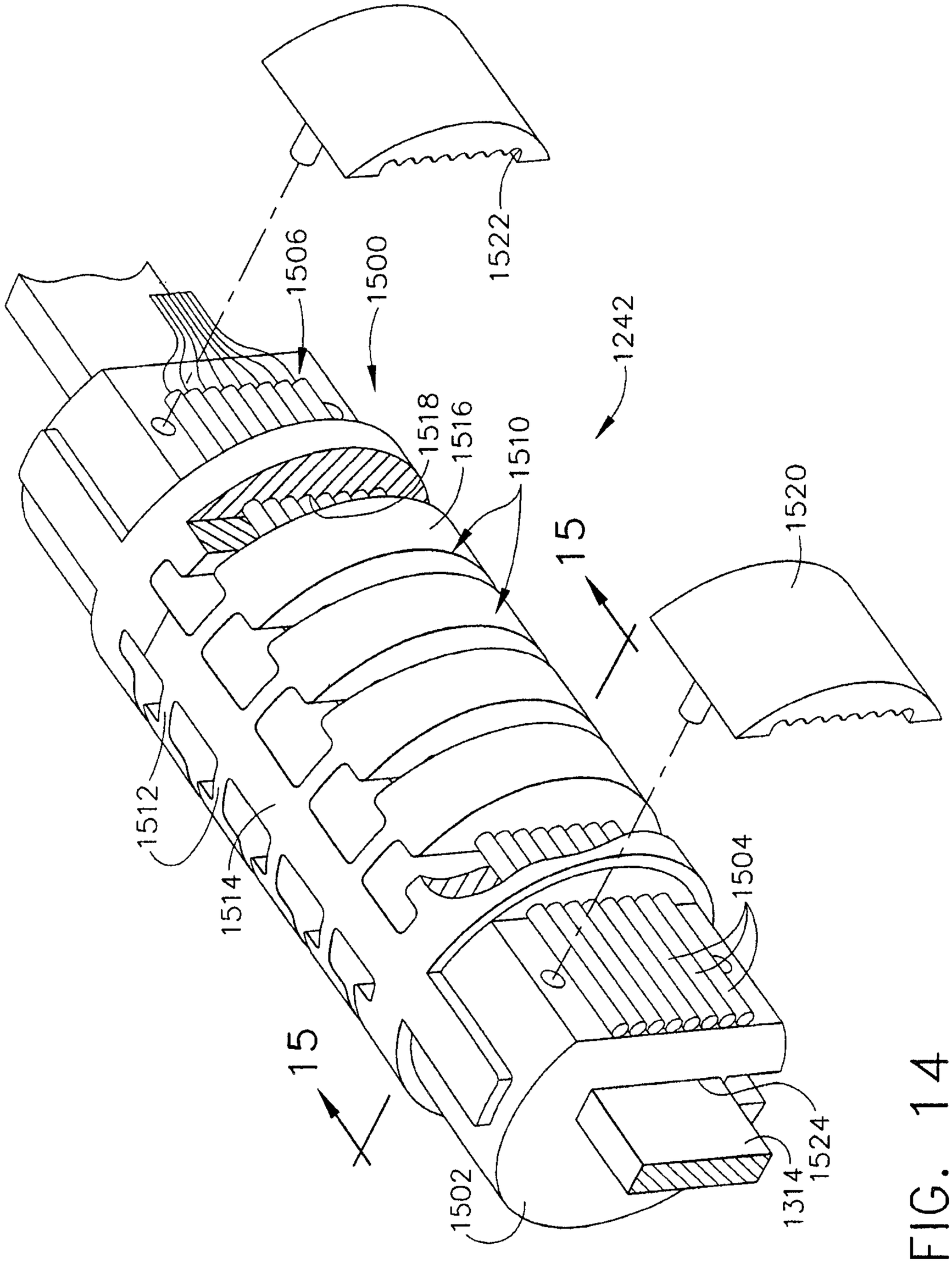

1522
1506
1500
1242
1518
1516
1510
1520
1512
1514
1504
1502
1314
1524

FIG. 14

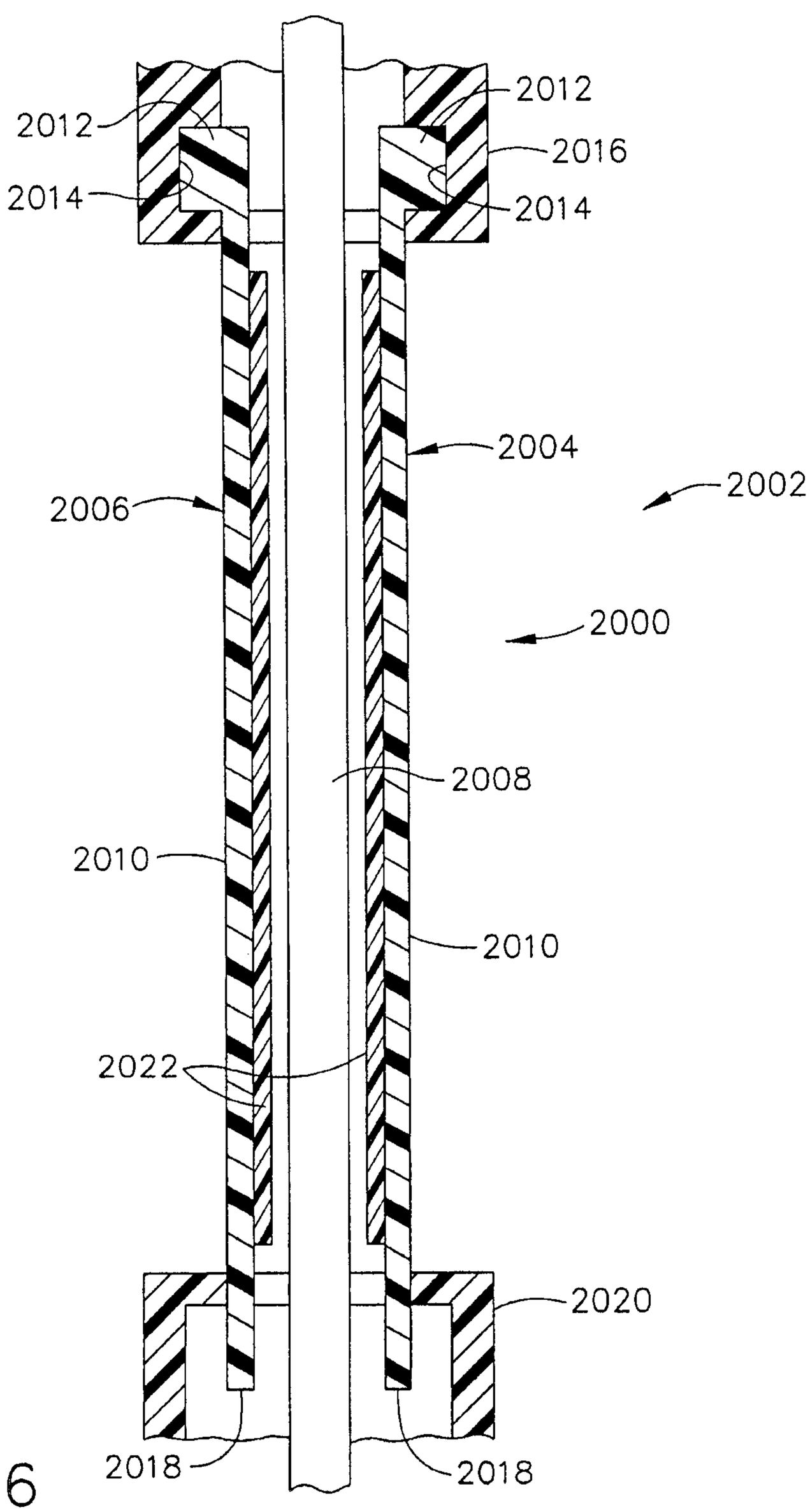

2012
2012
2016
2014
2014
2004
2002
2006
