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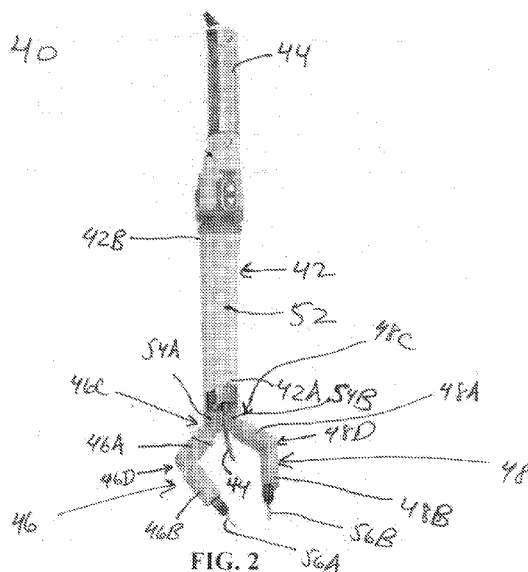
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(54) Title: **ROBOTICALLY ASSISTED SURGICAL SYSTEM AND RELATED DEVICES AND METHODS**



(57) Abstract: Disclosed herein are various robotic surgical systems having various robotic devices. Further, disclosed herein are removable coupleable connection ports, each of which can be coupled to a robotic device and a camera assembly that is disposed into and through the robotic device. Also disclosed herein are removable connection ports having at least one of a elongate device body coupling mechanism, a camera assembly coupling mechanism, and/or a presence detection mechanism. Further discussed herein is a camera assembly with at least one actuation mechanism for actuating movement of the steerable distal tip thereof.

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## ROBOTICALLY ASSISTED SURGICAL SYSTEM AND RELATED DEVICES AND METHODS

### Cross-Reference to Related Application(s)

[001] This application claims the benefit under 35 U.S.C. § 119(e) to U.S. Provisional Application 62/789,029, filed January 7, 2019 and entitled "Robotically Assisted Surgical System," which is hereby incorporated herein by reference in its entirety.

### Field

[002] The embodiments disclosed herein relate to various medical devices and related components that can make up a surgical system, including robotic and/or in vivo medical devices and related components. Certain embodiments include various robotic medical devices, including robotic devices that are disposed within a body cavity and positioned using a body or support component disposed through an orifice or opening in the body cavity. Other embodiments relate to various systems that have a robotic surgical device and a controller, wherein the device has one or more sensors and the controller has one or more motors such that the sensors transmit information that is used at the controller to actuate the motors to provide haptic feedback to a user.

### Background

[003] Invasive surgical procedures are essential for addressing various medical conditions. When possible, minimally invasive procedures such as laparoscopy are preferred.

[004] However, known minimally invasive technologies such as laparoscopy are limited in scope and complexity due in part to 1) mobility restrictions resulting from using rigid tools inserted through access ports, and 2) limited visual feedback. Known robotic systems such as the *da Vinci*® Surgical System (available from Intuitive Surgical, Inc., located in Sunnyvale, CA) are also restricted by the access ports, as well as having the additional disadvantages of being very large, very expensive, unavailable in most hospitals, and having limited sensory and mobility capabilities.

[005] There is a need in the art for improved surgical methods, systems, and devices.

### Brief Summary

[006] Discussed herein are various robotic surgical systems having various robotic devices. Certain of the robotic devices have coupleable connection ports (also referred to as "nests") that receive and couple to various camera assemblies. The various connection ports herein can have coupling mechanisms therein for coupling to the robotic device and/or the camera assembly. In addition, certain ports have presence detection mechanisms as well. Further discussed herein are camera assemblies with actuation mechanisms for actuating movement of the steerable distal tip thereof.

[007] In Example 1, a robotic surgical system comprises a robotic surgical device and a removable camera component. The robotic surgical device comprises an elongate device body comprising a distal end and a proximal end, a removable connection port disposed at the proximal end of the device body, and first and second robotic arms operably coupled to the distal end of the device body. The connection port comprises a device body coupling mechanism disposed within the

connection port, a camera receiving opening defined in a proximal end of the connection port; a seal package disposed in the removable connection port, the seal package comprising at least two seals; and a camera coupling mechanism disposed within the removable connection port. The removable camera component is removably disposable in the camera receiving opening and through the seal package, the removable camera component comprising a camera body, an elongate camera tube, a flexible section, and a distal imager.

**[008]** Example 2 relates to the robotic surgical system according to Example 1, wherein the device body coupling mechanism comprises first and second hinged coupling mechanisms hingedly coupled to the connection port.

**[009]** Example 3 relates to the robotic surgical system according to Example 2, wherein each of the first and second hinged coupling mechanisms comprises a coupling mechanism body, a tensioned hinge at a proximal end of the coupling mechanism body, wherein the tensioned hinge is hingedly coupled to the connection port, a coupleable structure at a distal end of the coupling mechanism, wherein the coupleable structure comprises at least one coupling feature configured to be coupleable with a matching coupling feature on the proximal end of the device body and an actuatable button.

**[010]** Example 4 relates to the robotic surgical system according to Example 1, wherein the elongate device body comprises a male connector disposed at a proximal end of the elongate device body, wherein the male connector is coupleable with the connection port.

**[011]** Example 5 relates to the robotic surgical system according to Example 1, wherein the removable connection port further comprises a presence detection mechanism operably coupled to the camera coupling mechanism.

**[012]** Example 6 relates to the robotic surgical system according to Example 1, wherein the camera coupling mechanism comprises a slidable body disposed within the connection port, a camera receiving opening defined within the slidable body, an actuatable camera release button attached to a first end of the slidable body, and a tensioned spring operably coupled to a second end of the slidable body.

**[013]** Example 7 relates to the robotic surgical system according to Example 6, wherein the slidable body is slidable along a plane substantially transverse to a longitudinal axis of the elongate device body.

**[014]** Example 8 relates to the robotic surgical system according to Example 1, further comprising a presence detection mechanism comprising a rotatable lever operably coupled to the camera coupling mechanism at a pivot point, wherein the rotatable lever rotates around the pivot point, a first sensing component disposed on the rotatable lever, and a second sensing component disposed on the elongate body, wherein the second sensing component is configured to sense the presence or absence of the first sensing component.

**[015]** Example 9 relates to the robotic surgical system according to Example 8, wherein the first sensing component is a magnet.

**[016]** In Example 10, a removable connection port for a robotic surgical device comprises a connection port body, a distal opening defined at a distal end of the port body, wherein the distal

opening is sized and shaped to receive a proximal end of an elongate device body, a proximal opening defined at a proximal end of the port body, wherein the proximal opening is sized and shaped to receive a camera assembly, a seal package disposed in the connection port body, the seal package comprising at least two seals configured to receive a shaft of a camera assembly, a device body coupling mechanism disposed within the connection port body, the device body coupling mechanism comprising first and second hinged coupling mechanisms hingedly coupled to the connection port body, and a camera coupling mechanism disposed within the connection port body. The camera coupling mechanism comprises a slidable body disposed within the connection port body, and a camera receiving opening defined within the slidable body.

**[017]** Example 11 relates to the removable connection port according to Example 10, wherein each of the first and second hinged coupling mechanisms comprises a coupling mechanism body, a tensioned hinge at a proximal end of the coupling mechanism body, wherein the tensioned hinge is hingedly coupled to the connection port body, and a coupleable structure at a distal end of the coupling mechanism, wherein the coupleable structure comprises at least one coupling feature configured to be coupleable with a matching coupling feature on the proximal end of the elongate device body and an actuatable button.

**[018]** Example 12 relates to the removable connection port according to Example 10, wherein the distal opening is sized and shaped to receive a male connector disposed at the proximal end of the elongate device body.

**[019]** Example 13 relates to the removable connection port according to Example 10, further comprising a presence detection mechanism operably coupled to the camera coupling mechanism.

**[020]** Example 14 relates to the removable connection port according to Example 10, wherein the camera coupling mechanism further comprises an actuatable camera release button attached to a first end of the slidable body and a tensioned spring operably coupled to a second end of the slidable body.

**[021]** Example 15 relates to the removable connection port according to Example 10, wherein the slidable body is slidable along a plane substantially transverse to a longitudinal axis of a lumen of the seal package.

**[022]** Example 16 relates to the removable connection port according to Example 10, further comprising a presence detection mechanism comprising a rotatable lever operably coupled to the camera coupling mechanism at a pivot point, wherein the rotatable lever rotates around the pivot point, and a first sensing component disposed on the rotatable lever, wherein the first sensing component is configured to interact with a second sensing component disposed on the elongate device body when the removable connection port is coupled to the elongate device body.

**[023]** Example 17 relates to the removable connection port according to Example 16, wherein the first sensing component is a magnet.

**[024]** In Example 18, a robotic surgical system comprises a robotic surgical device and a removable camera component. The robotic surgical device comprises an elongate device body comprising a distal end and a proximal end, a removable connection port disposed at the proximal

end of the device body, and first and second robotic arms operably coupled to the distal end of the device body. The connection port comprises a device body coupling mechanism disposed within the connection port, the device body coupling mechanism comprising first and second hinged coupling mechanisms hingedly coupled to the connection port, an camera receiving opening defined in a proximal end of the connection port, a seal package disposed in the removable connection port, the seal package comprising at least two seals, a camera coupling mechanism disposed within the removable connection port, and a presence detection mechanism operably coupled to the camera coupling mechanism. The camera coupling mechanism comprises a slidable body slidably disposed within the connection port, a camera receiving opening defined within the slidable body, an actuatable camera release button attached to a first end of the slidable body, and a tensioned spring operably coupled to a second end of the slidable body. The presence detection mechanism comprises a rotatable lever operably coupled to the camera coupling mechanism at a pivot point, wherein the rotatable lever rotates around the pivot point, a first sensing component disposed on the rotatable lever, and a second sensing component disposed on the elongate body, wherein the second sensing component is configured to sense the presence or absence of the first sensing component. The removable camera component is removably disposable in the camera receiving opening and through the seal package, and the removable camera component comprises a camera body, an elongate camera tube, a flexible section, and a distal imager.

**[025]** Example 19 relates to the robotic surgical system according to Example 18, wherein each of the first and second hinged coupling mechanisms comprises a coupling mechanism body, a tensioned hinge at a proximal end of the coupling mechanism body, wherein the tensioned hinge is hingedly coupled to the connection port, and a coupleable structure at a distal end of the coupling mechanism, wherein the coupleable structure comprises at least one coupling feature configured to be coupleable with a matching coupling feature on the proximal end of the device body and an actuatable button.

**[026]** Example 20 relates to the robotic surgical system according to Example 18, wherein the slidable body is slidable along a plane substantially transverse to a longitudinal axis of a lumen defined by the at least two seals in the seal package.

**[027]** In Example 21, a camera assembly for a robotic surgical system comprises an elongate camera shaft, a camera body coupled to a proximal end of the elongate camera shaft, a steerable tip disposed at the distal end of the elongate camera shaft, a first cable coupled at a first end to the first drive carriage and coupled at a second end to the steerable tip, and a second cable coupled at a first end to the second drive carriage and coupled at a second end to the steerable tip. The camera body comprises a distal end configured to be positionable within a robotic device, and at least one actuation mechanism disposed within the camera body. The distal end comprises a distal nose cone disposed around the elongate shaft, and a coupling mechanism acceptance slot defined proximal to the distal nose cone. The at least one actuation mechanism comprises a rotatable shaft, a first drive carriage threadably coupled to the rotatable shaft, and a second drive carriage threadably coupled to the rotatable shaft. The steerable tip comprises a steerable tip body comprising a camera imager and an illumination component, and a flexible section coupled to the elongate camera shaft

and the steerable tip body, wherein the steerable tip body is movable in relation to the elongate camera shaft via the flexible section. Further, actuation of the actuation mechanism causes linear movement of the first and second drive carriages in opposite directions, whereby the first and second cables steer the steerable tip.

**[028]** Example 21 relates to the camera assembly according to Example 21, wherein the camera body further comprises an external housing and a cylindrical heat sink structure, wherein the cylindrical heat sink structure is disposed within the external housing.

**[029]** While multiple embodiments are disclosed, still other embodiments will become apparent to those skilled in the art from the following detailed description, which shows and describes illustrative embodiments. As will be realized, the various embodiments are capable of modifications in various obvious aspects, all without departing from the spirit and scope thereof. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not restrictive.

### **Brief Description of the Drawings**

**[030]** FIG. 1 is a perspective view of a robotic surgical system in an operating room, according to one embodiment.

**[031]** FIG. 2 is perspective view of a robotic device, according to one embodiment.

**[032]** FIG. 3A is another perspective view of the robotic device of FIG. 2, according to one embodiment.

**[033]** FIG. 3B is a perspective view of camera that is insertable into the robotic device of FIG. 3A, according to one embodiment.

**[034]** FIG. 3C is an expanded perspective view of the distal end and robotic arms of the robotic device of FIG. 2, according to one embodiment.

**[035]** FIG. 4A is an expanded perspective view of the distal end and robotic arms of another robotic device, according to another embodiment.

**[036]** FIG. 4B is another expanded perspective view of the distal end and robotic arms of the robotic device of FIG. 4A, according to one embodiment.

**[037]** FIG. 5A is a perspective view of a robotic device attached to a support arm coupled to an operating table, according to one embodiment.

**[038]** FIG. 5B is an expanded perspective view of the device clamp and robotic device of FIG. 5A, according to one embodiment.

**[039]** FIG. 6 is a schematic perspective view of a robotic device and a camera component that is not positioned in the device and is instead being operated via a separate port in a patient, according to one embodiment.

**[040]** FIG. 7 is an expanded perspective view of the console of the surgical system of FIG. 1, according to one embodiment.

**[041]** FIG. 8A is a side view of camera assembly, according to one embodiment.

**[042]** FIG. 8B is a front view of the camera assembly of FIG. 8A, according to one embodiment.

- [043]** FIG. 9A is an expanded side view of the camera body of the camera assembly of FIG. 8A, according to one embodiment.
- [044]** FIG. 9B is an expanded cutaway side view of the camera body of FIG. 9A, according to one embodiment.
- [045]** FIG. 9C is an expanded cross-sectional view of the distal end of the camera body of FIG. 9A, according to one embodiment.
- [046]** FIG. 10A is a cross-sectional side view of the internal components of the camera body of FIG. 9A, according to one embodiment.
- [047]** FIG. 10B is a cross-sectional front view of the internal components of the camera body of FIG. 9A, according to one embodiment.
- [048]** FIG. 10C is a perspective cutaway view of an actuation mechanism for the camera body of FIG. 9A, according to one embodiment.
- [049]** FIG. 10D is a perspective view of the lead screw of the actuation mechanism of FIG. 10C, according to one embodiment.
- [050]** FIG. 10E is a cutaway view of certain components of the actuation mechanism of FIG. 10C, according to one embodiment.
- [051]** FIG. 10F is a cutaway view of certain components of the camera body of FIG. 9A, according to one embodiment.
- [052]** FIG. 11A is a perspective view of an elongate body and robotic arms of a robotic device and a nest that is coupleable thereto, according to one embodiment.
- [053]** FIG. 11B is a perspective view depicting the robotic device of FIG. 11 with the nest and a camera coupled thereto, along with an expanded view of the nest itself, according to one embodiment.
- [054]** FIG. 12A is a perspective cutaway view of the nest of FIG. 11B and a seal package disposed therein, according to one embodiment.
- [055]** FIG. 12B is a cross-sectional cutaway view of the seal package of FIG. 12A, along with an expanded view of the two seals disposed therein, according to one embodiment.
- [056]** FIG. 13 is a cross-sectional cutaway view of a proximal end of a device body with the nest of FIG. 11B attached thereto and a camera disposed therethrough, according to one embodiment.
- [057]** FIG. 14A is a cutaway view of the nest of FIG. 11B and two latches disposed therein, according to one embodiment.
- [058]** FIG. 14B is a perspective view of one of the latches of FIG. 14A, according to one embodiment.
- [059]** FIG. 15A is a side cutaway view of the nest of FIG. 11B disposed adjacent to the proximal end of the robotic device body of FIG. 11A, according to one embodiment.
- [060]** FIG. 15B is a side cutaway view of the nest and device body of FIG. 15A coupled together, according to one embodiment.

- [061] FIG. 16A is a side cutaway view of the nest of FIG. 11B disposed adjacent to the male connector of the device body of FIG. 11A, according to one embodiment.
- [062] FIG. 16B is a perspective expanded view of one latch of the nest of FIG. 16A being coupled with the male connector of FIG. 16A, according to one embodiment.
- [063] FIGS. 17A is a side cutaway view of the nest of FIG. 11B disposed adjacent to the male connector of the device body of FIG. 11A, according to one embodiment.
- [064] FIG. 17B is a side cutaway view of the nest and male connector of FIG. 17A coupled together, according to one embodiment.
- [065] FIG. 18 is a perspective cutaway view of the nest of FIG. 11B with a camera coupling mechanism disposed therein, according to one embodiment.
- [066] FIG. 19A is a side cross-sectional cutaway view of the nest and camera coupling mechanism of FIG. 18 in which the camera is not yet coupled to the nest, according to one embodiment.
- [067] FIG. 19B is a side cross-sectional cutaway view of the nest and camera coupling mechanism of FIG. 18 in which the camera is being urged into its fully coupled position in the nest, but is not yet fully coupled, according to one embodiment.
- [068] FIG. 19C is a side cross-sectional cutaway view of the nest and camera coupling mechanism of FIG. 18 in which the camera is fully coupled to the nest, according to one embodiment.
- [069] FIG. 20 is a perspective cutaway view of the nest of FIG. 11B with a presence detection mechanism disposed therein, according to one embodiment.
- [070] FIG. 21 is a side cross-sectional cutaway view of the nest and presence detection mechanism of FIG. 20 in which the camera is not yet coupled to the nest, according to one embodiment.
- [071] FIG. 22 is a side cross-sectional cutaway view of the nest and presence detection mechanism of FIG. 20 in which the camera is coupled to the nest, according to one embodiment.
- [072] FIG. 23 is a side cross-sectional cutaway view of the nest and presence detection mechanism of FIG. 20 in which the camera coupling mechanism button has been depressed, according to one embodiment.
- [073] FIG. 24 is a cross-sectional cutaway view of a forearm, according to one embodiment.
- [074] FIG. 25 is a perspective view of the forearm of FIG. 24, according to one embodiment.
- [075] FIG. 26 is a cross-sectional cutaway view of an upper arm coupled to a device body at the shoulder joint, according to one embodiment.
- [076] FIG. 27 is a cross-sectional cutaway view of the proximal end of the device body of FIG. 26, according to one embodiment.

#### Detailed Description

- [077] The various systems and devices disclosed herein relate to devices for use in medical procedures and systems. More specifically, various embodiments relate to various medical devices, including robotic devices and related methods and systems.

**[078]** It is understood that the various embodiments of robotic devices and related methods and systems disclosed herein can be incorporated into or used with any other known medical devices, systems, and methods.