2000
2008
2010
2010
2022
2020
2018
2018

FIG. 16

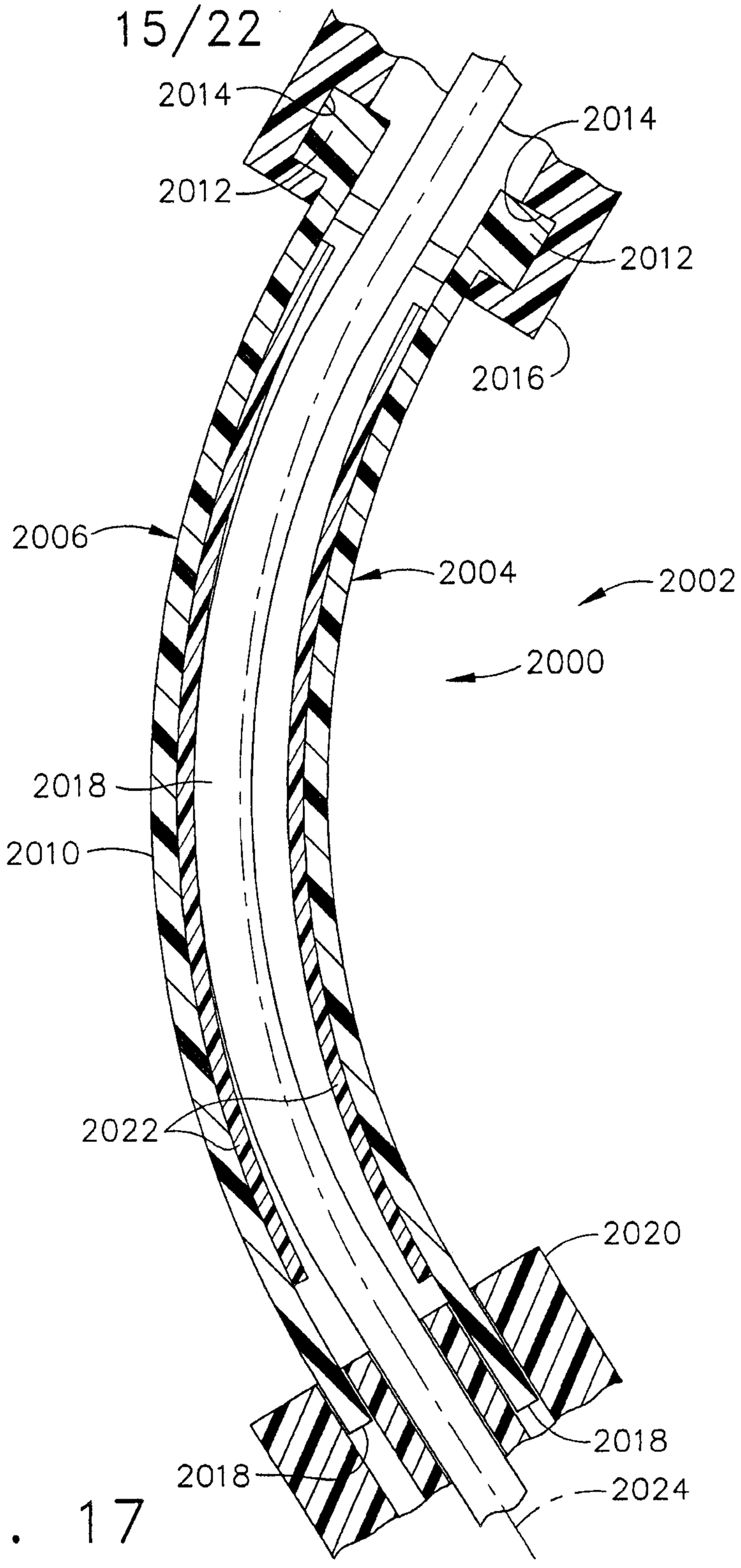

2014
2014
2012
2012
2016
2006
2004
2002
2000
2018
2010
2022
2020
2018
2018
2024

FIG. 17