**[079]** It is understood that the various embodiments of robotic devices and related methods and systems disclosed herein can be incorporated into or used with any other known medical devices, systems, and methods. For example, the various embodiments disclosed herein may be incorporated into or used with any of the medical devices and systems disclosed in U.S. Patent 8,968,332 (issued on March 3, 2015 and entitled "Magnetically Coupleable Robotic Devices and Related Methods"), U.S. Patent 8,834,488 (issued on September 16, 2014 and entitled "Magnetically Coupleable Surgical Robotic Devices and Related Methods"), U.S. Patent 10,307,199 (issued on June 4, 2019 and entitled "Robotic Surgical Devices and Related Methods"), U.S. Patent 9,579,088 (issued on February 28, 2017 and entitled "Methods, Systems, and Devices for Surgical Visualization and Device Manipulation"), U.S. Patent Application 61/030,588 (filed on February 22, 2008), U.S. Patent 8,343,171 (issued on January 1, 2013 and entitled "Methods and Systems of Actuation in Robotic Devices"), U.S. Patent 8,828,024 (issued on September 9, 2014 and entitled "Methods and Systems of Actuation in Robotic Devices"), U.S. Patent 9,956,043 (issued on May 1, 2018 and entitled "Methods and Systems of Actuation in Robotic Devices"), U.S. Patent Application 15/966,606 (filed on April 30, 2018 and entitled "Methods, Systems, and Devices for Surgical Access and Procedures"), U.S. Patent Application 12/192,663 (filed on August 15, 2008 and entitled "Medical Inflation, Attachment, and Delivery Devices and Related Methods"), U.S. Patent Application 15/018,530 (filed on February 8, 2016 and entitled "Medical Inflation, Attachment, and Delivery Devices and Related Methods"), U.S. Patent 8,974,440 (issued on March 10, 2015 and entitled "Modular and Cooperative Medical Devices and Related Systems and Methods"), U.S. Patent 8,679,096 (issued on March 25, 2014 and entitled "Multifunctional Operational Component for Robotic Devices"), U.S. Patent 9,179,981 (issued on November 10, 2015 and entitled "Multifunctional Operational Component for Robotic Devices"), U.S. Patent 9,883,911 (issued on February 6, 2018 and entitled "Multifunctional Operational Component for Robotic Devices"), U.S. Patent Application 15/888,723 (filed on February 5, 2018 and entitled "Multifunctional Operational Component for Robotic Devices"), U.S. Patent 8,894,633 (issued on November 25, 2014 and entitled "Modular and Cooperative Medical Devices and Related Systems and Methods"), U.S. Patent 8,968,267 (issued on March 3, 2015 and entitled "Methods and Systems for Handling or Delivering Materials for Natural Orifice Surgery"), U.S. Patent 9,060,781 (issued on June 23, 2015 and entitled "Methods, Systems, and Devices Relating to Surgical End Effectors" ), U.S. Patent 9,757,187 (issued on September 12, 2017 and entitled "Methods, Systems, and Devices Relating to Surgical End Effectors" ), U.S. Patent 10,350,000 (issued on July 16, 2019 and entitled "Methods, systems, and devices relating to surgical end effectors"), U.S. Patent Application 16/512,510 (filed on July 16, 2019 and entitled "Methods, Systems, and Devices Relating to Surgical End Effectors"), U.S. Patent 9,089,353 (issued on July 28, 2015 and entitled "Robotic Surgical Devices, Systems, and Related Methods"), U.S. Patent 10,111,711 (issued on October 30, 2018 and entitled "Robotic Surgical Devices, Systems, and Related Methods"), U.S. Patent Application 16/123,619 (filed on September 6, 2018 and entitled

“Robotic Surgical Devices, Systems and Related Methods”), U.S. Patent 9,770,305 (issued on September 26, 2017 and entitled “Robotic Surgical Devices, Systems, and Related Methods”), U.S. Patent Application 15/661,147 (filed on July 27, 2017 and entitled “Robotic Devices with On Board Control & Related Systems & Devices”), U.S. Patent Application 13/833,605 (filed on March 15, 2013 and entitled “Robotic Surgical Devices, Systems, and Related Methods”), U.S. Patent Application 13/738,706 (filed on January 10, 2013 and entitled “Methods, Systems, and Devices for Surgical Access and Insertion”), U.S. Patent Application 14/661,465 (filed on March 18, 2015 and entitled “Methods, Systems, and Devices for Surgical Access and Insertion”), U.S. Patent Application 15/890,860 (filed on February 7, 2018 and entitled “Methods, Systems, and Devices for Surgical Access and Insertion”), U.S. Patent 9,498,292 (issued on November 22, 2016 and entitled “Single Site Robotic Devices and Related Systems and Methods”), U.S. Patent 10,219,870 (issued on March 5, 2019 and entitled “Single site robotic device and related systems and methods”), U.S. Patent Application 16/293,135 (filed March 3, 2019 and entitled “Single Site Robotic Device and Related Systems and Methods”), U.S. Patent 9,010,214 (issued on April 21, 2015 and entitled “Local Control Robotic Surgical Devices and Related Methods”), U.S. Patent 10,470,828 (issued on November 12, 2019 and entitled “Local Control Robotic Surgical Devices and Related Methods”), U.S. Patent Application 16/596,034 (filed on October 8, 2019 and entitled “Local Control Robotic Surgical Devices and Related Methods”), U.S. Patent 9,743,987 (issued on August 29, 2017 and entitled “Methods, Systems, and Devices Relating to Robotic Surgical Devices, End Effectors, and Controllers”), U.S. Patent Application 15/687,787 (filed on August 28, 2017 and entitled “Methods, Systems, and Devices Relating to Robotic Surgical Devices, End Effectors, and Controllers”), U.S. Patent 9,888,966 (issued on February 13, 2018 and entitled “Methods, Systems, and Devices Relating to Force Control Surgical Systems”), U.S. Patent Application 15/894,489 (filed on February 12, 2018 and entitled “Methods, Systems, and Devices Relating to Force Control Surgical Systems”), U.S. Patent Application 14/212,686 (filed on March 14, 2014 and entitled “Robotic Surgical Devices, Systems, and Related Methods”), U.S. Patent Application 14/334,383 (filed on July 17, 2014 and entitled “Robotic Surgical Devices, Systems, and Related Methods”), U.S. Patent Application 14/853,477 (filed on September 14, 2015 and entitled “Quick-Release End Effectors and Related Systems and Methods”), U.S. Patent Application 16/504,793 (filed on July 8, 2019 and entitled “Quick-Release End Effectors and Related Systems and Methods”), U.S. Patent 10,376,322 (issued on August 13, 2019 and entitled “Robotic Device with Compact Joint Design and Related Systems and Methods”), U.S. Patent Application 16/538,902 (filed on August 13, 2019 and entitled “Robotic Device with Compact Joint Design and Related Systems and Methods”), U.S. Patent Application 15/227,813 (filed on August 3, 2016 and entitled “Robotic Surgical Devices, System and Related Methods”) U.S. Patent Application 15/599,231 (filed on May 18, 2017 and entitled “Robotic Surgical Devices, Systems, and Related Methods”), U.S. Patent Application 15/687,113 (filed on August 25, 2017 and entitled “Quick-Release End Effector Tool Interface”), U.S. Patent Application 15/691,087 (filed on August 30, 2017 and entitled “Robotic Device with Compact Joint Design and an Additional Degree of Freedom and Related Systems and Methods”), U.S. Patent Application 15/821,169 (filed on November 22, 2017 and entitled “Gross Positioning Device and Related Systems and Methods”), U.S. Patent Application

15/826,166 (filed on November 29, 2017 and entitled "User controller with user presence detection and related systems and methods"), U.S. Patent Application 15/842,230 (filed on December 14, 2017 and entitled "Releasable Attachment Device for Coupling to Medical Devices and Related Systems and Methods"), U.S. Patent Application 16/144,807 (filed on September 27, 2018 and entitled "Robotic Surgical Devices with Tracking Camera Technology and Related Systems and Methods"), U.S. Patent Application 16/241,263 (filed on January 7, 2019 and entitled "Single-Manipulator Robotic Device With Compact Joint Design and Related Systems and Methods"), U.S. Patent 7,492,116 (filed on October 31, 2007 and entitled "Robot for Surgical Applications"), U.S. Patent 7,772,796 (filed on April 3, 2007 and entitled "Robot for Surgical Applications"), and U.S. Patent 8,179,073 (issued on May 15, 2011, and entitled "Robotic Devices with Agent Delivery Components and Related Methods"), all of which are hereby incorporated herein by reference in their entireties.

**[080]** Certain device and system implementations disclosed in the applications listed above can be positioned within a body cavity of a patient, or a portion of the device can be placed within the body cavity, in combination with a support component similar to those disclosed herein. An "in vivo device" as used herein means any device that can be positioned, operated, or controlled at least in part by a user while being positioned within a body cavity of a patient, including any device that is coupled to a support component such as a rod or other such component that is disposed through an opening or orifice of the body cavity, also including any device positioned substantially against or adjacent to a wall of a body cavity of a patient, further including any such device that is internally actuated (having no external source of motive force), and additionally including any device that may be used laparoscopically or endoscopically during a surgical procedure. As used herein, the terms "robot," and "robotic device" shall refer to any device that can perform a task either automatically or in response to a command.

**[081]** Certain embodiments provide for insertion of the present invention into the cavity while maintaining sufficient insufflation of the cavity. Further embodiments minimize the physical contact of the surgeon or surgical users with the present invention during the insertion process. Other implementations enhance the safety of the insertion process for the patient and the present invention. For example, some embodiments provide visualization of the present invention as it is being inserted into the patient's cavity to ensure that no damaging contact occurs between the system/device and the patient. In addition, certain embodiments allow for minimization of the incision size/length. Other implementations include devices that can be inserted into the body via an incision or a natural orifice. Further implementations reduce the complexity of the access/insertion procedure and/or the steps required for the procedure. Other embodiments relate to devices that have minimal profiles, minimal size, or are generally minimal in function and appearance to enhance ease of handling and use.

**[082]** As in manual laparoscopic procedures, a known insufflation system can be used to pump sterile carbon dioxide (or other gas) into the patient's abdominal cavity. This lifts the abdominal wall from the organs and creates space for the robot. In certain implementations, the system has no direct interface with the insufflation system. Alternatively, the system can have a direct interface to the insufflation system.

**[083]** In certain implementations in which the device is inserted through an insertion port, the insertion port is a known, commercially-available flexible membrane placed transabdominally to seal and protect the abdominal incision. This off-the-shelf component is the same device or substantially the same device that is used in substantially the same way for Hand-Assisted Laparoscopic Surgery (HALS). The only difference is that the arms of the robotic device according to the various embodiments herein are inserted into the abdominal cavity through the insertion port rather than the surgeon's hand. The robotic device body seals against the insertion port when it is positioned therethrough, thereby maintaining insufflation pressure. The port is single-use and disposable. Alternatively, any known port can be used. In further alternatives, the device can be inserted through an incision without a port or through a natural orifice.

**[084]** Certain implementations disclosed herein relate to "combination" or "modular" medical devices that can be assembled in a variety of configurations. For purposes of this application, both "combination device" and "modular device" shall mean any medical device having modular or interchangeable components that can be arranged in a variety of different configurations.

**[085]** Certain embodiments disclosed or contemplated herein can be used for colon resection, a surgical procedure performed to treat patients with lower gastrointestinal diseases such as diverticulitis, Crohn's disease, inflammatory bowel disease and colon cancer. Approximately two-thirds of known colon resection procedures are performed via a completely open surgical procedure involving an 8- to 12-inch incision and up to six weeks of recovery time. Because of the complicated nature of the procedure, existing robot-assisted surgical devices are rarely used for colon resection surgeries, and manual laparoscopic approaches are only used in one-third of cases. In contrast, the various implementations disclosed herein can be used in a minimally invasive approach to a variety of procedures that are typically performed 'open' by known technologies, with the potential to improve clinical outcomes and health care costs. Further, the various implementations disclosed herein can be used for any laparoscopic surgical procedure in place of the known mainframe-like laparoscopic surgical robots that reach into the body from outside the patient. That is, the less-invasive robotic systems, methods, and devices disclosed herein feature small, self-contained surgical devices that are inserted in their entireties through a single incision in the patient's abdomen. Designed to utilize existing tools and techniques familiar to surgeons, the devices disclosed herein will not require a dedicated operating room or specialized infrastructure, and, because of their much smaller size, are expected to be significantly less expensive than existing robotic alternatives for laparoscopic surgery. Due to these technological advances, the various embodiments herein could enable a minimally invasive approach to procedures performed in open surgery today.

**[086]** FIG. 1 depicts one embodiment of a robotic surgical system 10 having several components that will be described in additional detail below. The components of the various system implementations disclosed or contemplated herein can include an external control console 16 and a robotic device 12 having a removable camera 14 as will also be described in additional detail below. In accordance with the implementation of FIG. 1, the robotic device 12 is shown mounted to the operating table 18 via a known, commercially available support arm 20. The system 10 can be, in certain implementations, operated by the surgeon 22 at the console 16 and one surgical assistant 24

positioned at the operating table 18. Alternatively, one surgeon 22 can operate the entire system 10. In a further alternative, three or more people can be involved in the operation of the system 10. It is further understood that the surgeon (or user) 22 can be located at a remote location in relation to the operating table 18 such that the surgeon 22 can be in a different city or country or on a different continent from the patient on the operating table 18.

**[087]** In this specific implementation, the robotic device 12 with the camera 14 are both connected to the surgeon console 16 via cables: a device cable 24A and a camera cable 24B that will be described in additional detail below. Alternatively, any connection configuration can be used. In certain implementations, the system can also interact with other devices during use such as an electrosurgical generator, an insertion port, and auxiliary monitors.

**[088]** FIG. 2 depicts one exemplary implementation of a robotic device 40 that can be incorporated into the exemplary system 10 discussed above or any other system disclosed or contemplated herein. The device 40 has a body (or "torso") 42 having a distal end 42A and proximal end 42B, with the imaging device (or "camera") 44 disposed therethrough, as mentioned above and as will be described in additional detail below. Briefly, the robotic device 40 has two robotic arms 46, 48 operably coupled thereto and the camera 44 is removably positionable through the body 42 and disposed between the two arms 46, 48. That is, device 40 has a first (or "right") arm 46 and a second (or "left") arm 48, both of which are operably coupled to the device 40 as discussed in additional detail below. In this embodiment, the body 42 of the device 40 as shown has an enclosure (also referred to as a "cover" or "casing") 52 such that the internal components and lumens of the body 42 are disposed within the enclosure 52. The device body 42 has two rotatable cylindrical bodies (also referred to as "shoulders" or "turrets") 54A, 54B: a first (or "right") shoulder 54A and a second (or "left") shoulder 54B. Each arm 46, 48 in this implementation also has an upper arm (also referred to herein as an "inner arm," "inner arm assembly," "inner link," "inner link assembly," "upper arm assembly," "first link," or "first link assembly") 46A, 48A, and a forearm (also referred to herein as an "outer arm," "outer arm assembly," "outer link," "outer link assembly," "forearm assembly," "second link," or "second link assembly") 46B, 48B. The right upper arm 46A is operably coupled to the right shoulder 54A of the body 42 at the right shoulder joint 46C and the left upper arm 48A is operably coupled to the left shoulder 54B of the body 42 at the left shoulder joint 48C. Further, for each arm 46, 48, the forearm 46B, 48B is rotatably coupled to the upper arm 46A, 48A at the elbow joint 46D, 48D. In various embodiments, the forearms 46B, 48B are configured to receive various removeable, interchangeable end effectors 56A, 56B.

**[089]** The end effectors 56A, 56B on the distal end of the arms 46, 48 can be various tools 56A, 56B (scissors, graspers, needle drivers and the like), as will be described in additional detail below. In certain implementations, the tools 56A, 56B are designed to be removable, including in some instances by a small twist of the tool knob that couples the end effector 56A, 56B to the arm 46, 48. In certain implementations, at least two single-use, interchangeable, disposable surgical end effectors can be used with any of the robotic device embodiments herein (including device 40). Such end effectors can include, but are not limited to, a fenestrated grasper capable of bi-polar cautery, scissors that deliver mono-polar cautery, a hook that delivers mono-polar cautery, and a left/right

needle driver set. The tools can be selected for the specific surgical task. Certain forearm and end effector configurations that allow for the removability and interchangeability of the end effectors are disclosed in detail in U.S. Application 14/853,477, which is incorporated by reference above. Further, it is understood that any known forearm and end effector combinations can be used in any of the robotic device embodiments disclosed or contemplated herein.

**[090]** In various implementations, the body 40 and each of the links of the arms 46, 48 can contain a variety of actuators or motors. In certain implementations, the body 40 has no motors disposed therein, while there is at least one motor in each of the arms 46, 48. In one embodiment, any of the motors discussed and depicted herein can be brush or brushless motors. Further, the motors can be, for example, 6 mm, 8 mm, or 10 mm diameter motors. Alternatively, any known size that can be integrated into a medical device can be used. In a further alternative, the actuators can be any known actuators used in medical devices to actuate movement or action of a component. Examples of motors that could be used for the motors described herein include the EC 10 BLDC + GP10A Planetary Gearhead, EC 8 BLDC + GP8A Planetary Gearhead, or EC 6 BLDC + GP6A Planetary Gearhead, all of which are commercially available from Maxon Motors, located in Fall River, MA. There are many ways to actuate these motions, such as with DC motors, AC motors, permanent magnet DC motors, brushless motors, pneumatics, cables to remote motors, hydraulics, and the like. As such, the actuation source can be at least one motor, hydraulic pressure source, pneumatic pressure source, or any other actuation source disposed remotely from or proximally to the device 40 such that an appropriate coupling or transmission mechanism (such as at least one cable, at least one hydraulic transmission hose, at least one pneumatic transmission hose, or any other transmission mechanism) is disposed through the body 42.

**[091]** In one embodiment, the various joints discussed above in accordance with any of the embodiments disclosed or contemplated herein can be driven by electrical motors disposed within the device and, in some implementations, near each joint. Other embodiments include the incorporation of pneumatic or hydraulic actuators in any of the device implementations herein. In additional alternative embodiments, the driving actuators are disposed outside the device and/or body cavity and power transmission mechanisms are provided to transmit the energy from the external source to the various joints of any device herein. Such a transmission mechanism could, for example, take the form of gears, drive shafts, cables, pulleys, or other known mechanisms, or any combination thereof.

**[092]** FIGS. 3A and 3B depict one embodiment of the robotic device 40 with the camera assembly 44 removed, according to one implementation. That is, FIG. 3A depicts the device 40 without the camera positioned through the body 42, and FIG. 3B depicts one embodiment of the camera 44. In certain implementations, and as best shown in FIG. 3B, the camera 44 has a handle (or "camera body") 60 with an elongate shaft 62 coupled thereto such that the shaft 62 extends distally from the distal end of the handle 60. In addition, the camera 44 has a steerable tip 64 coupled to the distal end of the shaft 62 via a flexible section 68 such that the steerability allows the user to adjust the viewing direction, as will be discussed in further detail below. Further, the tip 64 also includes a camera imager 66 at the distal end of the tip 64 that is configured to capture the desired images. Further, the tip 64 in certain implementations has an illumination light (not shown) disposed

thereon, such that the light can illuminate the objects in the field of view. In one specific implementation, the camera 44 provides 1080p 60 Hz. digital video. Alternatively, the camera 44 can provide any known video quality.

**[093]** As best shown in FIGS. 3A and 3C, the camera assembly 44 can be inserted into the body 42 of the robotic device 40 by positioning the distal end of the shaft 62 through a lumen (not shown) defined through the body 42 of the robotic device 40 as shown by the arrow A in FIG. 3A. As will be described in further detail below, certain implementations of the device 40 include a removable nest (or “dock”) (not shown) disposed near the proximal end of the body 42 that includes a seal (not shown) that operates to ensure that the patient’s cavity remains insufflated. When the shaft 62 is inserted through the lumen of the body 42 as desired, according to certain embodiments as best shown in FIG. 2 and 3C, the distal end of the shaft 62, including the flexible section 68 and the steerable tip 64 (containing the imager 66) extends out of an opening at the distal end of the body 42 such that the tip 64 is positioned between the two arms 46, 48 in the surgical environment as shown. Thus, the imager 66 is positioned to capture the view between the two arms 46, 48 and the steerable tip 64 can be actuated to provide views of the surgical tools and surgical target. That is, the tip 64 can be moved such that the surgical tools and/or surgical target are captured within the field of view of the imager 66. It is understood that this camera 44 embodiment and any other such camera embodiment disclosed or contemplated herein can be used with any similar robotic device having a camera lumen defined therethrough.

**[094]** In various implementations, as best shown in FIG. 3C, the steerable tip 64 and therefore also the camera imager 66 can be steered or otherwise moved in two independent directions in relation to the shaft 62 at a flexible section 68 disposed between the shaft 62 and the steerable tip 64 to change the direction of view. That is, FIG. 3C shows that the steerable tip 64 can be robotically articulated in the yaw direction (left and right in relation to the device 40) as represented by arrow B or pitch direction (up and down in relation to the device 40) as represented by arrow C. In various implementations, the camera 44 can be controlled via a console (such as console 16 discussed above, for example) or via control buttons (not shown) as will be discussed in additional detail below. In one embodiment, the features and operation (including articulation) of the steerable tip are substantially similar to the steerable tip as described in U.S. Applications 14,334,383 and 15/227,813, both of which are incorporated by reference above. Alternatively, any known robotic articulation mechanism for cameras or similar apparatuses can be incorporated into any camera embodiment utilized in any device or system disclosed or contemplated herein.

**[095]** In various implementations, the camera 44 can be re-sterilized for multiple uses. In one specific embodiment, the camera 44 can be reused up to one hundred times or more. Alternatively, it is understood that any known endoscopic camera that can fit through a device body according to any implementation herein can be utilized.

**[096]** Focusing now on the robotic arms 82, 84 of a robotic device 80 according to one embodiment as shown in FIGS. 4A-4B, each robot arm 82, 84 in this implementation has six degrees of freedom, including the open/close function of the tool, as best shown in FIG. 4A. For purposes of this discussion, the various degrees of freedom will be discussed in the context of the right arm 82 as

shown in FIG. 4A, but it is understood that both arms have the same degrees of freedom. The right shoulder joint 86 is approximately a spherical joint similar to a human shoulder. The upper arm 88 can yaw (J1), pitch (J2), and roll about the shoulder joint 86 (J3). These first three axes of rotation roughly intersect at the shoulder joint 86. The robot elbow 90 (J4) allows rotation of the forearm 92 with respect to the upper arm 88. Finally, the end effector 94 can roll (J5) about the long axis of the tool 94 and some tools that can be replaceably attached to the forearm 92 have an open/close actuation function. On the other hand, it is understood that a hook cautery tool, for example, does not open/close.

**[097]** The robotic arms 82, 84 in this implementation have significant dexterity. As shown in FIG. 4B, the six degrees of freedom described above allow the arms 82, 84 to reach into the confined spaces of the abdominal cavity. FIG. 4B schematically depicts the entire workspace 110 of the arms 82, 84 of the robotic device 80, according to certain implementations. In these implementations, "workspace" 110 means the space 110 around the robotic device 80 in which either arm 82, 84 (and/or end effector thereof) can move, access, and perform its function within that space 110. According to one embodiment, the arms 82, 84 herein are substantially the same as the arms, the degrees of freedom, and the overall workspace and the individual workspaces of each arm as disclosed in U.S. Published Application 2019/0090965, which is hereby incorporated herein by reference in its entirety.

**[098]** FIG. 4B depicts a perspective view of the device 80 and further schematically shows the collective workspace 110 of the first and second arms 82, 84. Note that the each arm 82, 84 has a range of motion and corresponding workspace that extends from the front 112 of the device 80 to the back 114 of the device 80. Thus, the first arm 82 moves equally to the front 112 and the back 114, through about 180° of space relative to the axis of the device body 80A for each arm 14, 16. This overall workspace 110, which constitutes an intersecting or collective workspace 110 based on the separate workspaces of the two arms 82, 84, allows the robotic device 80 to work to the front 112 and back 114 equally well without having to reposition the body 80A. Thus, the workspace 110 represents a region that is reachable by both the left and right arms 112, 114 and is defined as the bi-manual robot workspace 110. The surgeon will have full robot dexterity when working in this bi-manual region 110.

**[099]** The bi-manual workspace 110 is approximated by an ellipse that is rotated 180 degrees about the shoulder pitch joint (J2 in FIG. 4A) and is shown in FIG. 4B. For one specific design implementation, the ellipse is approximately 4.5" (11.5 cm) on the long axis and 3.25" (8.25 cm) on the minor axis. The bi-manual workspace 110 extends from in front of the robotic device 80 to below the device 80 and is also behind the back of the device 80. This dexterity of the robotic arms 82, 84 allows the surgeon to operate the arms 82, 84 to work equally well anywhere inside this bi-manual workspace 110.

**[0100]** As can be seen in FIG. 4A, the arms 82, 84 in this exemplary implementation have a molded silicon protective sleeve 96 that is disposed over the arms 82, 84 and shoulder turrets 98A, 98B. In one embodiment, the sleeve 96 is fluidically sealed such that it protects the arms 82, 84 and the robotic device 80 from fluid ingress and also helps to simplify post-surgery cleaning and

sterilization. The fluidically sealed sleeve 96 is substantially similar to any of the sleeve embodiments disclosed or contemplated in U.S. Applications 14/334,383, 15/227,813, and 16/144,807, all of which are incorporated by reference above.

**[0101]** Additional features and components of the robotic device include those disclosed in U.S. Applications 14/334,383, 15/227,813, and 16/144,807, all of which are incorporated by reference above, along with all of the other patents and applications incorporated by reference above. It is understood that any robotic device embodiment disclosed or contemplated herein (including, for example, the robotic devices 12, 40, 80 discussed above), can be incorporated into not only the system embodiments disclosed herein, but any other known robotic surgical system. It is further understood that, according to certain implementations, any robotic device disclosed or contemplated herein can be configured such that it can be cleaned and sterilized for multiple uses. In some embodiments, the device can be reused up to ten times or more.

**[0102]** As shown in FIGS. 5A and 5B (and as discussed above with respect to FIG. 1), the device 12 is attached to the operating table 18 via support arm 20. More specifically, the support arm 20 is coupled at one end to the operating table 18 as shown. Further, the support arm 20 has a robotic device body clamp 116 at the other end of the arm 20 such that the clamp 116 can be coupled to a clamp interface ring 118 defined in an outer surface of the enclosure 52 of the device body 42, as best shown in FIG. 5B. Certain embodiments of the clamp 116 are disclosed in additional detail in U.S. Published Application 2017/0035526, which is hereby incorporated herein by reference in its entirety. In addition, the support arm 20 has an adjustment knob 119 that allows for the arm 20 to be adjusted such that the attached device 12 can be repositioned to numerous different position options as needed. As such, the device 12 is adjustably attached to the table 18 via the arm 20. Alternatively, any known support arm can be used to support the various robotic device embodiments herein. Thus, in addition to the positioning of the device 12 and arms 46, 48 as discussed above, in various implementations, the robotic device 12 can reach any area of the surgical cavity because it can be easily repositioned during the procedure via "gross positioning." That is, the device 12 can be quickly, in a matter of seconds, moved by manually adjusting the external support arm 20 and robot clamp 116. The combination of gross positioning of the robotic device 12 and the dexterity of the robot arms 46, 48 as described above allow the surgeon to place the device 12 so it can work anywhere in the target cavity of the patient with, in certain embodiments, the arms 46, 48 well triangulated for the given procedure, as discussed elsewhere herein.

**[0103]** The various camera embodiments herein (including cameras 14 and 44, for example) can, in certain implementations, be coordinated with the device to which it is coupled to create coordinated triangulation between the camera and the arms and end effectors for any configuration, positioning, and use of the device. Further, the steerable tip of any such camera can be robotically articulated so as to reposition the field of view, either automatically or via control by the surgeon using the system console. That is, the camera articulates to ensure the surgeon can view all possible locations of the robotic arms as well as the desired areas of the surgical theater. Further, as the robotic arms move - the steerable camera tip can be coordinated with the arms to move using active joints in coordination with the arm movements to view the entire robot workspace. In certain

implementations, the joints of the camera are actively controlled using motors and sensors and a processor (and, in some implementations, a control algorithm contained therein). In these implementations, the processor allows for automated and / or semi-automated positioning and re-positioning of the camera 12 about the pitch ( $\alpha$ ) and / or yaw ( $\beta$ ) rotations relative to the robotic device. It is understood that the various embodiments of systems and devices having such a coordination between the camera and the device (and arms) and the resulting features thereof are disclosed in detail in U.S. Published Application 2019/0090965, which is incorporated by reference above.

**[0104]** Alternatively, in certain implementations as shown in FIG. 6, the camera 44 can be removed from the robotic device 40 and positioned through another, known laparoscopic port 120 typically used with a standard manual laparoscope. As such, in this embodiment, the device 40 is disposed through a main port (also known as an "insertion port") 122 and the camera 44 is positioned through the known laparoscopic port 120 as shown. It is understood that this arrangement may be useful to visualize the robotic device 40 to ensure safe insertion and extraction via the main port 122. According to various embodiments, the camera 44 can also be removed from the robotic device 40 so the optics can be cleaned, the camera 44 can be repaired, or for any other reason in which it is beneficial to remove the camera 44. It is understood that while the device 40 and camera 44 are depicted and discussed herein, any device or camera according to any implementation disclosed or contemplated herein can also be used in a similar arrangement and any such camera can also be removed from the device for any reason as discussed herein.

**[0105]** It is understood that the insertion port 122 also can represent the port 122 through which any robotic device embodiment disclosed or contemplated herein is positioned for any procedure as contemplated herein (including those procedures in which the camera 44 is disposed through the device 40). In one embodiment, the insertion port 122 can be a single use commercially available flexible membrane disposed transabdominally to seal and protect the abdominal incision and allow for positioning the body 42 of the device 40 therethrough. In specific implementations, the insertion port 122 is the same device used in Hand-Assisted Laparoscopic Surgery (HALS), including the exemplary port 122 depicted in FIG. 6, which, according to one embodiment, is a GelPort™ 122. The device body 42 seals against the insertion port 122, thereby establishing a fluidic seal and thus maintaining insufflation pressure. Alternatively, any known insertion port (or incision) that is configured to receive a device similar to that disclosed herein can be used.

**[0106]** Returning to the overall system embodiments, such as the system 10 depicted in FIG. 1 and discussed above, the robotic device (such as device 12 or device 40) can be piloted, in accordance with certain embodiments, via the surgeon console 16 as shown in FIGS. 1 and 7. This exemplary implementation of the surgeon console 16 contains a main processor (not shown) that performs robot control functions, system monitoring, and any other known processes or functionalities necessary or beneficial for controlling a system according to any embodiment herein. In these implementations, the console 16 also has a real-time display 130 that can display real-time images of the surgical environment using the output of the camera (such as camera 14 or 44). In one embodiment, the display 130 is a high definition display 130. Alternatively, any known display can be

used. In addition, the console 16 can also have a touchscreen interface 132 that can be used to control several functions of the console 16 and device 12 (or device 40). In certain implementations, the touch screen 132 can also display various types of information about the state of the robotic device 12 (or 40) or any other component of the system 10. Alternatively, any known console can be used with the various implementations of the system disclosed or contemplated herein.

**[0107]** The console 16 in this implementation also has right and left hand controllers (or "input devices") 134A, 134B that can be used to control various aspects of the device 12, 40 and/or camera 14, 44, including movement thereof. The surgeon can interface with the input devices 134A, 134B using the surgeon's hands such that the input devices 134A, 134B can track the movement of the surgeon's hands. In certain embodiments, each of the input devices 134A, 134B can have a surgeon presence sensor to track whether the surgeon's hands are properly engaged. In one exemplary embodiment, the user presence sensor is any of the embodiments disclosed or contemplated in U.S. Patent Application 15/826,166, which is incorporated by reference above. In certain implementations, the input devices 134A, 134B can also be configured to provide haptic feedback by pushing on the surgeon's hands to indicate things such as workspace boundaries and collisions between the robot arms, as is described in detail in U.S. Patent Application 15/227,813 and U.S. Patent 9,888,966, both of which are incorporated by reference above. According to various embodiments, the input devices 134A, 134B can also control open/close functions of the robot's end effectors.

**[0108]** In accordance with some implementations, the surgeon console 16 can also have foot pedals 136 that are configured to be operable by the surgeon's feet to control various robot functions, including, for example, clutching, camera movements, and various electro cautery functions. Alternatively, the pedals 136 can be used to operate any known functions of the robotic device 12, 40 or any other component of the system 10. In a further alternative, any other input devices on the console 16 can be used to control those various functions.

**[0109]** The surgeon console 16 according to certain implementations can be configured such that it can be operated by a surgeon positioned in either a sitting position (similar to Intuitive's da Vinci console) or a standing position (similar to manual laparoscopy). The console 16 in this exemplary embodiment is designed to be easily transported between operating rooms using castors 138 and a transport handle 140. In certain embodiments, the height of the console 16 is adjustable.

**[0110]** Other console and system embodiments that can be incorporated into any system disclosed or contemplated herein are disclosed in U.S. Applications 14/334,383, 15/227,813, and 16/144,807, all of which are incorporated by reference above, along with any of the other relevant patents and applications incorporated by reference above. The various components in said applications include companion carts, an interface pod, an electrosurgical generator, and the appropriate cables and connections, for example. Further, it is understood that any other known console or controller can be utilized with any robotic device or system disclosed or contemplated herein.

**[0111]** Another camera embodiment is depicted in FIGS. 8A and 8B (with FIG. 8A depicting a side view and FIG. 8B depicting a front view), in which the camera assembly 150 has a handle (or "camera body") 152 with an elongate shaft 154 coupled thereto such that the shaft 154 extends

distally from the distal end of the handle 152. In addition, the camera 150 has a steerable tip 156 coupled to the distal end of the shaft 154 via a flexible section 158 that couples the tip 156 to the shaft 154 such that the steerability allows the user to adjust the viewing direction, as will be discussed in further detail below. The tip 156 includes a camera imager (also referred to as an "imaging sensor") 160 at the distal end of the tip 156 that is configured to capture the desired images, along with optics and support electronics (not shown). In this embodiment, the camera 150 also has light fibers (not shown) that are disposed through the shaft 154, flexible section 158, and tip 156 such that the light fibers provide light output at the tip 156 so as to light the surgical target for imaging. In addition, the assembly 150 has a cable 162 that is coupled to the handle 152 and extends therefrom to an external controller (such as the console 16 discussed above or any other controller) such that the cable 162 can provide electrical signals to and from the camera 150, including a video signal and any power and other signals or information necessary to operate the camera 150.

**[0112]** The steerable tip 156 can be robotically articulated in two independent directions, according to one embodiment. More specifically, as discussed above in additional detail with respect to the camera assembly 44 embodiment and depicted in FIG. 3C, the steerable tip 156 can be articulated to move in both the pitch and yaw directions.

**[0113]** FIGS. 9A, 9B, and 9C are expanded views of the camera handle 152 according to one embodiment. In this exemplary implementation, the camera handle 152 has an outer enclosure (also referred to as "exterior housing," "housing," or "enclosure") 180, as best shown in FIG. 9A, with an inner housing 182 disposed within the enclosure 180, as best shown in FIG. 9B. In certain embodiments, the inner housing 182 is an inner heat distribution sink 182 that can function to distribute heat inside the camera handle exterior housing 180. More specifically, the heat distribution sink 182 is a cylinder 182 or structure 182 of any appropriate shape that is disposed within the enclosure 180 and around the internal components of the handle 152. The sink 182 is made of a material that distributes heat across the structure 182 and has a thermal capacity for heat. In one specific embodiment, the material is aluminum. Alternatively, the sink 182 can be made of any known heat sink material. The outer enclosure 180 helps to enclose the heat sink 182 and the internal mechanical and electrical components of the handle 152.

**[0114]** In addition, the handle 152 according to various implementations also has a cable strain relief assembly 184 extending from the proximal end of the handle 152 such that the cable 162 is disposed through the relief assembly 184. In one embodiment, the relief assembly 184 is a tube 184 or other elongate structure 184 through which the cable 162 can be disposed such that the relief assembly 184 has a reinforced structure to reduce the strain applied on the cable 162 when force is applied to the cable 162. It is understood that the cable strain relief assembly 184 can be any known structure for providing strain relief. Alternatively, the assembly 184 can be any known cable strain relief assembly.

**[0115]** The camera handle 152 also has, in this specific implementation, two O-ring seals 186A, 186B disposed around the cable connection 188. The seals 186A, 186B are disposed between the connection 188 and the housing 180, thereby establishing a fluidic seal therebetween and thus helping to prevent fluid ingress. Alternatively, there can be one seal, three seals, or any number of

seals disposed around the connection 188. In a further alternative, the seal(s) need not be an O-ring seal, and instead can be any known type of seal.

**[0116]** The distal end of the camera handle 152 has a nose cone 190 extending therefrom, according to one embodiment. As best shown in FIG. 9C, the nose cone 190 is a distal structure 190 that extends distally from the handle 152. The nose cone 190 includes a nose cone tip 192 at the distal end of the nose cone 190 and slot 194 defined in the nose cone proximal to the tip 192. In one embodiment, the nose cone slot 194 is a camera coupling mechanism acceptance slot 194 such that the camera latch 420 discussed in further detail below can be received in the slot 194. As such, the camera latch acceptance slot 194 can work in conjunction with the camera latch 420 to assist with attaching the camera to the elongate body 42 of the elongate device 40 (or any other device embodiment herein) via the nest structure 346 as also discussed in detail below.

**[0117]** In addition, the nose cone 190 has a protrusion (or "collar") 196 that is disposed around the cone 190 and has both an outer O-ring seal 198A and an inner O-ring seal 198B attached to the protrusion 196 as shown. The outer O-ring seal 198A is disposed on an outer circumference of the collar 196 such that the seal 198A is disposed between the collar 196 and the camera body enclosure 180. Further, the inner O-ring seal 198B is disposed on an inner circumference of the collar 196 such that the seal 198B is disposed between the collar 196 and the cone 190. As such, the seals 198A, 198B help to establish a fluidic seal between the nose cone 190 and the camera housing 180, thereby creating a sealed camera handle 152 that helps to protect the internal mechanical and electrical components during use and cleaning.

**[0118]** In use, the camera assembly 150 is typically held by a user (such as a surgical assistant and/or surgeon) via the camera handle/body 152 when the camera 150 is moved around and inserted into or removed from the device body 42 (or any other device body embodiment herein) (or when used independently of any robotic device as discussed above). Further, the nose cone 190 of the handle 152 is sized and shaped to couple with and assist with attachment to the elongate body 42 (or any other device body embodiment herein) as discussed in additional detail below.

**[0119]** In accordance with one embodiment as shown in FIGS. 10A and 10B, the camera body/handle 152 can contain several internal components. FIG. 10A is a side view of the internal components of the handle 152 (the same view as that provided in FIGS. 8A, 9A, and 9B), while FIG. 10B is a front view (the same view as FIG. 8B). As best shown in FIG. 10A, the handle 152 in this implementation has an LED light source 220 with two light transmission fibers 222A, 222B coupled thereto that extend distally from the light source 220 through the interior of the handle 152 and toward and toward through camera shaft 154 to the distal tip of the shaft 154. Thus, the fibers 222A, 222B transmit light from the source 220 along the fibers 222A, 222B to the field of view of the imager 160 as discussed above. As such, the light from the light source 220 ultimately shines on the imaging target. It is understood that the light source 220 can be adjusted via a controller (such as the console 16), including via software in the controller or console 16, in a known fashion to adjust the light intensity produced therefrom. Alternatively, the handle 152 can have two LED light sources, with each separate source coupled to a different one of the two transmission fibers. In a further alternative, one transmission fiber can be used, or three or more fibers can be used. In yet another

alternative, any configuration for transmitting light to the steerable tip 156 can be incorporated into any of the camera embodiments disclosed or contemplated herein.