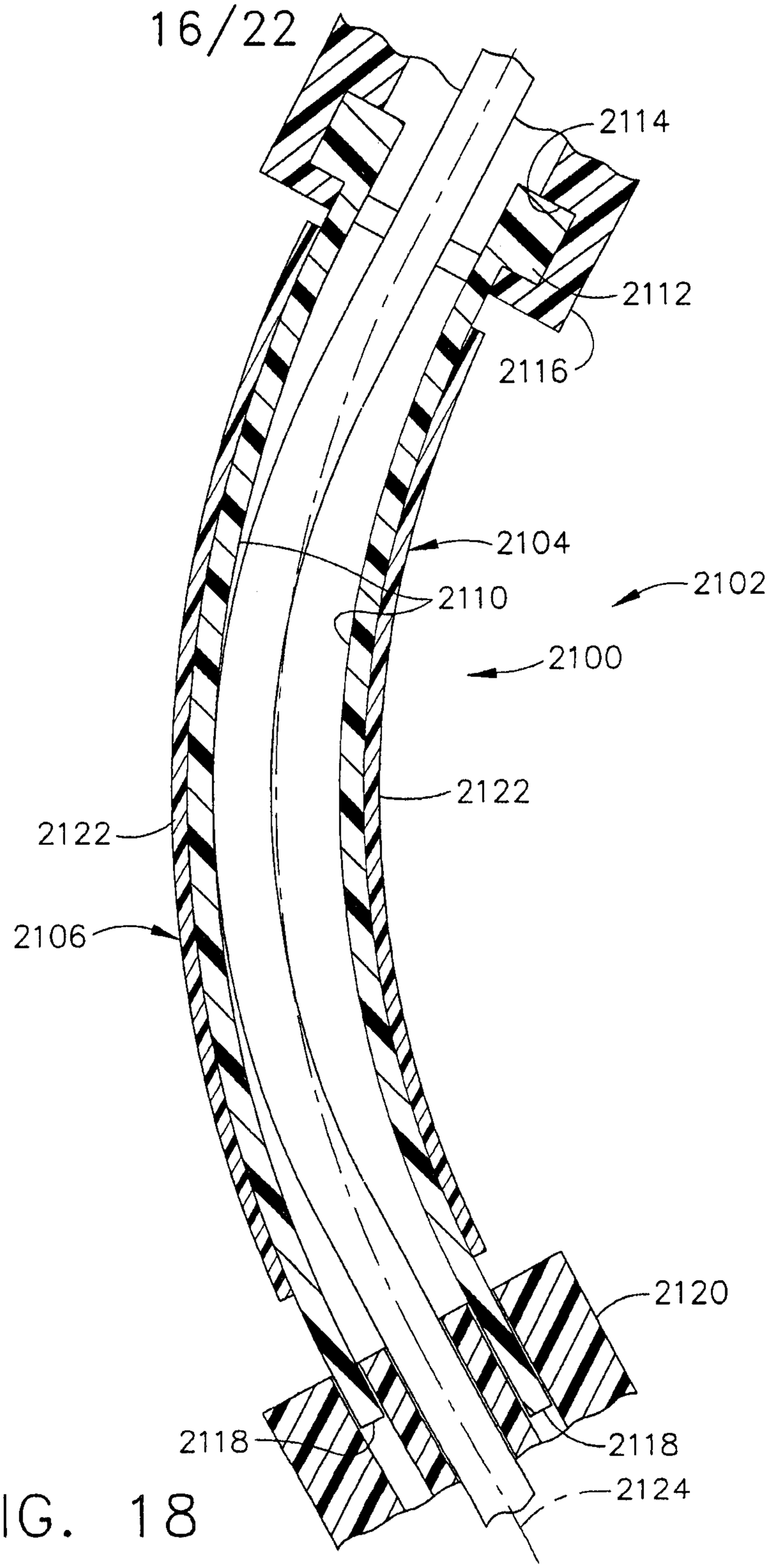

2114
2112
2116
2104
2110
2102
2100
2122
2122
2106
2120
2118
2118
2124

FIG. 18

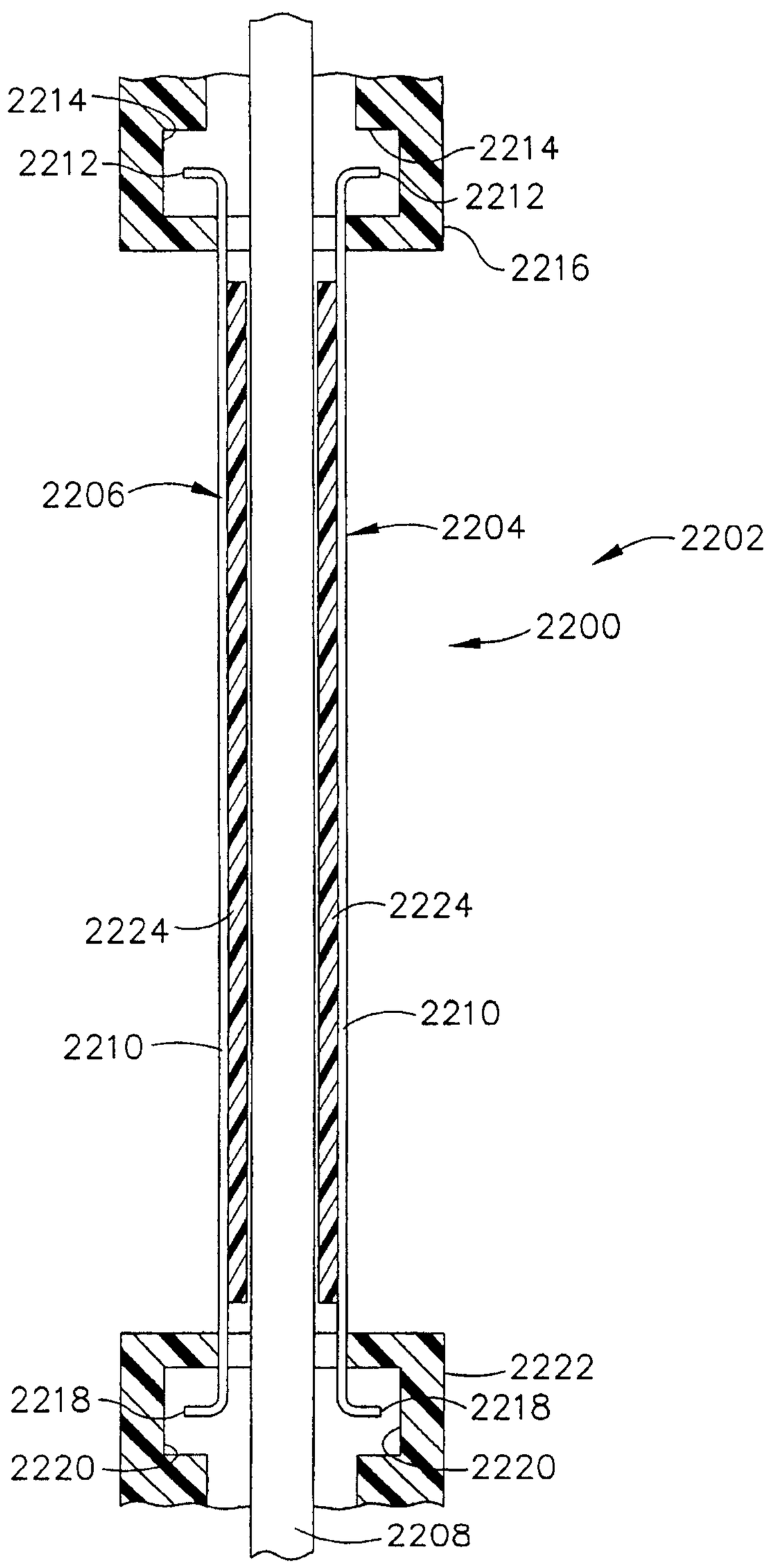

2214
2212
2214
2212
2216
2206
2204
2202
2200
2224
2224
2210