**[0120]** In addition, the camera body 152 also has at least one circuit board 224 disposed therein. In one embodiment, the at least one circuit board 224 can be used to control the camera assembly 150 in any number of known ways. In some non-limiting examples, the at least one circuit board 224 can control the light source 220 or any facet of the lighting, the video signal, the image sensor 160, the actuation mechanisms 226A, 226B, or any sensors present anywhere on or in the camera 150. Alternatively, the camera body 152 can have two or more circuit boards for controlling various components and/or features of the camera 150. Further, the camera body 152 also has an actuator unit (also referred to herein as an "articulation unit") 226 that actuates the steerable tip 156. That is, the actuator unit 226 is operably coupled to the steerable tip 156 such that the actuator unit 226 actuates the tip 156 to move in both directions as described in additional detail herein: pitch and yaw. In this specific embodiment, the actuator unit 226 is actually made up of two actuator mechanisms: a first (or yaw or left/right) actuation mechanism 226A and a second (or pitch or north/south) actuation mechanism 226B. As will be described in additional detail below, each of the two mechanisms is coupled to the steerable tip 156 via cables that can be used to transfer the motive force use to move the steerable tip 156 as described herein. In one embodiment as best shown in FIG. 10B, each of the two mechanisms is coupled to the steerable tip 156 via a pair of cables, with the first mechanism 226A coupled to the tip 156 via cable pair 228 and the second mechanism 226B coupled to the tip 156 via cable pair 230. That is, as best shown in the side view of FIG. 10A, the first pair of cables 228A, 228B is coupled at the proximal ends of the pair 228A, 228B to the first mechanism 226A and further is coupled at the distal ends of the pair 228A, 228B to the steerable tip 156. Similarly, as shown in profile in FIG. 10B, the second pair of cables 230 is coupled at the proximal ends thereof to the second mechanism 226B and at the distal ends of the pair 230 to the steerable tip 156. In one embodiment, the cable pairs 228, 230 are known Bowden cables 228, 230, as will be described in additional detail below.

**[0121]** FIG. 10C depicts one of the two actuation mechanisms, according to one embodiment. That is, the first actuation mechanism 226A is depicted in FIG. 10C, but it is understood that the second actuation mechanism 226B has similar components and operates in a similar fashion, according to one embodiment. The mechanism 226A has a drive motor 240, a gear train 242 rotationally coupled to the drive motor 240, and a double thread lead screw 244 rotationally coupled to the gear train 242. Thus, actuation of the drive motor 240 causes rotation of the gear train 242, which causes rotation of the lead screw 244. Alternatively, the motor 240 can be rotationally coupled to the lead screw 244 via any gear or other rotational coupling combination. According to one implementation, the actuation mechanism 226A can also have two sensors 262, 264 that are used to measure the angular position of the lead screw 244. One sensor 262 has a magnet 262 that is rotatably coupled to the lead screw 244 such that the sensor 262 provides for absolute position measurement. The other sensor 264 in this implementation is a position sensor 264 as shown. It is understood that either of these sensors 262, 264 can be any known sensors for tracking the position of the lead screw 244. In accordance with certain implementations, the actuation mechanism 226A

also allows for manually driving the lead screw 244. That is, this embodiment has a manual drive input 266 which, in this exemplary embodiment, is a nut 266 that can be turned using a simple tool such as a wrench or the user's fingers. This manual drive mechanism 266 can be used for unpowered movement during assembly or service of the actuation mechanism 226A.

**[0122]** As best shown in FIGS. 10C and 10D, the double thread lead screw 244 has two sets of threads: a first set of threads 246A and a second set of threads 246B. In one embodiment, the two sets of threads 246A, 246B have opposite threads. That is, one of the two sets of threads 246A, 246B has right-handed threads, while the other set has left-handed threads. As best shown in FIGS. 10C and 10E, the actuation mechanism 226A also has two carriages threadably coupled to the double thread lead screw 244. More specifically, the first carriage 248A is threadably coupled to the first set of threads 246A, while the second carriage 248B is threadably coupled to the second set of threads 246B. Each of the two carriages 248A, 248B are slidably disposed in the actuation mechanism 226A along the rods (also referred to as "linear bearings") 250A, 250B. That is, each of the carriages 248A, 248B have lumens 252A, 252B, 254A, 254B disposed therethrough as shown such that the rods 250A, 250B are disposed therethrough. In other words, the first carriage 248A is slidably disposed on the rods 250A, 250B via lumens 252A, 252B, while the second carriage 248B is slidably disposed on the rods 250A, 250B via lumens 254A, 254B as shown. Thus, given that the sets of threads 246A, 246B have opposite threads, rotation of the lead screw 244 in one direction causes the carriages 248A, 248B to move linearly toward each other (closer together), while rotation of the lead screw 244 in the opposite direction causes the carriages 248A, 248B to move linearly away from each other (farther apart). It is understood that, according to certain embodiments, if the threads of the two sets 246A, 246B have the same pitch, then the carriages 248A, 248B will move in equal and opposite directions.

**[0123]** In addition, each carriage 248A, 248B is coupled to a separate one of the two cables of the cable pair 228, as mentioned above with respect to FIGS. 10A and 10B. More specifically, the first carriage 248A is coupled to the first cable 228A of the pair 228, and the second carriage 248B is coupled to the second cable 228B. In one specific embodiment as best shown in FIG. 10C, each carriage has a coupling structure 258A, 258B that is used to attach the cable 228A, 228B in place. That is, the first carriage 248A has the first coupling structure 258A that can removably couple the cable 228A to the carriage 248A. Similarly, the second carriage 258B has the second coupling structure 258B that can removably couple the cable 228B to the carriage 248B. In this specific implementation, the coupling structures 258A, 258B are clamping structures 258A, 258B in which screws 260A, 260B can be used to loosen or tighten the clamping structures 258A, 258B to removably couple the cables 228A, 228B thereto. Further, each of the coupling structures 258A, 258B also have a half lumen 261A, 261B defined in the side of each carriage 248A, 248B such that the cable 228A, 228B can be disposed within the half lumen 261A, 261B and the clamping structure 258A, 258B can be positioned against the cable 228A, 228B and tightened with the screws 260A, 260B to fix the cables 228A, 228B in place. It is understood that the cables 228A, 228B are coupled at their distal ends to the steerable tip 156, as discussed above. More specifically, one of the two cables 228A, 228B is coupled to the steerable tip 156 such that actuation of that cable 228A, 228B

causes the tip 156 to move to the left, while the other of the two cables 228A, 228B is coupled to the tip 156 such that actuation of that cable 228A, 228B causes the tip 156 to move to the right.

**[0124]** FIG. 10F depicts an expanded view of a section of FIG. 10A depicting the internal components of the camera body 152, according to one embodiment. More specifically, FIG. 10F depicts the relationship between the cables 228A, 228B and the connection assemblies 280A, 280B disposed distally of the actuation mechanism 226A. In this exemplary implementation, each of the cables 228A, 228B is a known Bowden cable having an inner cable that is slidably disposed within a cable housing along part of the length of the inner cable. More specifically, the first cable 228A has both an inner cable 282A and a housing 282B. The inner cable 282A extends from the actuation assembly 226A to the steerable tip 156, while the housing 282B extends from the connection assembly 280A to the steerable tip 156. Similarly, the second cable 228B has an inner cable 284A that extends from the actuation assembly 226A to the steerable tip 156 and a housing 284B extending from the connection assembly 280B to the steerable tip 156. Thus, a distal length of the inner cable 282A is slidably disposed within the cable housing 282B, while a proximal length of the inner cable 282A extends out of the housing 282B at the connection assembly 280A and extends toward the actuation assembly 226A as shown at arrow D. Similarly, a distal length of the inner cable 284A is slidably disposed within the cable housing 284B, while a proximal length of the inner cable 284A extends out of the housing 284B at the connection assembly 280B and extends toward the actuation assembly 226A as shown at arrow E. Thus, the inner cables 282A, 284A are actuatable by the actuation assembly 226A as discussed above to articulate the steerable tip 156 via linear movement of the inner cables 282A, 284A. In one embodiment, each of the cable housings 282B, 284B is made of a known composite construction with an inner lining (to facilitate movement of the inner cable therein) and is longitudinally incompressible.

**[0125]** Each connection assembly 280A, 280B has both a tension spring assembly 286A, 286B and a tension adjustment mechanism 288A, 288B, both of which will be described in detail below.

**[0126]** According to one embodiment, each tension spring assembly 286A, 286B is operable to absorb force applied to the cable housings 282B, 284B and thereby reduce the strain applied thereto and potentially prevent resulting damage. That is, each tension spring assembly 286A, 286B has a tension spring retainer body 300A, 300B that is slidably disposed through a bushing 302A, 302B and an opening 304A, 304B defined in a body wall 306. Each bushing 302A, 302B is fixedly attached to the body wall 306 such that each spring retainer body 300A, 300B is slidable in relation to the body 152. Each retainer body 300A, 300B has a tension spring 308A, 308B disposed around the body 300A, 300B and positioned between a lip 307A, 307B on the retainer body 300A, 300B and the body wall 306 such that each tension spring 308A, 308B can move between an extended state (as shown in assembly 280A) and a compressed state (as shown in assembly 280B). In addition, each retainer body 300A, 300B has an extendable barrel 310A, 310B extending from a distal end of the retainer body 300A, 300B. Each cable housing 282B, 284B is coupled to the extendable barrel 310A, 310B as shown. It is understood that both the retainer bodies 300A, 300B and the extendable barrels

310A, 310B have lumens 312A, 312B defined therethrough as shown such that the inner cables 282A, 284A can extend therethrough as shown.

**[0127]** Thus, each tension spring assembly 286A, 286B is structured to provide strain relief. For example, if the steerable tip 156 has force applied thereto from an external source (such as a user's hand or collision of the tip 156 with an object), that external force is applied to one or both of the cable housings 282B, 284B. Given that each of the cable housings 282B, 284B is longitudinally incompressible, the force is transferred axially along the length of the housing 282B, 284B and into the retainer body 300A, 300B, which causes the tension spring 308A, 308B to be urged from its relaxed state toward either its compressed or its extended state. All of this occurs without any external force being applied to the inner cable 282A, 284A. Thus, each tension spring assembly 286A, 286B helps to prevent damage to the cables 228A, 228B by absorbing any application of external force thereto through the cable housings 282B, 284B and tension springs 308A, 308B. That is, compression of the tension springs 308A, 308B allows for adjustment of the length of the cable housing 282B, 284B as a result of the external force while protecting the inner cables 282A, 284A from that external force.

**[0128]** Alternatively, the configuration of the tension spring assemblies 286A, 286B need not be limited to the specific components thereof. It is understood that any known assembly for absorbing strain from external forces can be incorporated herein.

**[0129]** Turning now to the tension adjustment mechanisms 288A, 288B, each such assembly 288A, 288B is operable to allow for manually adjusting the tension of each inner cable 282A, 284A. That is, if a user determines that either cable 282A, 284A is too loose or too tight, the user can utilize the appropriate adjustment mechanism 288A, 288B to adjust the tension thereof. Each mechanism 288A, 288B includes the extendable barrel 310A, 310B extending from a distal end of the retainer body 300A, 300B, as discussed above. Each adjustable barrel 310A, 310B has an adjuster nut 314A, 314B that is threadably coupled to the barrel 310A, 310B such that rotation of either nut 314A, 314B by a user causes axial extension or retraction of the respective barrel 310A, 310B. Thus, if either cable 282A, 284A is too loose, the user can rotate either nut 314A, 314B to lengthen the respective barrel 310A, 310B, thereby tightening the cable 282A, 284A. On the other hand, if either cable 282A, 284A is too tight, the user can rotate either nut 314A, 314B to shorten the appropriate barrel 310A, 310B, thereby loosening the cable 282A, 284A.

**[0130]** Alternatively, the configuration of the tension adjustment assemblies 286A, 286B need not be limited to the specific components thereof. It is understood that any known assembly for adjusting the tension of the cables can be incorporated herein.

**[0131]** Further, it is understood that the various camera body embodiments disclosed or contemplated herein are not limited to the specific components and features discussed above. That is, the camera body/handle can incorporate any known mechanisms or components for lighting, transmission of energy/information, articulation, and adjustment/strain relief mechanisms.

**[0132]** As shown in FIGS. 11A and 11B, various implementations of the robotic device 340 can include a removable nest 346 that is removably coupleable to a proximal end of the device body 342 (as best shown in FIG. 11A) and is designed to receive an insertable camera assembly 344

(including, for example, any camera embodiment disclosed or contemplated herein) and couple or lock the device 340 and camera 344 together, as is shown in FIG. 13. That is, the nest 346 is a coupling component or port that can couple to both the device 340 and camera 344 as shown such that the nest 346 is disposed between the device body 342 and the camera 344 when the three components 342, 344, 346 are coupled together (as best shown in FIG. 11B and FIG. 13). In this embodiment, the nest 346 removably attaches to the proximal portion of the elongate body 342 as best shown in FIG. 11A, and can be released therefrom by the nest release buttons 348 as best shown in FIG. 11B (in which one of the two buttons 348 is visible, with the other button disposed on the opposing side of the nest 346). The release buttons 348 will be discussed in additional detail below. Further, as best shown in FIG. 11B, the nest 346 has a proximal opening 350 which is also known as the camera acceptance opening 350 that receives the camera (such as camera 344) such that the camera 344 mechanically couples or mates with the nest 346 in the opening 350. The lip 352 of the opening 350 in this embodiment includes a slot 354, which is a rotation registration feature 354 that mates with a matching feature (in this case, a protrusion) on the camera 344 to ensure that the camera 344 will only fully mate with the nest 346 in one specific orientation. Further, the nest 346 also has a seal package 356 disposed therein that helps to ensure the insufflation pressure in the target cavity of the patient does not leak out through the camera lumen (not shown) in the device body 342, regardless of whether the camera 344 is disposed in the lumen or not. In addition, the nest 346 has a camera lock/release button 358 as shown. Both the seal package 356 and the button 358 will be discussed in additional detail below.

**[0133]** One embodiment of the seal package 356 is depicted in FIGS. 12A and 12B. As best shown in FIG. 12A, the seal package 356 is disposed within the nest 346 such that the seal package 356 receives the camera (such as camera 344) as it is positioned in the nest 346 and thus disposed in and coupled to the device body 342 (as shown in FIG. 13). It is understood that the seal package 356 is any structure having at least one seal disposed therein for establishing a fluidic seal in the presence or absence of the camera. In various implementations, the structure 356 can have one seal, two seals, three seals, or any number of seals as needed to maintain the fluidic seal as described herein. As best shown in FIG. 12B, the seal package 356 in this exemplary embodiment has two seals: a first seal 358 and a second seal 360. In one embodiment as shown, the first seal 358 is disposed above the second seal 360. Alternatively, the second seal 360 can be disposed above the first seal 358.

**[0134]** As best shown in FIG. 12B, the first seal 358 is configured to receive the camera 344 and maintain a fluidic seal between the camera 344 and the seal 358. In the exemplary embodiment as shown, the seal 358 is a circular seal with tensioned seal walls 362 in which an opening 364 is defined. The opening 364 has a diameter that is less than the outer diameter of the camera 344 to be positioned therethrough. When the camera 344 is disposed through the opening 364 in the first seal 358 (as shown in FIG. 13, for example), the walls 362 are urged away from the center of the seal 358 as a result of the smaller diameter of the opening 364, thereby causing the tension in the walls 362 to increase. As such, the tension in the walls 362 causes the walls 362 to be urged toward the camera

344, thereby establishing a seal therebetween. Alternatively, the first seal 358 can be any seal that can receive a camera therethrough and establish a fluidic seal between the seal and the camera.

**[0135]** The second seal 360 is configured to maintain a fluidic seal when the camera is not disposed through the seal package 356. In this embodiment as shown, the seal 360 is a circular seal having hinged seal walls 366 that can move between an open position (when the camera is disposed therethrough) and a closed position (when the camera is not present) such that the closed walls 366 establish a fluidic seal. According to one implementation, the seal walls 366 are urged closed by the higher gas pressure inside the target cavity of the patient, thereby reducing or preventing leakage or loss of air pressure as a result. Alternatively, the second seal 360 can be any seal that can receive a camera therethrough and establish a fluidic seal when the camera is not present.

**[0136]** Continuing with FIG. 12B, the seal structure 356 also has a frame 368 having a top frame structure 370 and a bottom frame structure 372 coupled to the top frame structure 370. The two seals 358, 360 are disposed between the top and bottom frame structures 370, 372 as shown. In one embodiment, the bottom frame structure 372 also has a third seal 374 disposed therein. More specifically, in this specific embodiment, the third seal 374 is an O-ring seal 374. Alternatively, the third seal 374 can be any known seal.

**[0137]** In use, the seal package 356 allows for the camera 344 to be inserted or removed at any time, including during a procedure, without risking loss of insufflation. That is, the first seal 358 maintains a fluidic seal while the camera 344 is present (such as shown in FIG. 13), and the second seal 360 maintains a fluidic seal while the camera 344 is not present.

**[0138]** It is understood that the seal structure 346 embodiments disclosed or contemplated herein can be incorporated into any nest embodiment disclosed or contemplated herein. Further, it is also understood that any other known seal mechanisms or structures can be used to establish a fluidic seal within any nest embodiment for receiving any camera embodiment herein.

**[0139]** Returning to the coupling of the nest 346 to the proximal end of the device body 342, FIG. 14A depicts two hinged latches 380A, 380B disposed within the nest 346 such that the latches 380A, 380B can be used to couple the nest 346 to the device body 342, and FIG. 14B depicts an expanded view of one of those latches 380B. The latches 380A, 380B are coupling mechanisms that can be used to both couple the nest 346 to the proximal end of the device body 342 and to uncouple therefrom. While FIG. 14B depicts solely the hinged latch 380B for purposes of describing the latch 380B in further detail, it is understood that the other hinged latch 380A has substantially the same or similar components. The latch 380B has a proximal end 382 that is hingedly coupled to or cantilevered from an interior portion of the nest 346 such that the distal end 384 of the latch 380B is movable in relation to the nest 346. Further, each latch 380A, 380B is hingedly attached in such a fashion that the latches 380A, 380B are tensioned such that when the latches 380A, 380B are urged radially inward, force is applied to the latches 380A, 380B such that the force is directed to urge them back to their natural state (and thus the force is applied such that the latches 380A, 380B are urged radially outwardly). In addition, the latch button 348 discussed above with respect to FIG. 11B is disposed at the distal end of the latch 380B, with the latch button 348 coupled to the latch body 386 via an arm 388 such that the button 348 is disposed at a distance from the latch body 386. The arm

388 has several structural features that assist with interaction with and coupling/uncoupling of the latch 380B in relation to the device body 342. That is, the arm 388 includes a protrusion or protruding body 390 with an angled surface 392 on the side of the protrusion 390 and a nest latching surface 394 on the top of the protrusion 390. Further, the sides of the arm 388 are guidance surfaces 396. The functions of these surfaces are explained in detail below.

**[0140]** FIGS. 15A and 15B show the coupling of the nest 346 to the proximal end of the device body 342. More specifically, FIG. 15A depicts the nest 346 positioned in close proximity to the proximal end of the body 342, while FIG. 15B depicts the nest 346 coupled to the proximal end of the body 342. The proximal end of the device body 342 has a male connector 400 disposed on the proximal end of the body 342 that is configured to couple with the nest 346 such that the nest 346 is disposed over the male connector 400 when the nest 346 is coupled thereto.

**[0141]** FIGS. 16A-17B depict the operation of the hinged latches 380A, 380B in coupling the nest 346 to the device body 342. As best shown in FIGS. 16A and 16B, the male connector 400 has V-shaped receiving slots 402 defined on both sides thereof, with only one of the slots 402 depicted in the figures. The slots 402 are disposed on opposing sides of the connector 400 and are aligned to receive the two hinged latches 380A, 380B. Further, as also shown in FIGS. 16A and 16B, the slot 402 (and the undepicted slot on the opposing side of the connector 400) is in communication with a protrusion receiving opening 404 that is also defined in the side of the connector 400. Again, the connector has two such protrusion receiving openings, with one such opening 404 depicted and the other opening positioned on the opposing side of the connector 400 but not depicted in the figures.

**[0142]** Thus, as the nest 346 is urged downward toward the male connector 400, the latches 380A, 380B are aligned with the V-shaped slots (including the slot 402), as best shown in FIG. 16A, such that the guidance surfaces 396 of the arms 388 are aligned as well. As the distal ends 384 of the latches 380A, 380B approach and come into contact with the connector 400 (as best shown in FIG. 17A), the arms 388 are aligned with the V-shaped slots 402 and the angled surfaces 392 contact the inner walls 408 of the connector 400. Thus, as the nest 346 is urged further downward, the V-shaped slots 402 help to guide the arms 388 of the latches 380A, 380B and the angled surfaces 392 contacting the inner walls 408 cause the distal ends of the latches 380A, 380B to be urged radially inward, as indicated by the arrows F in FIG. 17A. Once the nest 346 is urged into full connection with the connector 400, the protrusions 390 of the latches 380A, 380B are positioned parallel with the protrusion receiving openings 404 such that the tensioned nature of the latches 380A, 380B results in the latches 380A, 380B being urged radially outwardly such that the protrusions 390 are urged into the openings 404. That is, the distal ends of the latches 380A, 380B and the buttons 348 thereon are urged radially outwardly as depicted by the arrows G in FIG. 17B. At this point, the nest latching surfaces 394 are disposed to be in contact with the upper walls 406 of the openings 404, thereby retaining the latches 380A, 380B in place.

**[0143]** When the nest 346 is coupled to the device body 342 as described herein, the latches 380A, 380B are releasably locked to the male connector 400 as described above. Thus, in order to remove the nest 346, a user must reverse the process described above by pressing both buttons 348 on the latches 380A, 380B, thereby urging the distal ends of the latches 380A, 380B radially inwardly

such that the nest latching surfaces 394 are no longer in contact with the upper walls 406. As such, once the buttons 348 are depressed far enough, the latches 380A, 380B release and the nest 346 can be urged proximally off of the proximal end of the device body 342, thereby removing the nest from the device 340.

**[0144]** It is understood that the latch 380A, 380B embodiments disclosed or contemplated herein can be incorporated into any nest embodiment disclosed or contemplated herein, and can be used to couple to any device body disclosed or contemplated herein. Further, it is also understood that any other known attachment mechanisms can be used to removably couple any nest embodiment herein to any device body herein.

**[0145]** As shown in FIG. 18, once the nest 346 is coupled to the device body 342 as described above, the nest 346 can have a camera coupling mechanism (or "latch mechanism") 420 that can be used to couple the camera (such as camera 344) to the nest 346 and thus the device 340, according to one embodiment. Further, the mechanism 420 can also be used to release or uncouple the camera 344 from the device body 342. In addition, the mechanism 420 can also have a presence detection mechanism 422 coupled thereto that can operate in conjunction with the latch mechanism 420 to detect the presence or absence of the camera 344. Both the camera coupling mechanism 420 and the presence detection mechanism 422 will be described in further detail below.

**[0146]** Continuing with FIG. 18, the camera latch mechanism 420 has a slidable latch body 424 with a camera receiving opening 426 defined therein as shown. The camera receiving opening 426 is disposed above the camera lumen 432 in the seal package 356 as shown. Further, the coupling mechanism 420 also has a latch button 428 attached to the body 424 on one side, and a tension spring 430 attached to the body 424 on the side opposite the button 428 as shown. The tension spring 430 is configured to urge the latch body 424 away from the spring 430 as shown by arrow H such that the opening 426 is not aligned with the camera lumen 432 in the seal package 356.

**[0147]** Insertion of a camera 150 into the nest 346 (and thus the device 340) and the resulting interaction with the camera latch mechanism 420 will now be described with respect to FIGS. 19A-19C, according to one embodiment. As shown in FIG. 19A, as the shaft 154 of the camera (such as camera 150) is inserted into the nest 346 but before the distal end of the handle 152 reaches the latch mechanism 420, the tension spring 430 continues to urge the mechanism 420 toward the button in the direction represented by arrow I. As shown in FIG. 19B, when the camera 150 is urged distally into the nest 346 such that the nose cone tip 192 is urged through the opening 426 in the latch body 424, the tip 192 contacts the body 424 and urges the body 424 back toward the tension spring 430 as represented by arrow J. This allows for passage of the tip 192 through the opening 426 in the latch body 424. As shown in FIG. 19C, once the tip 192 passes through the opening 426, the latch receiving slot 194 is disposed in the opening 426, which releases the force applied by the tip 192 and allows the force of the tension spring 430 to once again urge the latch body 424 away from the spring 430 as again represented by arrow I. This urges the latch body 424 into the slot 294 in the camera 150, thereby coupling the latch mechanism 420 and the camera 150 such that the camera 150 is locked into place in the nest 346 and thus the elongate body 342. When it is desirable to remove the camera 150, a user can depress the button 428, thereby urging the latch mechanism 420 toward the

latch springs, thereby urging the latch body 424 out of the slot 194, which releases the camera 150 such that a user can remove it proximally from the nest 346 and the device body 342.

**[0148]** It is understood that the camera coupling mechanism 420 embodiments disclosed or contemplated herein can be incorporated into any nest embodiment disclosed or contemplated herein, and can be used to couple to camera embodiment disclosed or contemplated herein. Further, it is also understood that any other known camera coupling mechanisms can be used to removably couple any camera embodiment herein to any device body herein.

**[0149]** As mentioned above, the nest 346 also has a presence detection mechanism 422 that will now be described in detail with respect to FIGS. 20-22B, according to one embodiment. The mechanism 422 includes a lever 440 that is pivotally coupled to the latch body 424 at a pivot point 442 as best shown in FIG. 21. The lever 440 has a contact pad 444 at one end of the lever 440 as shown, and a magnet 446 at the opposite end of the lever 440. In addition, the detection mechanism 422 also includes a tension spring 448 in contact with the lever 440 at a point along the lever identified by arrow K as best shown in FIGS. 20 and 21, such that the tension spring 448 urges the lever 440 to rotate clockwise around the pivot point 442 as shown in FIG. 21. Further, the detection mechanism 422 includes a sensor 450 disposed in a proximal end of the device body 342 such that the magnet 446 on the lever 440 is configured to interact with the sensor 450 as described in further detail below.

**[0150]** According to one embodiment, the presence detection mechanism 422 can detect three different configurations: (1) the presence of the fully installed camera (such as camera 150), (2) the proper coupling of the nest 346 to the device body 342, and (3) actuation of the camera release button 428 by a user. Each of these will be described in turn below.

**[0151]** FIG. 21 depicts the presence detection mechanism 422 when the camera 150 is not yet coupled properly to the nest 346 and device body 342. Because the camera body 152 is not positioned adjacent to and in contact with the contact pad 444, the force applied by the tension spring 448 urges the portion of the lever 440 forward, which urges the magnet 446 away from the sensor 450. The gap between the magnet 446 and the sensor 450 causes the sensor 450 to indicate that the magnet 446 is not in contact with the sensor 450, thereby indicating that the camera 150 is not properly coupled to the device body 342.

**[0152]** FIG. 22 depicts the present detection mechanism 422 when the camera 150 is properly coupled to the nest 346 and the device body 342. With the camera body 152 positioned in contact with the contact pad 444, that urges the contact pad 444 and thus the portion of the lever 440 above the pivot point 442 radially outward as represented by arrow L. Thus, the magnet 446 is urged into contact with the sensor 450 such that the sensor 450 indicates the presence of the magnet 446, thereby indicating that the camera 150 is properly coupled to the device body 342. In addition, this position of the lever 440 and contact of the magnet 446 with the sensor 450 also indicates that the nest 346 is properly coupled to the device body 342.

**[0153]** FIG. 23 depicts the present detection mechanism 422 when the camera latch button 428 is depressed by a user as indicated by arrow M. Given that the lever 440 is pivotally coupled to the latch body 424 at the pivot point 442, the depression of the latch button 428 causes the pivot point

442 to move away from the button 428 (in the direction of arrow M). The movement of the pivot point 442 in combination with the force applied by the tension spring 448 causes the portion of the lever 440 below the pivot point 442 to move radially outward such that the magnet 446 is urged away from the sensor 450. The gap between the magnet 446 and the sensor 450 causes the sensor 450 to indicate that the magnet 446 is not in contact with the sensor 450, thereby indicating that the button 428 has been depressed. This indication of the depression of the button 428 is a precursor to removal of the camera. Thus, in certain embodiments, the overall system might use this information to straighten the camera tip (bring the tip co-axial with the camera shaft) so that it can be more easily removed, or take any other similar steps.

**[0154]** Alternatively, the magnet 446 need not be a magnet. Instead, the component at the end of the lever 440 can be any sensor component or sensor detectable component that can interact with the sensor 450 to indicate whether that end of the lever 440 is in contact (or close proximity) with the sensor 450 or is not in proximity with the sensor 450. For example, both the component 446 and the sensor 450 can be sensors that can sense the presence of the other sensor. Alternatively, the component 446 and the sensor 450 can be any types of mechanisms that provide for sensing the presence or absence of that end of the lever 440.

**[0155]** It is understood that the presence detection mechanism embodiments disclosed or contemplated herein can be incorporated into any nest embodiment disclosed or contemplated herein. Further, it is also understood that any other known presence detection mechanisms can be used in any nest embodiment herein to detect the presence of any camera embodiment herein.

**[0156]** It is understood that the various nest embodiments disclosed or contemplated herein are not limited to the specific coupling and uncoupling mechanisms, sensors, etc. as described above with respect to the exemplary nest embodiment described herein. It is understood that other known mechanisms or components that can accomplish the same results can be incorporated herein.

**[0157]** In one implementation, the various device embodiments herein can have fluidic seals at all potential fluid entry points in the device, thereby reducing or eliminating the risk of fluid entering any of the internal areas or components of the device. For example, in one embodiment, each of the robotic arms in the device can have fluidic seals disposed at certain locations within the arms to reduce or prevent fluidic access to the internal portions of the arms. In addition, the arms can also have a flexible protective sleeve disposed around the arms as discussed above. The sleeve at one end is attached at the distal end of the elongate device body and at the other end is attached at the distal end of the forearm of each arm.

**[0158]** One exemplary forearm 460 with appropriate fluidic seals is depicted in FIGS. 23 and 24, according to one embodiment. As best shown in FIG. 23, the forearm 460 has a tool lumen 462 defined therein, with a tool drive 464 disposed at the proximal end of the lumen 462. Further, the forearm 460 has a protective sleeve 472 around the forearm body 470 and fluidic seals at both ends of the lumen 462: a proximal seal 468 at the proximal end and an arrangement of seals at the distal end. As best shown in FIG. 24, the arrangement of seals at the distal end of the forearm 460 includes a seal 476 (which can be a compression ring 476) that engages the protective sleeve 472 and retains it in place around the opening to the tool lumen 462. The seal 476 can be molded into the protective

sleeve 472 or alternatively can be a separate component. In addition, the arrangement of distal seals also includes a threaded seal holder 478 that is threaded into the lumen opening in the forearm body 470. This holder 478 compresses the seal 476 and the protective sleeve 472, thereby forming a fluidic seal between the protective sleeve 472 and the threaded seal holder 478. In certain implementations, the threaded seal holder 478 is removable, thereby allowing the protective sleeve 472 to be removed and replaced as necessary. Further, the arrangement of distal seals includes a ring seal 466 that can be positioned to form a seal between the threaded seal holder 478 and the tool lumen 462 while still allowing relative rotation between the tool lumen 462 and the forearm body 470. Finally, a tool bayonet 480 is positioned over the seal assembly as shown. The bayonet 480 is configured to receive and couple to any interchangeable end effectors (not shown) that are inserted into the tool lumen 462. It is understood that the bayonet interface 480 can be used to allow only certain end effectors to be inserted into the forearm 460.

**[0159]** The fluidic seals 466, 468 establish a fluidic seal between the tool lumen 462 and the internal areas and components of the forearm body 470. More specifically, each of the fluidic seals 466, 468 prevent fluid ingress while still allowing the tool lumen body 474 to rotate relative to the forearm body 470. The distal seal 466 establishes a fluidic seal between the tool lumen 462 and the protective sleeve 472, as mentioned above, while the proximal 468 seal establishes a fluidic seal between the tool lumen 462 and the internal portions of the body 470, thereby preventing fluids that enter the lumen 462 from accessing the internal portions of the body 470. As such, the two seals 466, 468 in combination with the protective sleeve 472 and the rest of the distal seal assembly discussed above prevent fluid from entering the forearm body 470 even if an end effector (not shown) is not present in the tool lumen 462.

**[0160]** As shown in FIG. 25, a fluidic seal is also established at the shoulder joint 500 between the device body 502 and the upper arm 504. As discussed above, the protective sleeve 472 is disposed around the upper arm 504 and extends across the shoulder joint 500 to the elongate body 502. In one embodiment as shown, the sleeve 472 is mechanically retained against the elongate body 502 with a retention band 506 that is disposed around the sleeve 472 at a groove 508 formed in the body 502 such that the band 506 pulls the sleeve 472 into the groove 508. Further, according to certain implementations, the sleeve 472 can have two seals 510 molded or otherwise formed into the sleeve 472 itself as shown. These bands 510 extend around the outer circumference of the sleeve 472 and act similarly to two O-rings by establishing a redundant compression seal between the sleeve 472 (at the bands 510) and the robot assembly. The camera lumen 512 in the device body 502 extends past and adjacent to the sleeve 472 such that it allows the camera (not shown) to be positioned therethrough and pass by the protective sleeve 472 and extend in front of the body 502 unencumbered.

**[0161]** As shown in FIG. 26, a fluidic seal is also established at the proximal end of the elongate device body 502 via several seals to prevent fluid ingress. First, the body housing 520 is coupled to the groove ring body 522 with a seal 524 (such as, for example, an O-ring 524) to establish a fluidic seal between the housing 520 and the groove ring body 522. Further, a fluidic seal is established between the groove ring body 522 and the light ring 526 with another seal 528 (such as,

for example, an O-ring seal 528). Finally, a fluidic seal is established between the light ring 526 and the male connector 530 with another seal 532 (such as, for example, an O-ring seal 532). In certain embodiments, there can also be seals 534 where the electrical cable 536 enters the elongate body 502 and also seals 538 where the elongate body is pierced by the camera lumen 512.

**[0162]** It is understood that the fluidic seals as disclosed or contemplated herein can be incorporated into any device embodiment disclosed or contemplated herein. Further, it is also understood that any other known seal mechanisms can be used and positioned in any known fashion in any device embodiment herein to establish a fluidic seal for any device embodiment herein.

**[0163]** Although the various inventions have been described with reference to preferred embodiments, persons skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope thereof.

### Claims

What is claimed is:

1. A robotic surgical system, comprising:
  - (a) a robotic surgical device comprising:
    - (i) an elongate device body comprising a distal end and a proximal end;
    - (ii) a removable connection port disposed at the proximal end of the device body, the connection port comprising:
      - (A) a device body coupling mechanism disposed within the connection port;
      - (B) an camera receiving opening defined in a proximal end of the connection port;
      - (C) a seal package disposed in the removable connection port, the seal package comprising at least two seals; and
      - (D) a camera coupling mechanism disposed within the removable connection port; and
    - (ii) first and second robotic arms operably coupled to the distal end of the device body; and
  - (b) a removable camera component removably disposable in the camera receiving opening and through the seal package, the removable camera component comprising a camera body, an elongate camera tube, a flexible section, and a distal imager.
2. The robotic surgical system of claim 1, wherein the device body coupling mechanism comprises first and second hinged coupling mechanisms hingedly coupled to the connection port.
3. The robotic surgical system of claim 2, wherein each of the first and second hinged coupling mechanisms comprises:
  - (a) a coupling mechanism body;
  - (b) a tensioned hinge at a proximal end of the coupling mechanism body, wherein the tensioned hinge is hingedly coupled to the connection port; and
  - (c) a coupleable structure at a distal end of the coupling mechanism, wherein the coupleable structure comprises at least one coupling feature configured to be coupleable with a matching coupling feature on the proximal end of the device body and an actuable button.
4. The robotic surgical system of claim 1, wherein the elongate device body comprises a male connector disposed at a proximal end of the elongate device body, wherein the male connector is coupleable with the connection port.

5. The robotic surgical system of claim 1, wherein the removable connection port further comprises a presence detection mechanism operably coupled to the camera coupling mechanism.

6. The robotic surgical system of claim 1, wherein the camera coupling mechanism comprises:

- (a) a slidable body disposed within the connection port;
- (b) a camera receiving opening defined within the slidable body;
- (c) an actuable camera release button attached to a first end of the slidable body; and
- (d) a tensioned spring operably coupled to a second end of the slidable body.

7. The robotic surgical system of claim 6, wherein the slidable body is slidable along a plane substantially transverse to a longitudinal axis of the elongate device body.

8. The robotic surgical system of claim 1, further comprising a presence detection mechanism comprising:

- (a) a rotatable lever operably coupled to the camera coupling mechanism at a pivot point, wherein the rotatable lever rotates around the pivot point;
- (b) a first sensing component disposed on the rotatable lever; and
- (c) a second sensing component disposed on the elongate body, wherein the second sensing component is configured to sense the presence or absence of the first sensing component.

9. The robotic surgical system of claim 8, wherein the first sensing component is a magnet.

10. A removable connection port for a robotic surgical device, the port comprising:

- (a) a connection port body;
- (b) a distal opening defined at a distal end of the port body, wherein the distal opening is sized and shaped to receive a proximal end of an elongate device body;
- (c) a proximal opening defined at a proximal end of the port body, wherein the proximal opening is sized and shaped to receive a camera assembly;
- (d) a seal package disposed in the connection port body, the seal package comprising at least two seals configured to receive a shaft of a camera assembly;
- (e) a device body coupling mechanism disposed within the connection port body, the device body coupling mechanism comprising first and second hinged coupling mechanisms hingedly coupled to the connection port body; and

- (f) a camera coupling mechanism disposed within the connection port body, the camera coupling mechanism comprising:
  - (i) a slidable body disposed within the connection port body; and
  - (ii) a camera receiving opening defined within the slidable body.

11. The removable connection port of claim 10, wherein each of the first and second hinged coupling mechanisms comprises:

- (a) a coupling mechanism body;
- (b) a tensioned hinge at a proximal end of the coupling mechanism body, wherein the tensioned hinge is hingedly coupled to the connection port body; and
- (c) a coupleable structure at a distal end of the coupling mechanism, wherein the coupleable structure comprises at least one coupling feature configured to be coupleable with a matching coupling feature on the proximal end of the elongate device body and an actuable button.

12. The removable connection port of claim 10, wherein the distal opening is sized and shaped to receive a male connector disposed at the proximal end of the elongate device body.

13. The removable connection port of claim 10, further comprising a presence detection mechanism operably coupled to the camera coupling mechanism.

14. The removable connection port of claim 10, wherein the camera coupling mechanism further comprises:

- (a) an actuable camera release button attached to a first end of the slidable body; and
- (b) a tensioned spring operably coupled to a second end of the slidable body.

15. The removable connection port of claim 10, wherein the slidable body is slidable along a plane substantially transverse to a longitudinal axis of a lumen of the seal package.

16. The removable connection port of claim 10, further comprising a presence detection mechanism comprising:

- (a) a rotatable lever operably coupled to the camera coupling mechanism at a pivot point, wherein the rotatable lever rotates around the pivot point; and
- (b) a first sensing component disposed on the rotatable lever, wherein the first sensing component is configured to interact with a second sensing component disposed on the elongate device body when the removable connection port is coupled to the elongate device body.

17. The removable connection port of claim 16, wherein the first sensing component is a magnet.
18. A robotic surgical system, comprising:
- (a) a robotic surgical device comprising:
    - (i) an elongate device body comprising a distal end and a proximal end;
    - (ii) a removable connection port disposed at the proximal end of the device body, the connection port comprising:
      - (A) a device body coupling mechanism disposed within the connection port, the device body coupling mechanism comprising first and second hinged coupling mechanisms hingedly coupled to the connection port;
      - (B) an camera receiving opening defined in a proximal end of the connection port;
      - (C) a seal package disposed in the removable connection port, the seal package comprising at least two seals;
      - (D) a camera coupling mechanism disposed within the removable connection port, the camera coupling mechanism comprising:
        - (1) a slidable body slidably disposed within the connection port;
        - (2) a camera receiving opening defined within the slidable body;
        - (3) an actuable camera release button attached to a first end of the slidable body; and
        - (4) a tensioned spring operably coupled to a second end of the slidable body; and
      - (E) a presence detection mechanism operably coupled to the camera coupling mechanism, the presence detection mechanism comprising:
        - (1) a rotatable lever operably coupled to the camera coupling mechanism at a pivot point, wherein the rotatable lever rotates around the pivot point;
        - (2) a first sensing component disposed on the rotatable lever; and
        - (3) a second sensing component disposed on the elongate body, wherein the second sensing component is configured to sense the presence or absence of the first sensing component; and

- (iii) first and second robotic arms operably coupled to the distal end of the device body; and
- (b) a removable camera component removably disposable in the camera receiving opening and through the seal package, the removable camera component comprising a camera body, an elongate camera tube, a flexible section, and a distal imager.