2210
2218
2220
2222
2218
2220
2208

FIG. 19

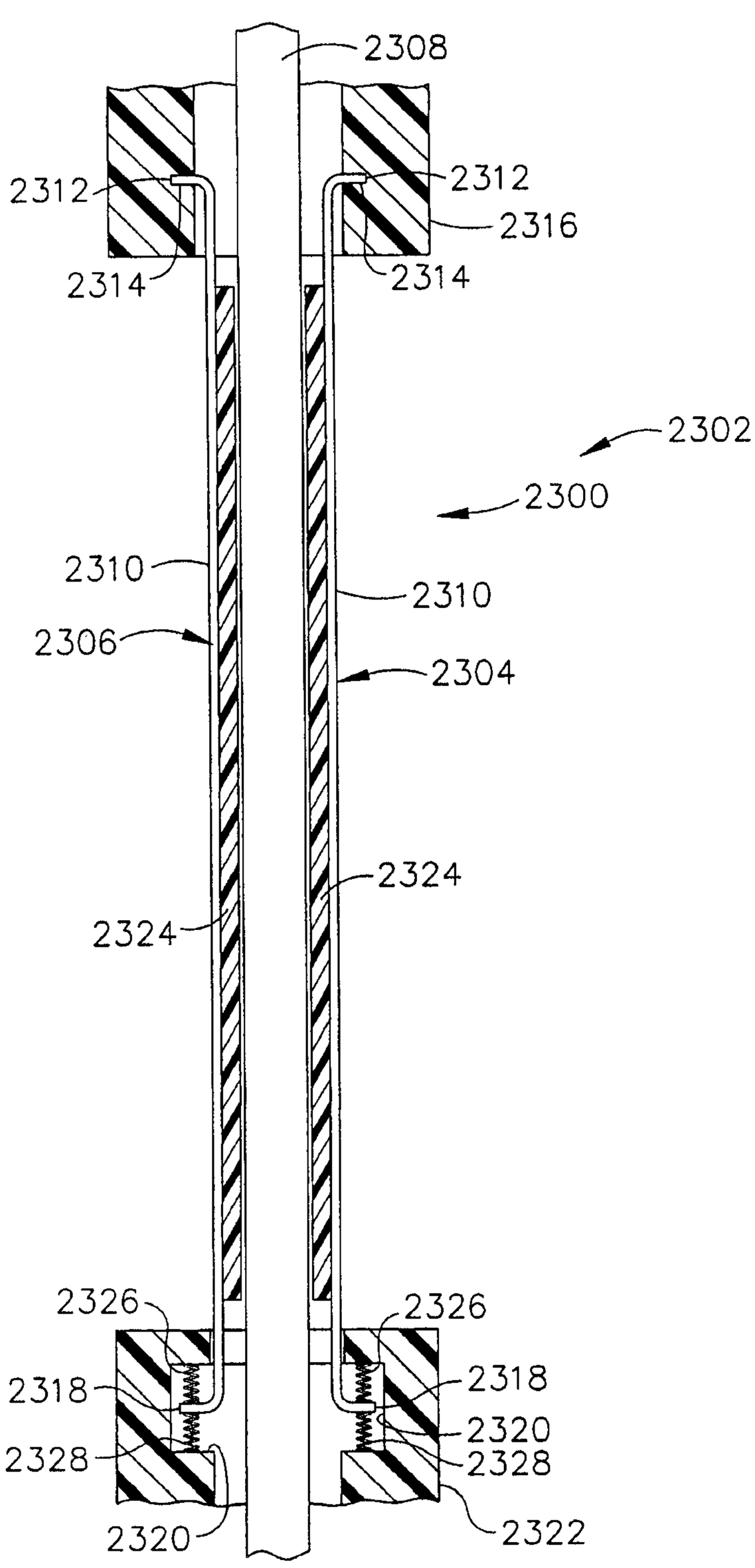

2308
2312
2312
2316
2314
2314
2302
2300
2310
2310
2306
2304
2324
2324
2326
2326
2318
2318
2320
2328
2328
2320
2322

FIG. 20

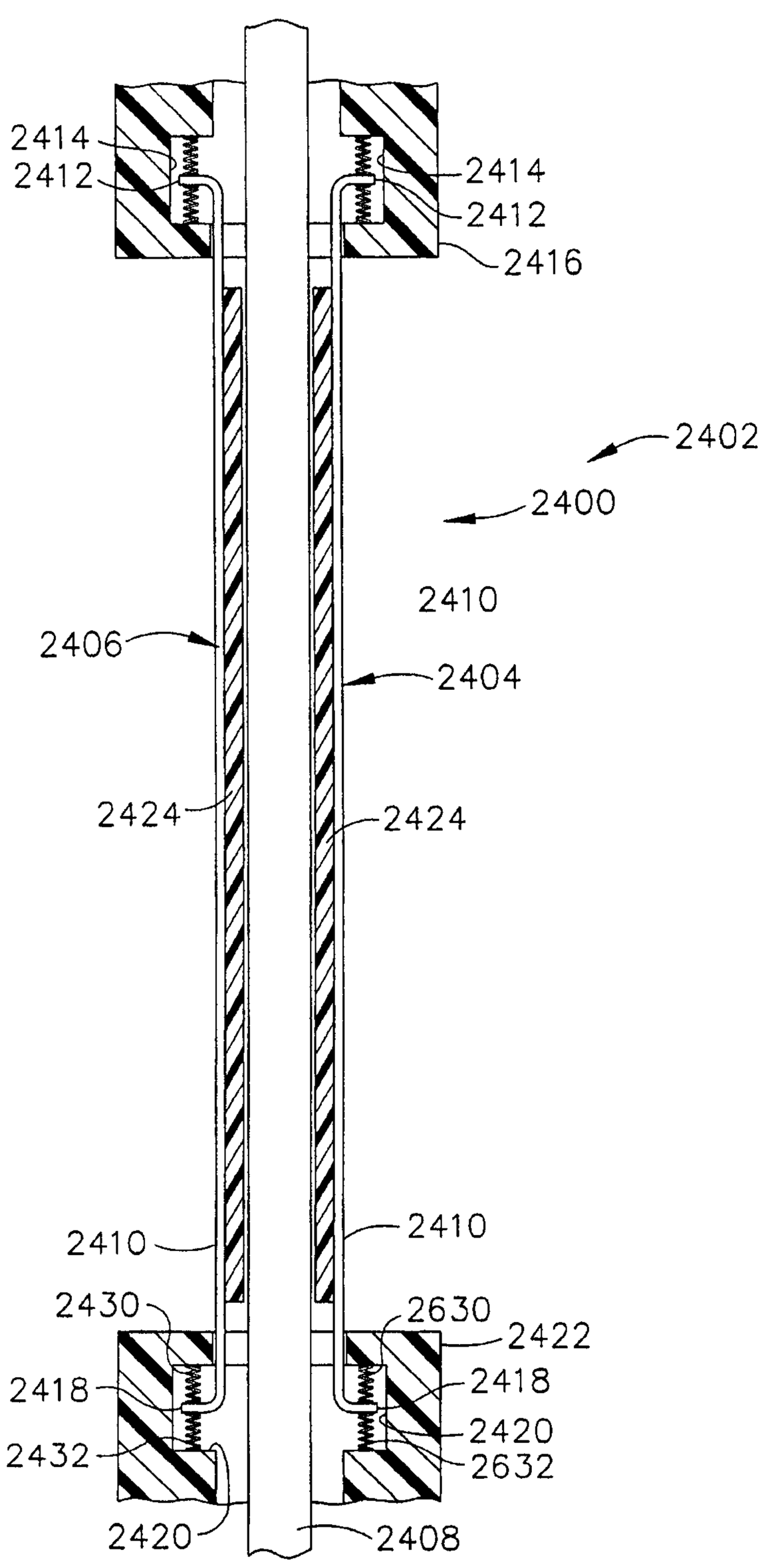

2414
2412
2414
2412
2416
2402
2400
2410
2406
2404
2424
2424
2410
2410
2430
2630
2422
2418
2418
2420
2432
2632
2420
2408