19. The robotic surgical system of claim 18, wherein each of the first and second hinged coupling mechanisms comprises:

- (a) a coupling mechanism body;
- (b) a tensioned hinge at a proximal end of the coupling mechanism body, wherein the tensioned hinge is hingedly coupled to the connection port; and
- (c) a coupleable structure at a distal end of the coupling mechanism, wherein the coupleable structure comprises at least one coupling feature configured to be coupleable with a matching coupling feature on the proximal end of the device body and an actuable button.

20. The robotic surgical system of claim 18, wherein the slidable body is slidable along a plane substantially transverse to a longitudinal axis of a lumen defined by the at least two seals in the seal package.

21. A camera assembly for a robotic surgical system, the camera assembly comprising:
- (a) an elongate camera shaft;
  - (b) a camera body coupled to a proximal end of the elongate camera shaft, the camera body comprising:
    - (i) a distal end configured to be positionable within a robotic device, the distal end comprising:
      - (A) a distal nose cone disposed around the elongate shaft; and
      - (B) a coupling mechanism acceptance slot defined proximal to the distal nose cone;
    - (ii) at least one actuation mechanism disposed within the camera body, the at least one actuation mechanism comprising:
      - (A) a rotatable shaft;
      - (B) a first drive carriage threadably coupled to the rotatable shaft; and
      - (C) a second drive carriage threadably coupled to the rotatable shaft;
  - (c) a steerable tip disposed at the distal end of the elongate camera shaft, the steerable tip comprising:

- (i) a steerable tip body comprising a camera imager and an illumination component; and
- (ii) a flexible section coupled to the elongate camera shaft and the steerable tip body,

wherein the steerable tip body is movable in relation to the elongate camera shaft via the flexible section; and

- (d) a first cable coupled at a first end to the first drive carriage and coupled at a second end to the steerable tip; and
- (e) a second cable coupled at a first end to the second drive carriage and coupled at a second end to the steerable tip,

wherein actuation of the actuation mechanism causes linear movement of the first and second drive carriages in opposite directions, whereby the first and second cables steer the steerable tip.

22. The camera assembly of claim 21, wherein the camera body further comprises:

- (a) an external housing; and
- (b) a cylindrical heat sink structure, wherein the cylindrical heat sink structure is disposed within the external housing.