FIG. 21

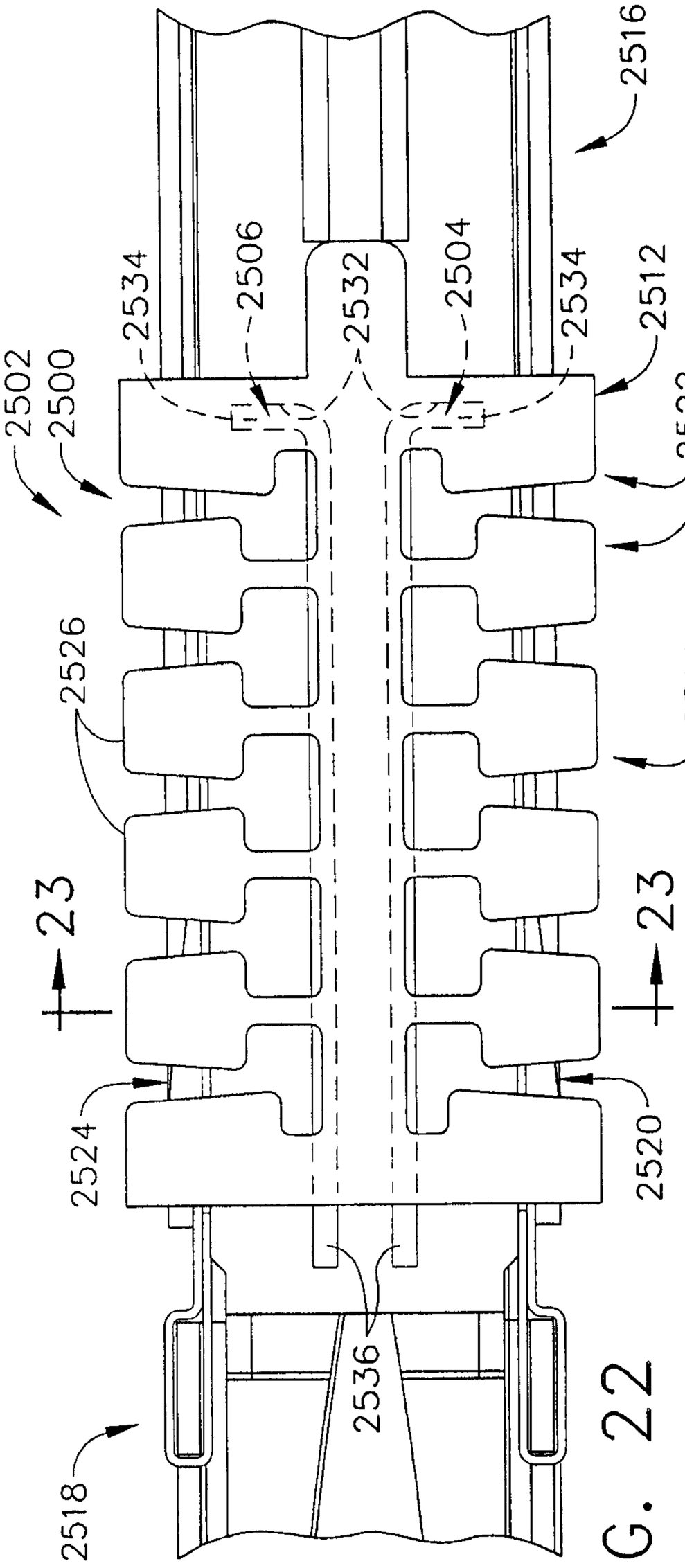

2502
2500
2534
2506
2532
2504
2534
2516
2512
2522
2526
2514
23
23
2524
2520
2518
2536

FIG. 22

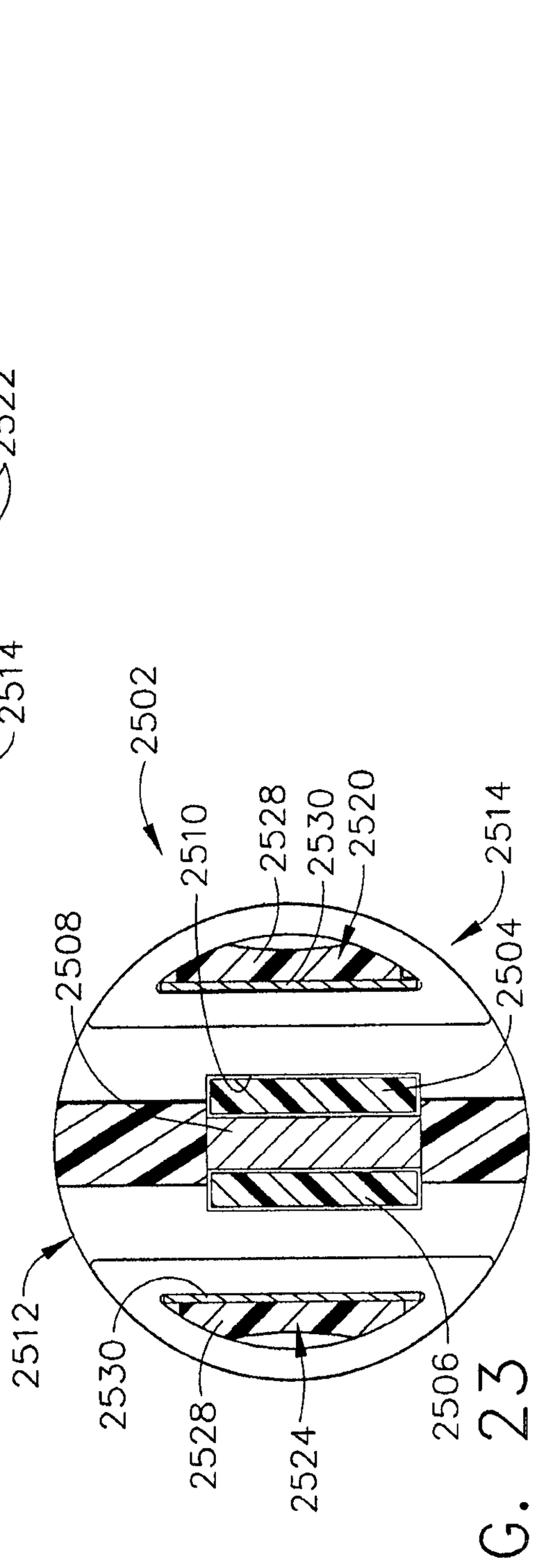

2502
2508
2510
2528
2530
2520
2514
2504
2512
2530
2528
2524
2506

FIG. 23

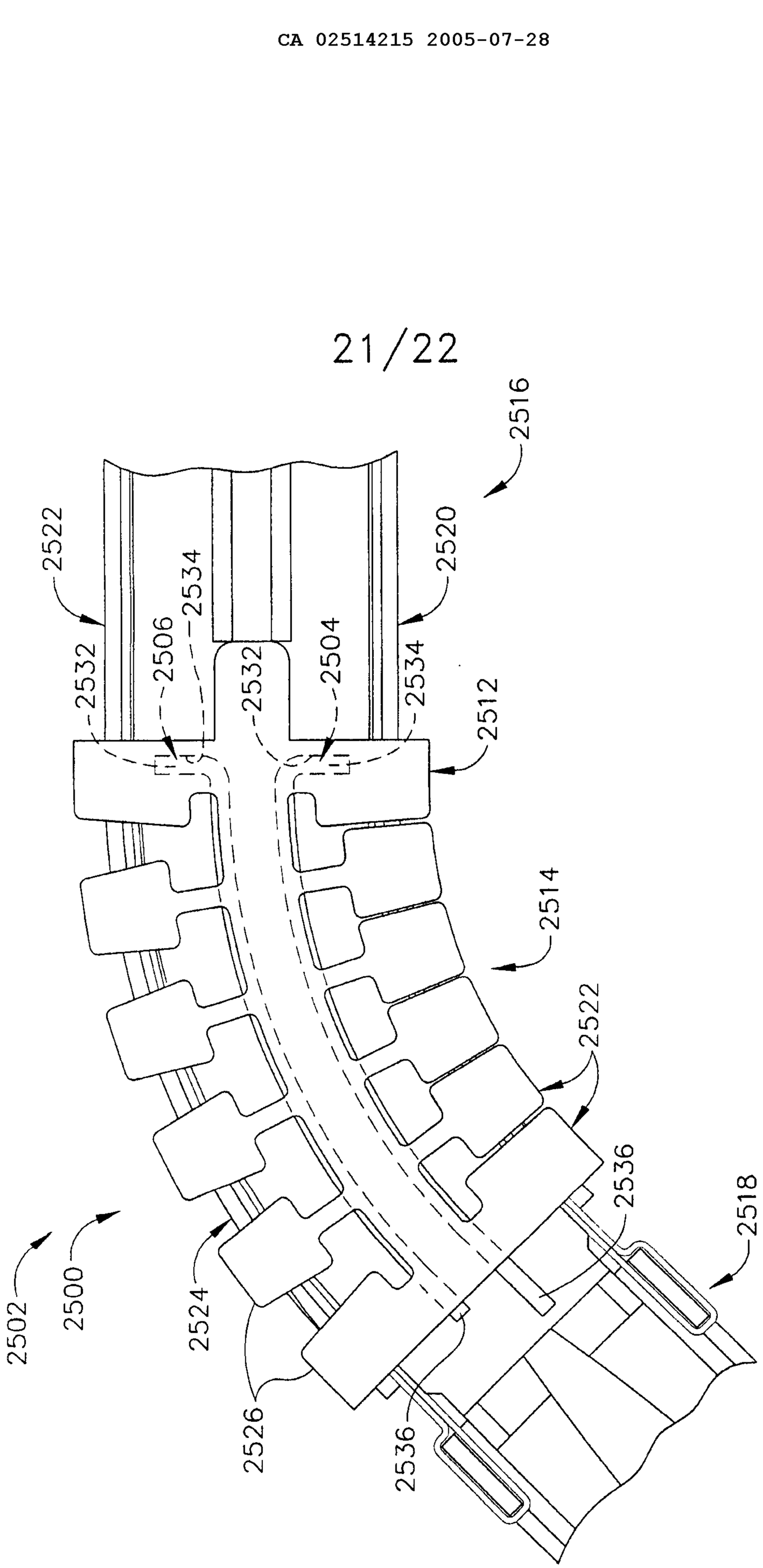

2516
2522
2534
2506
2532
2532
2504
2534
2520
2512
2514
2522
2536
2518
2502
2500
2524
2526
2536