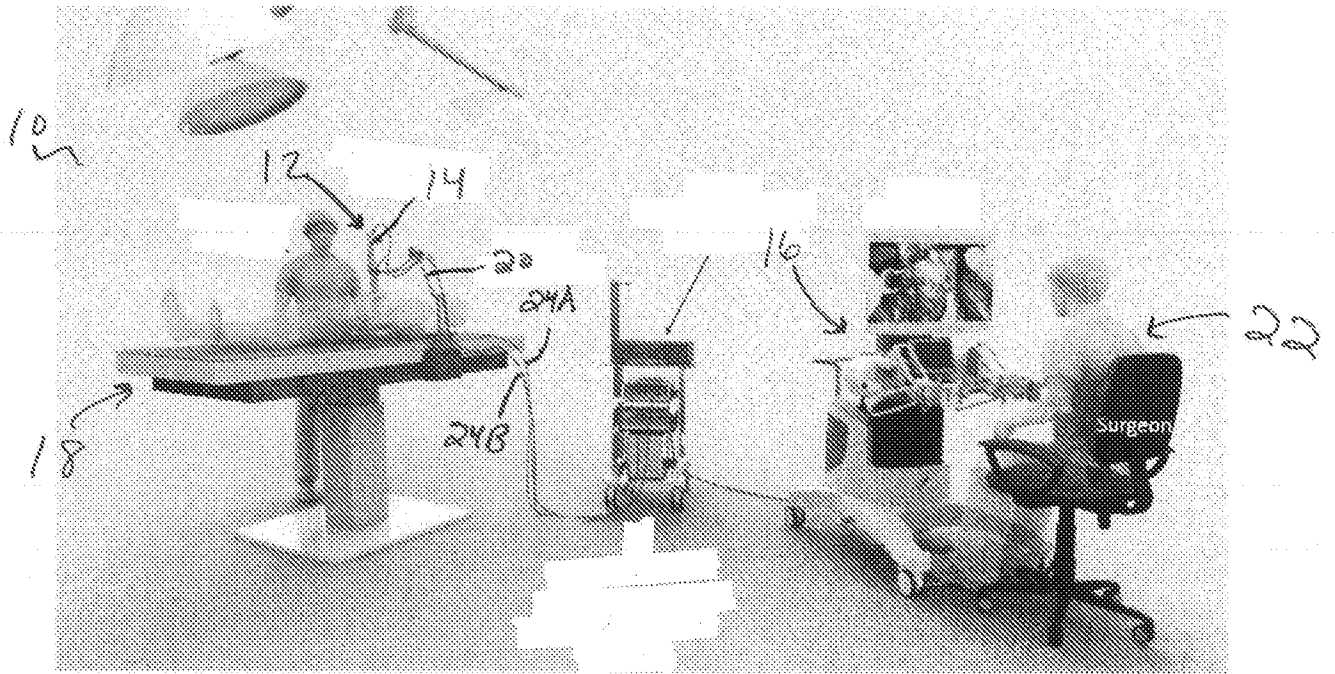


FIG. 1

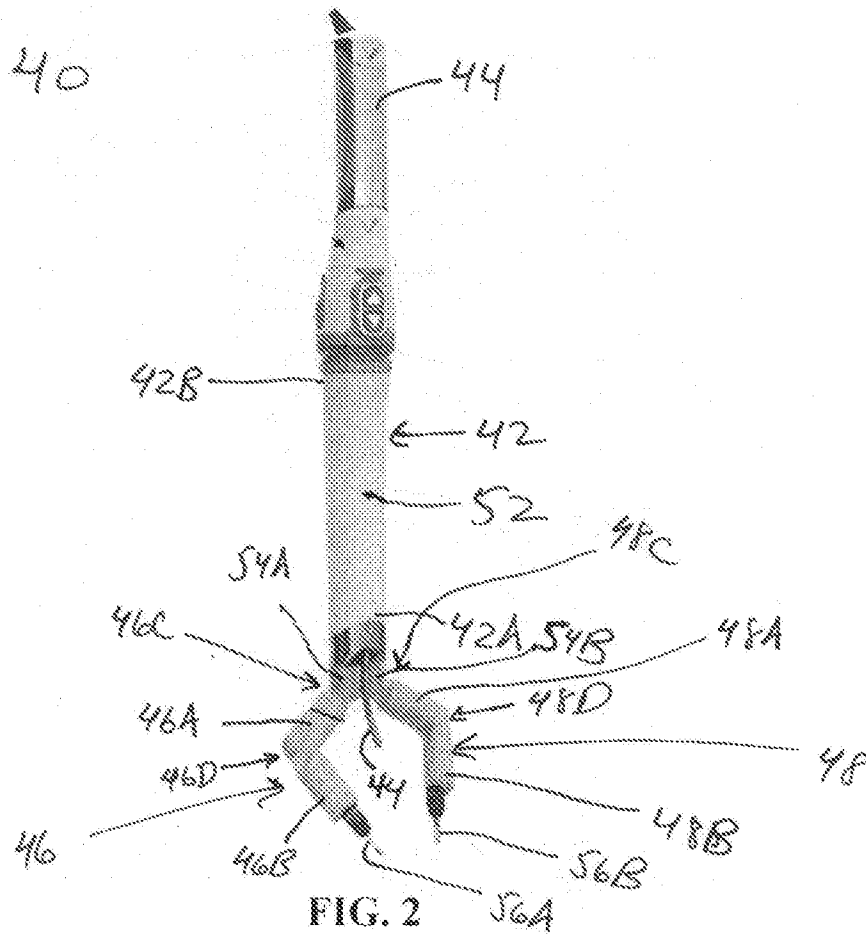


FIG. 2

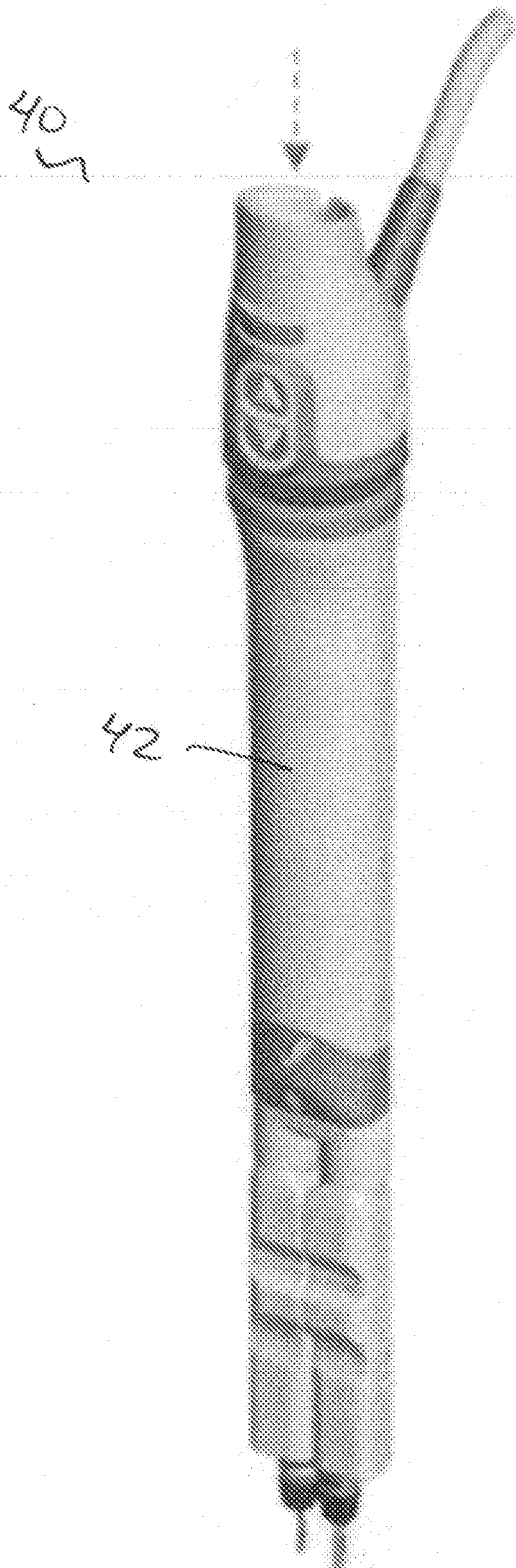


FIG. 3A

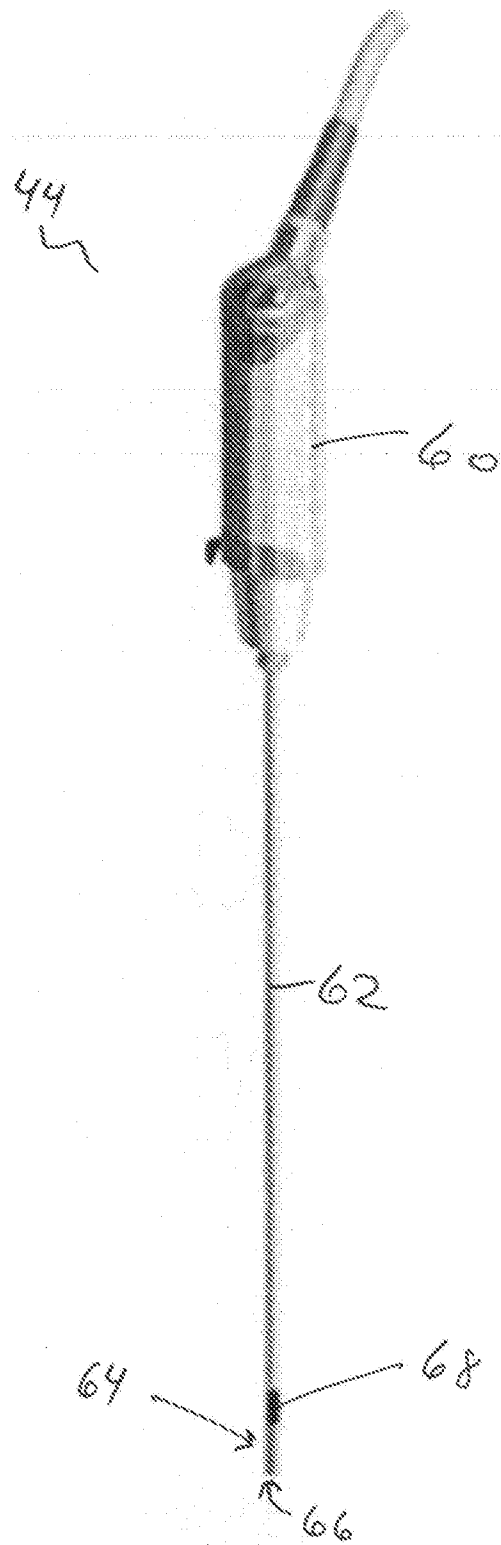


FIG. 3B

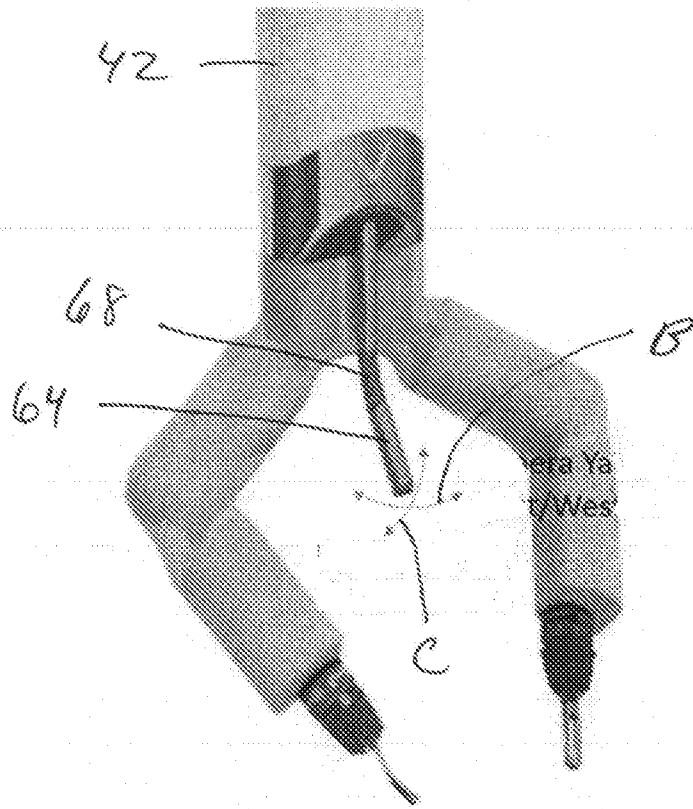


FIG. 3C

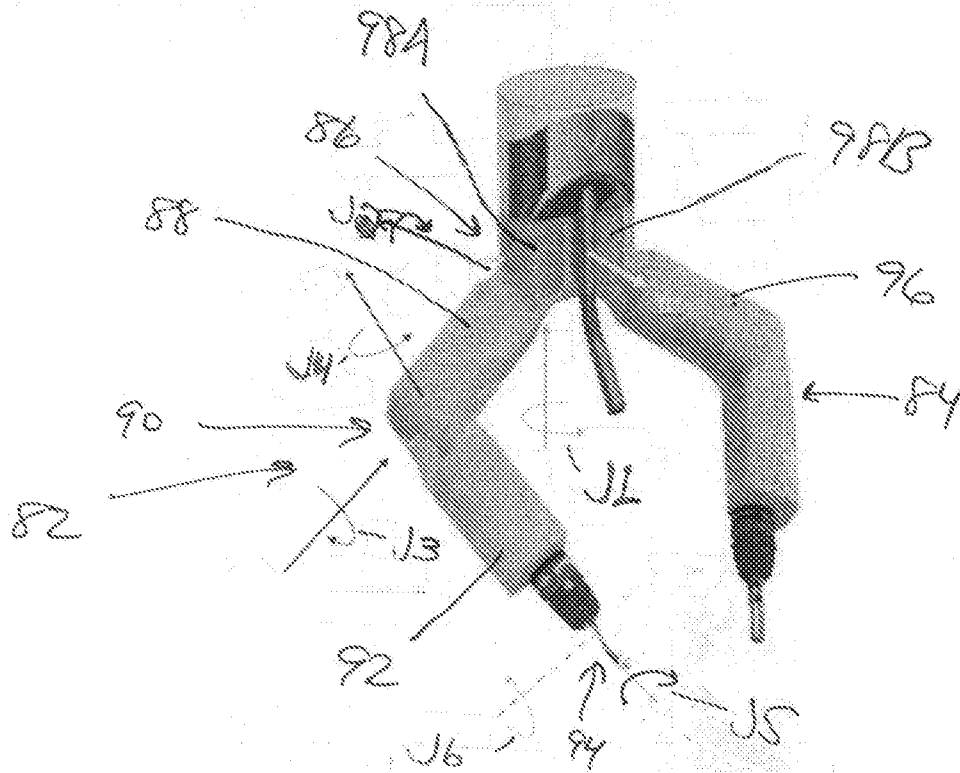


FIG. 4A

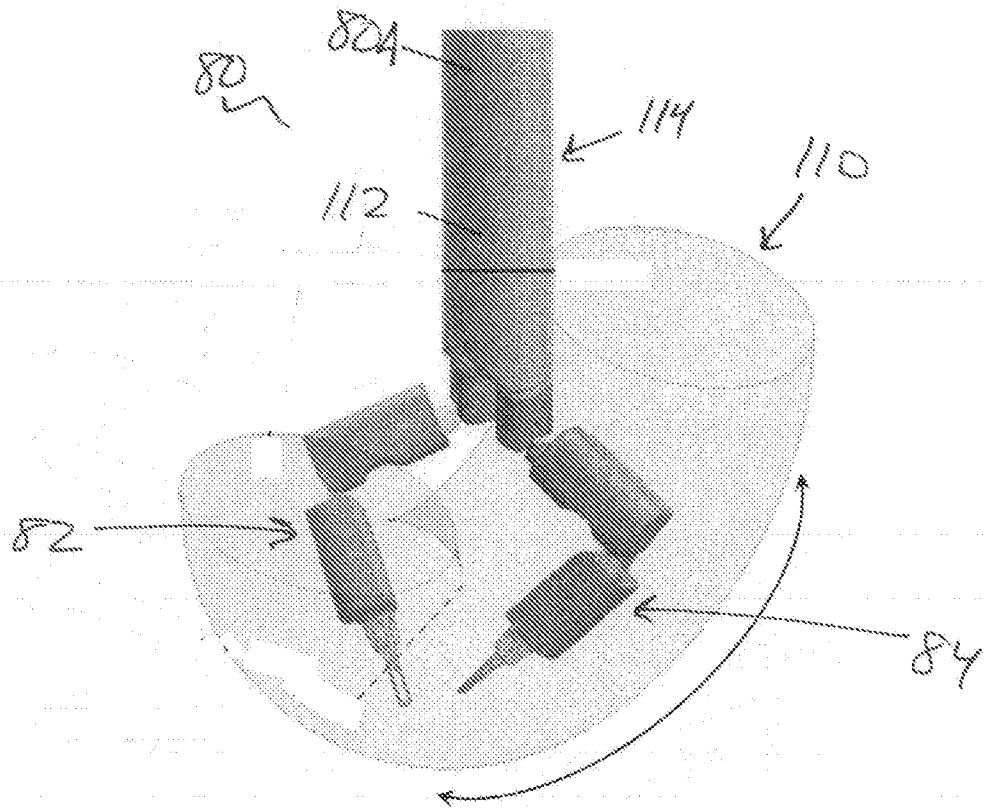


FIG. 4B

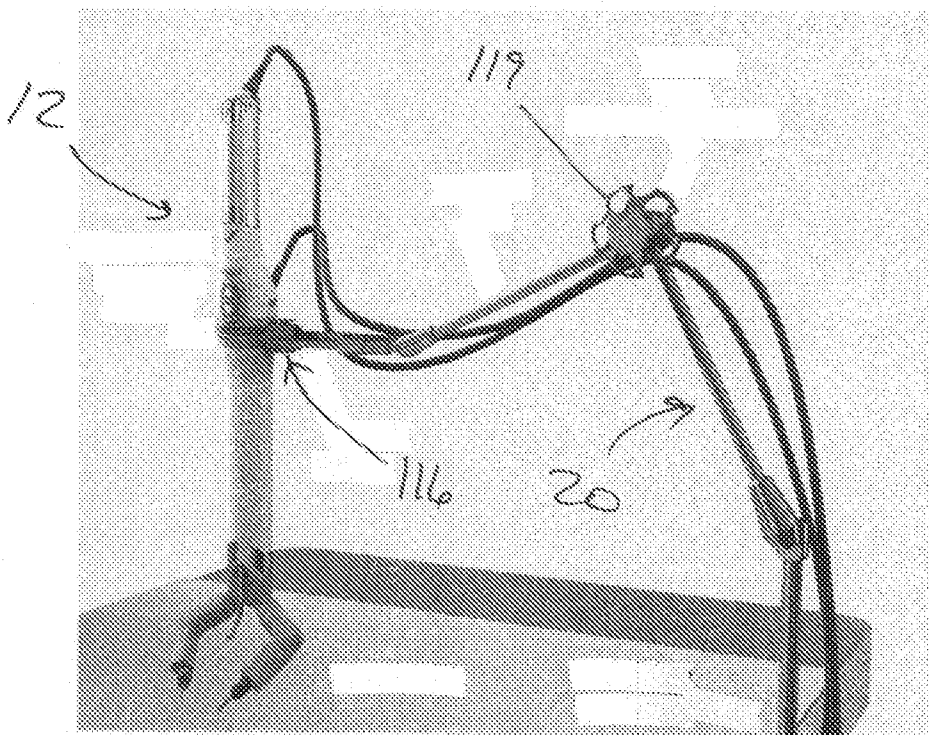


FIG. 5A

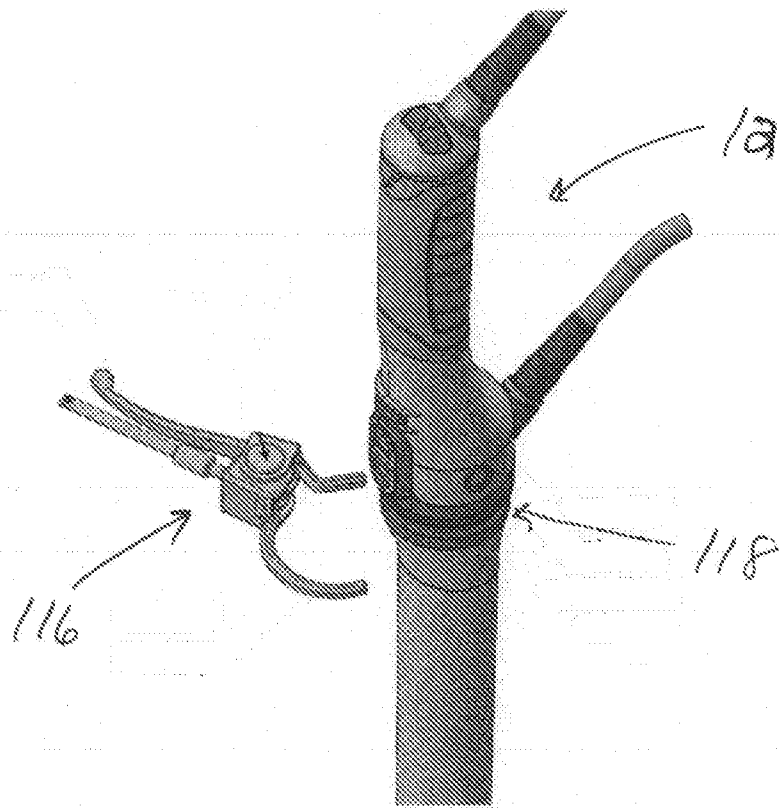


FIG. 5B

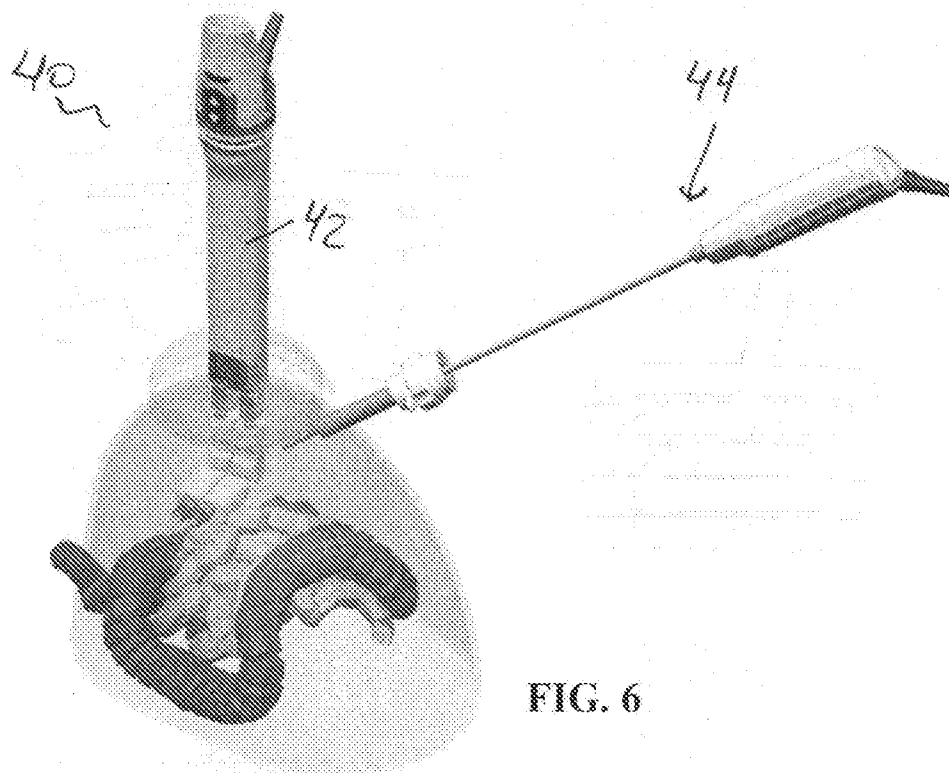


FIG. 6

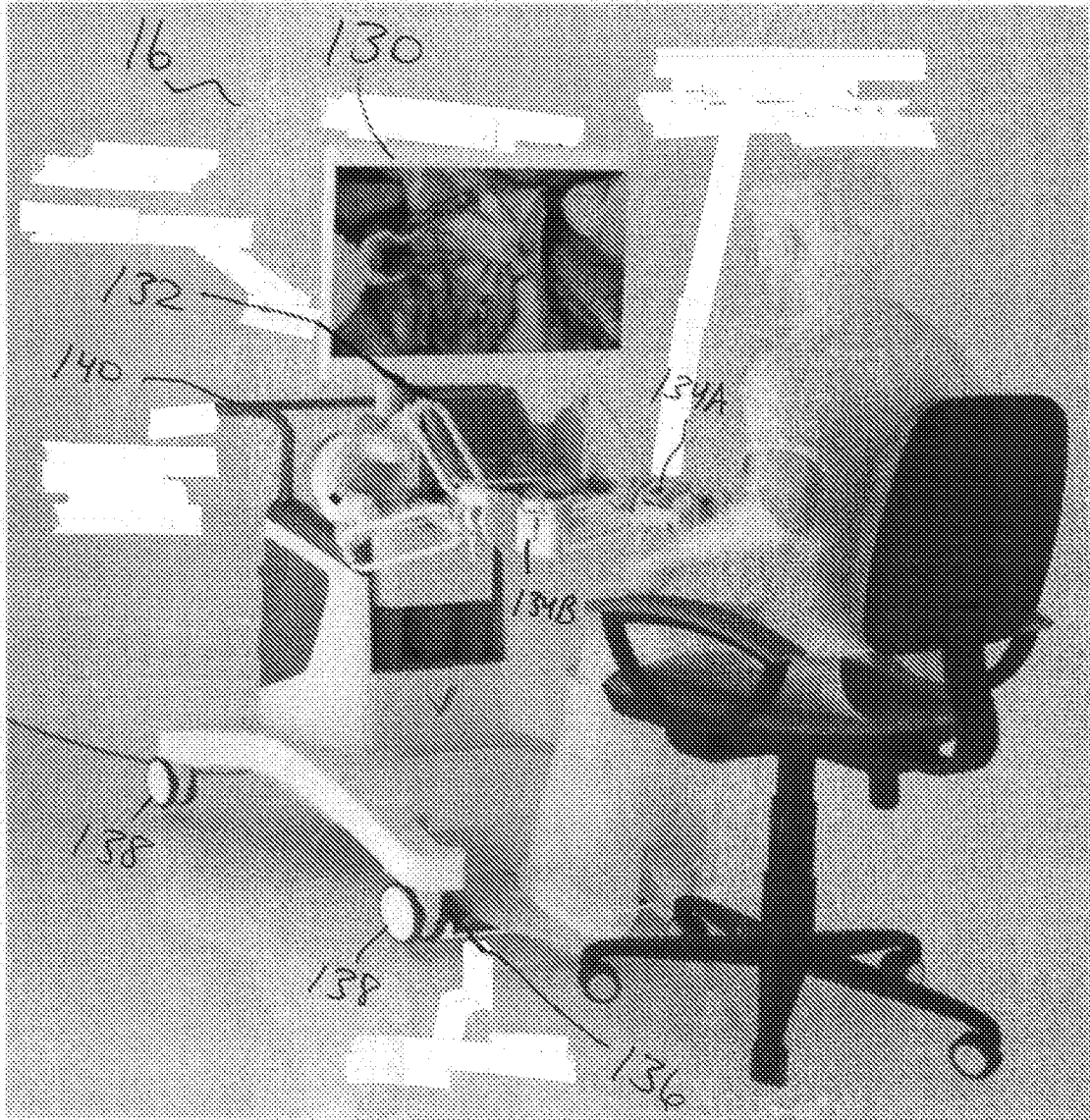
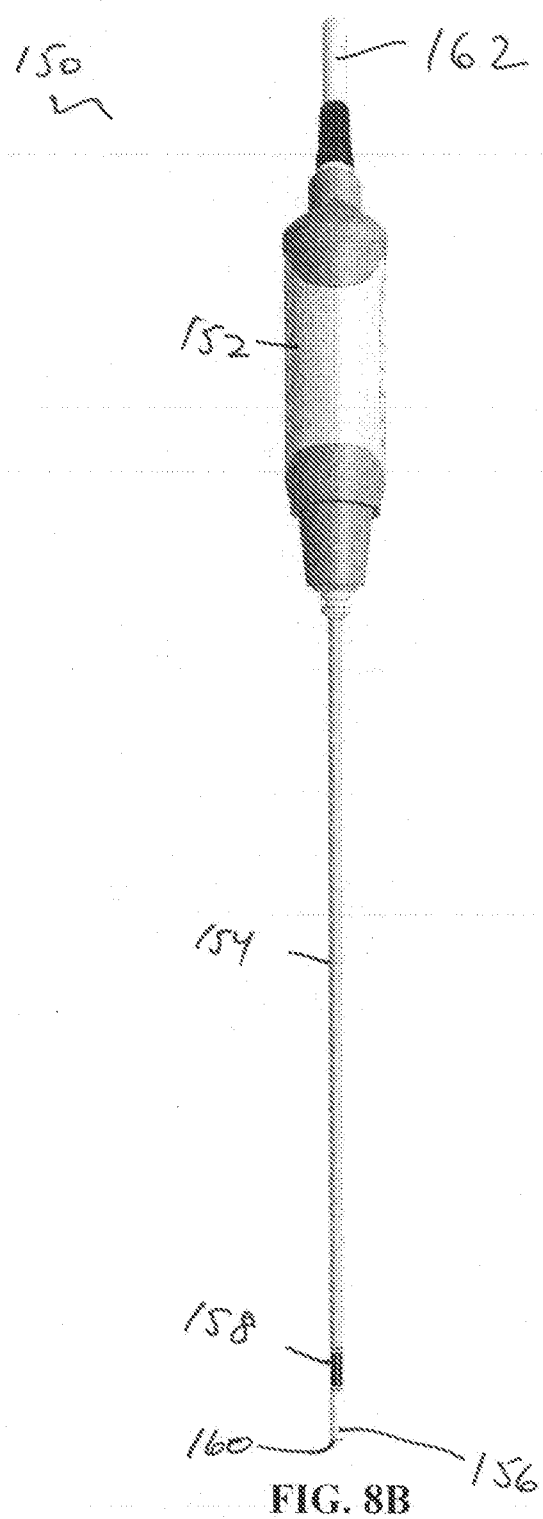
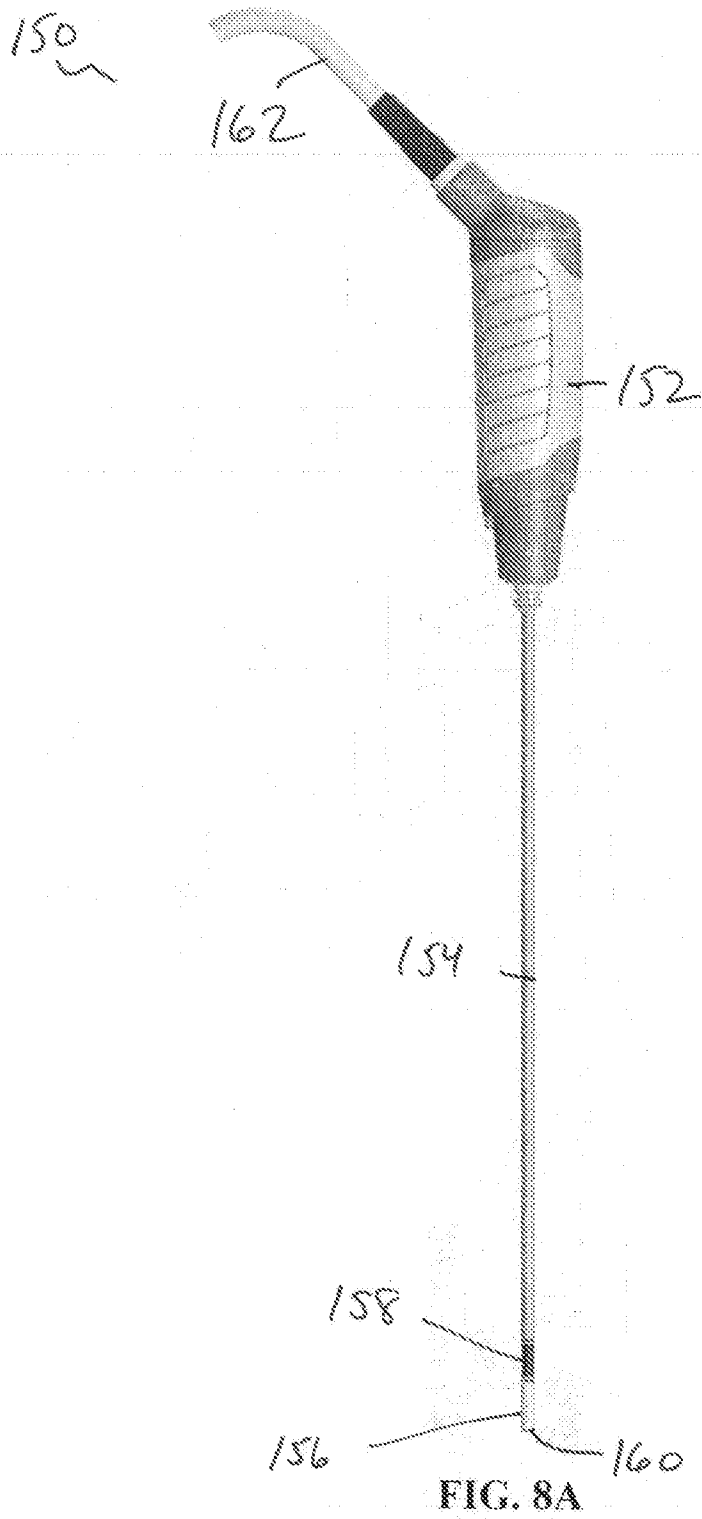