FIG. 24

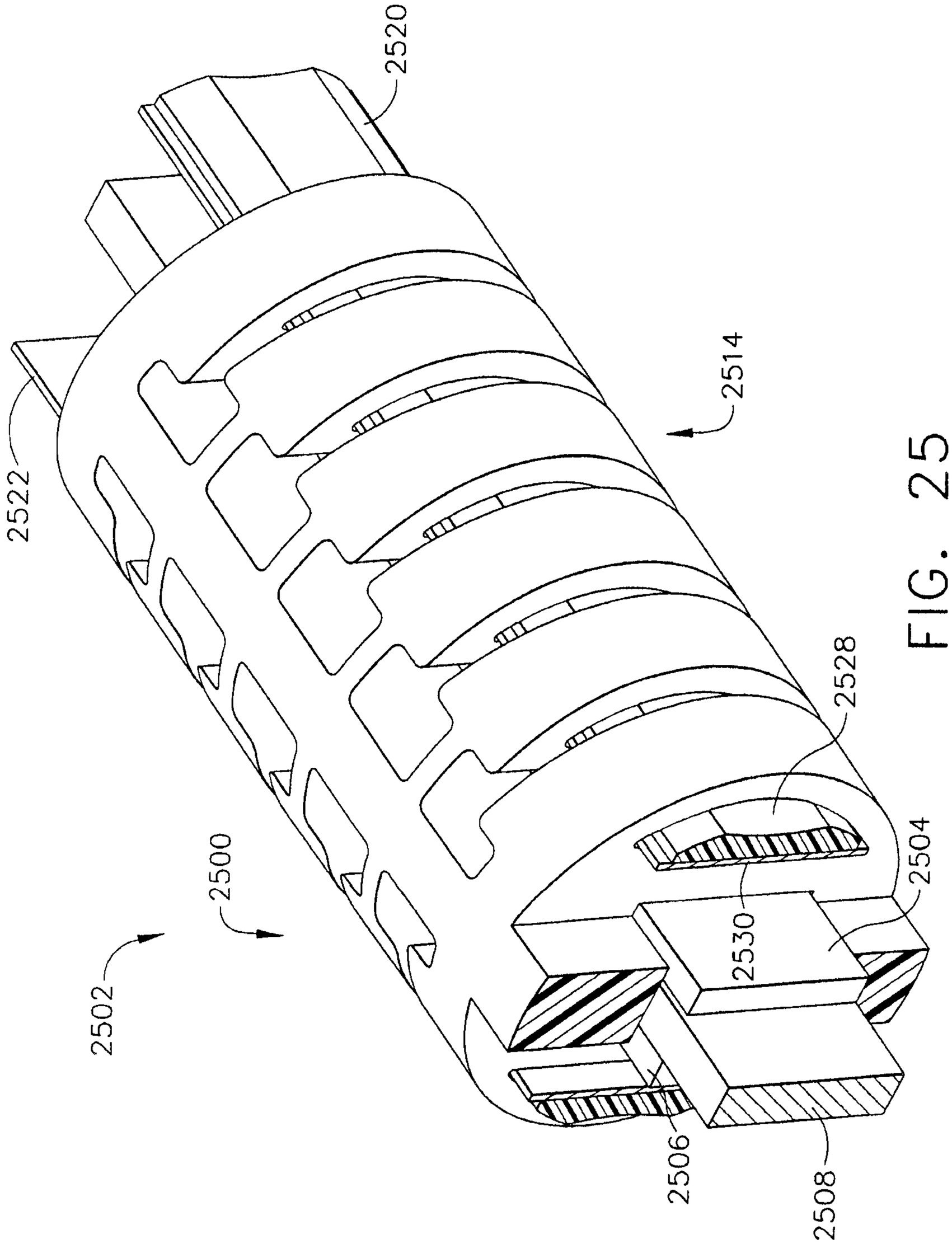
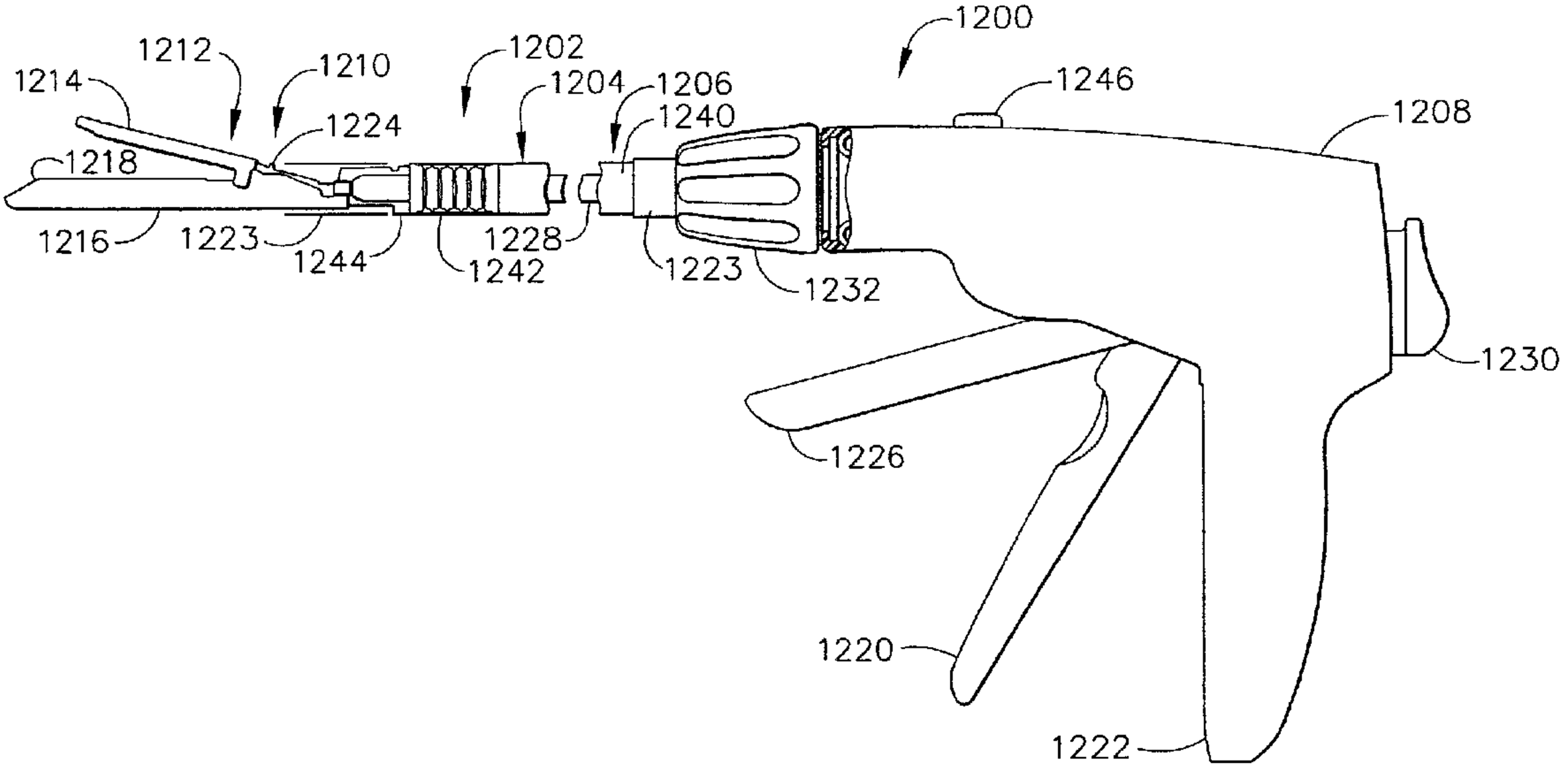


FIG. 25


1200
1212
1210
1202
1214
1204
1206
1246
1208
1240
1224
1218
1216
1223
1244
1242
1228
1223
1232
1230
1226
1220
1222