FIG. 7



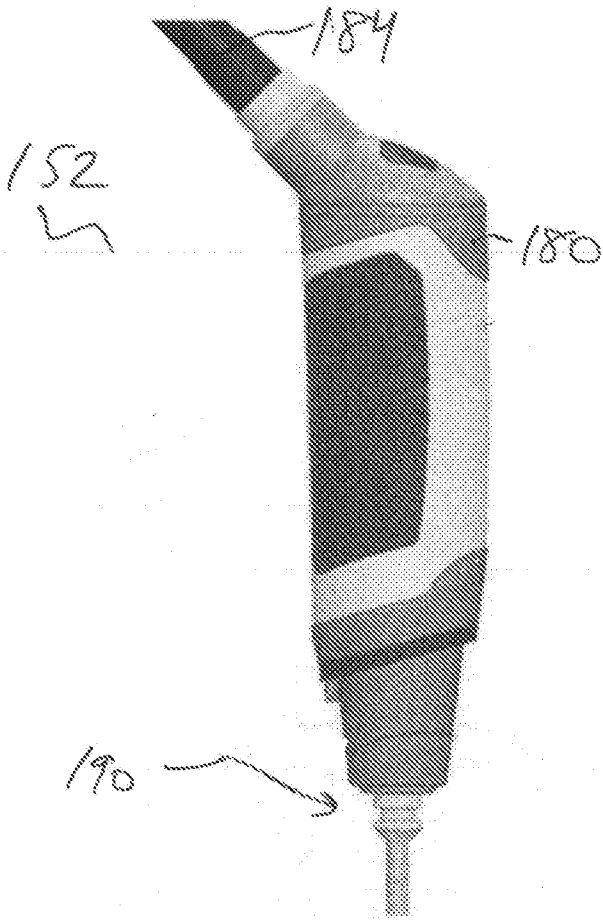


FIG. 9A

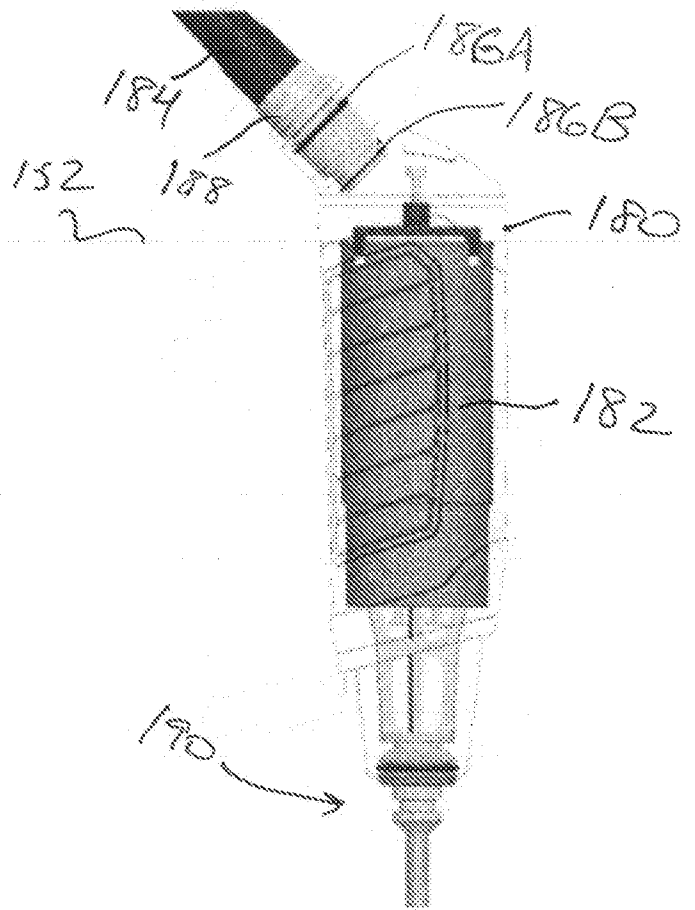


FIG. 9B

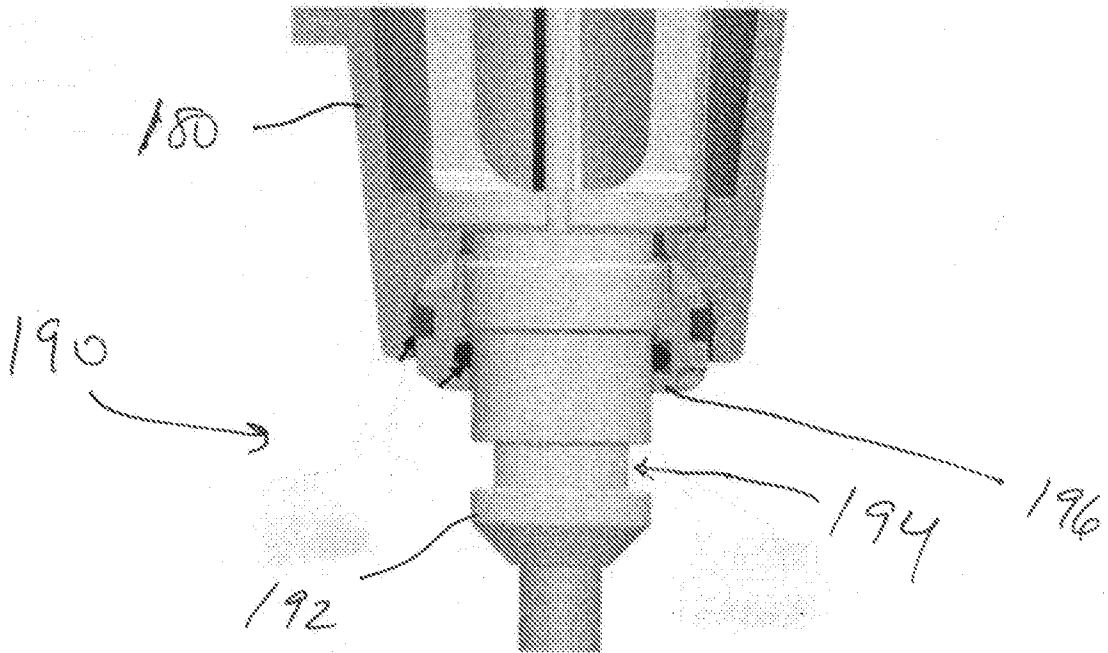
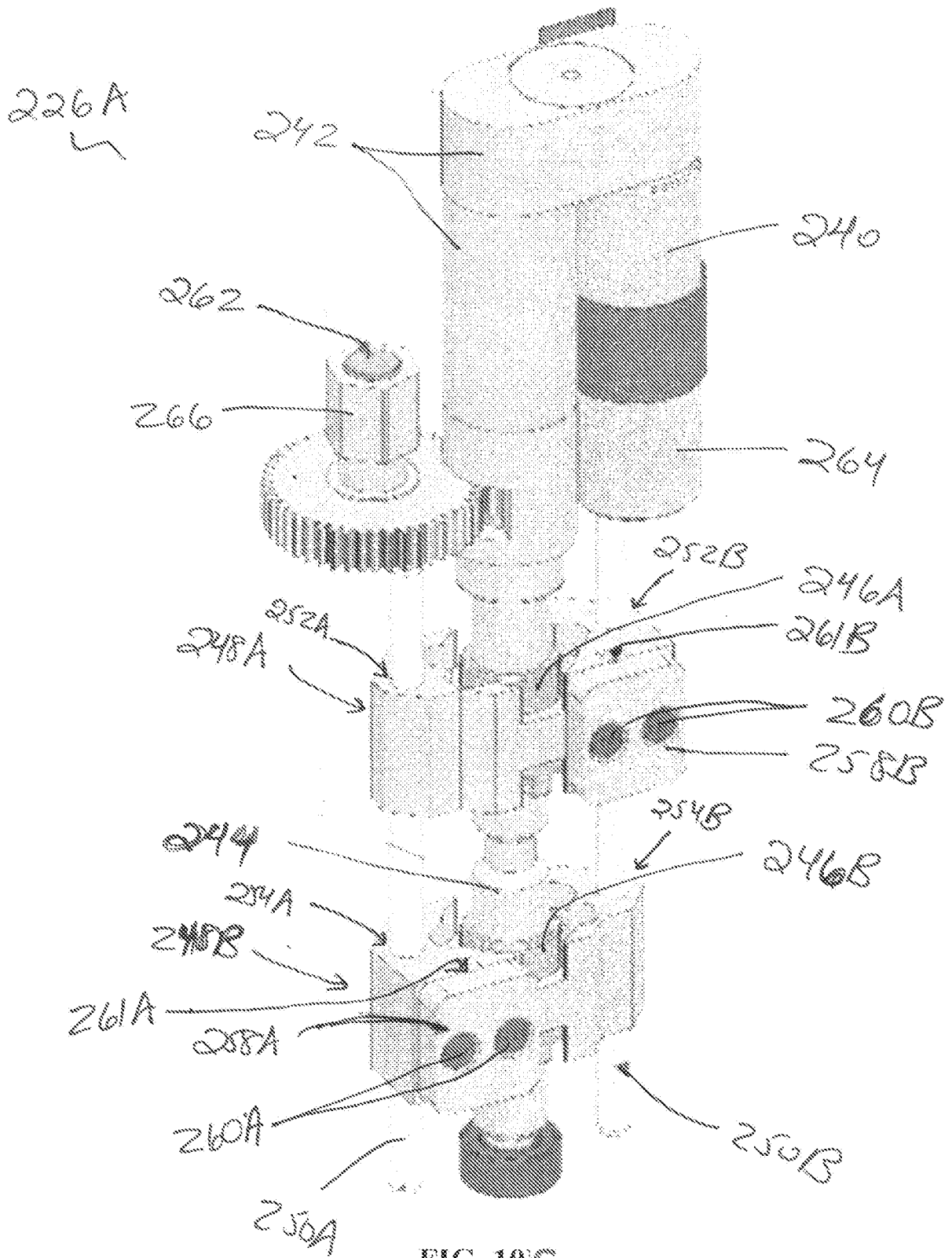
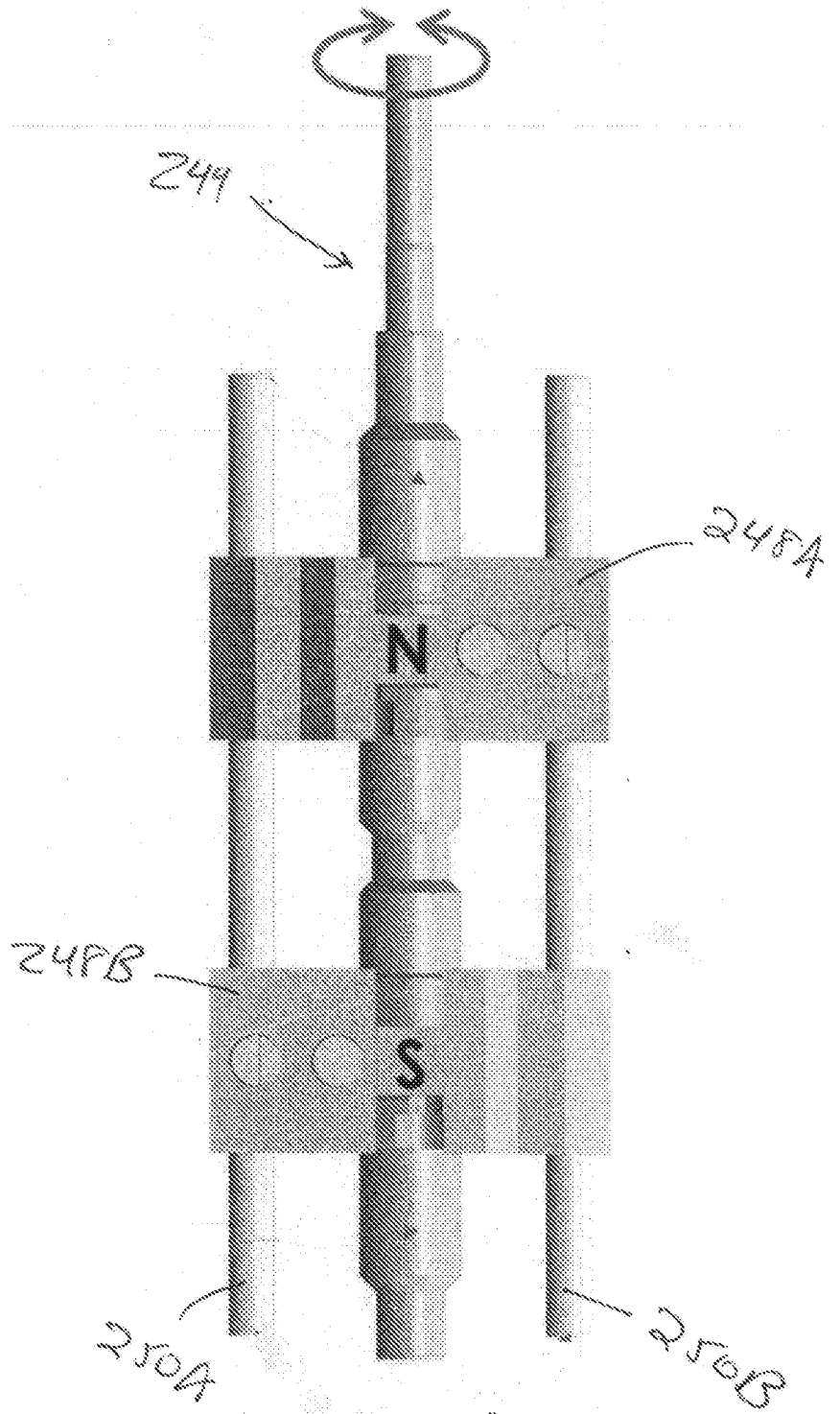
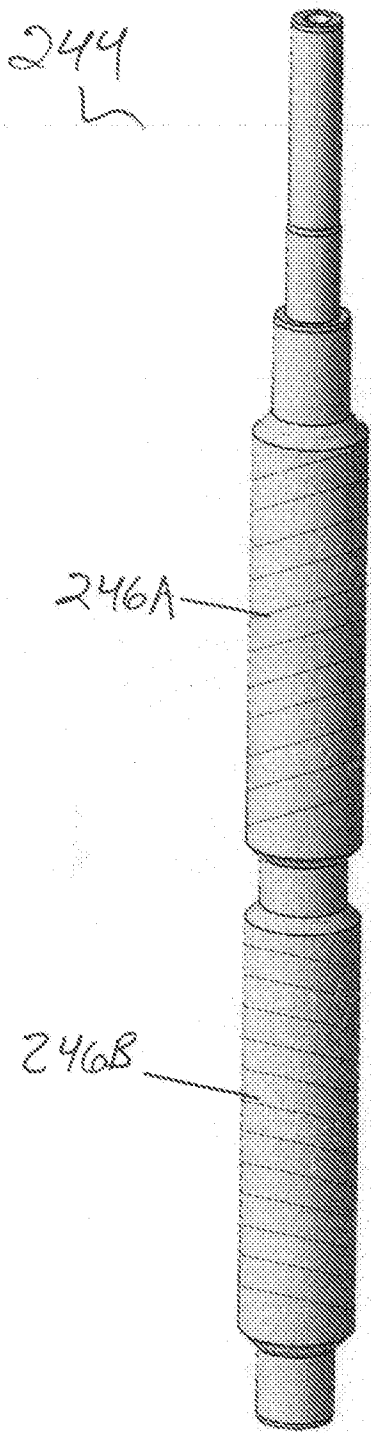


FIG. 9C







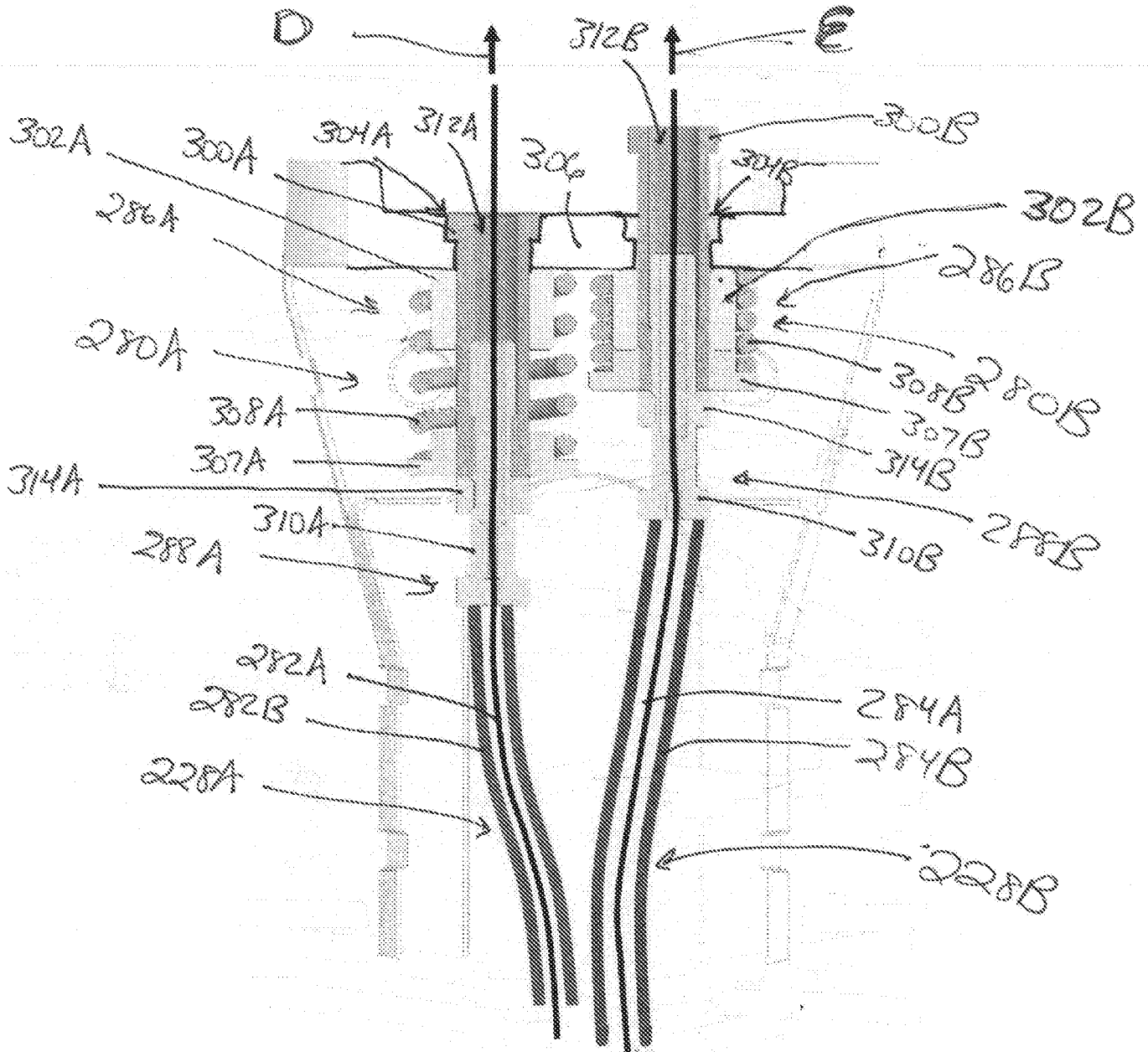


FIG. 10F

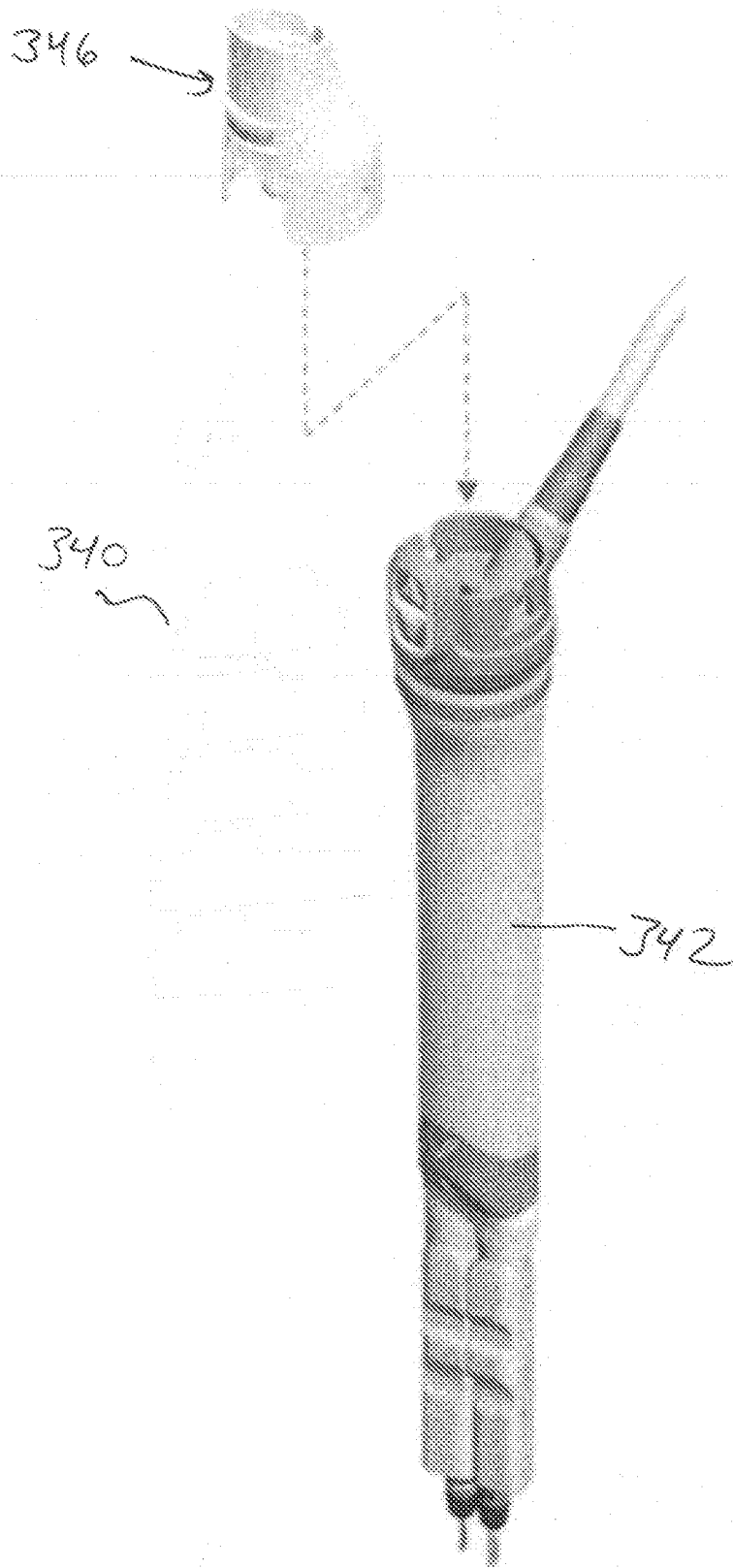


FIG. 11A

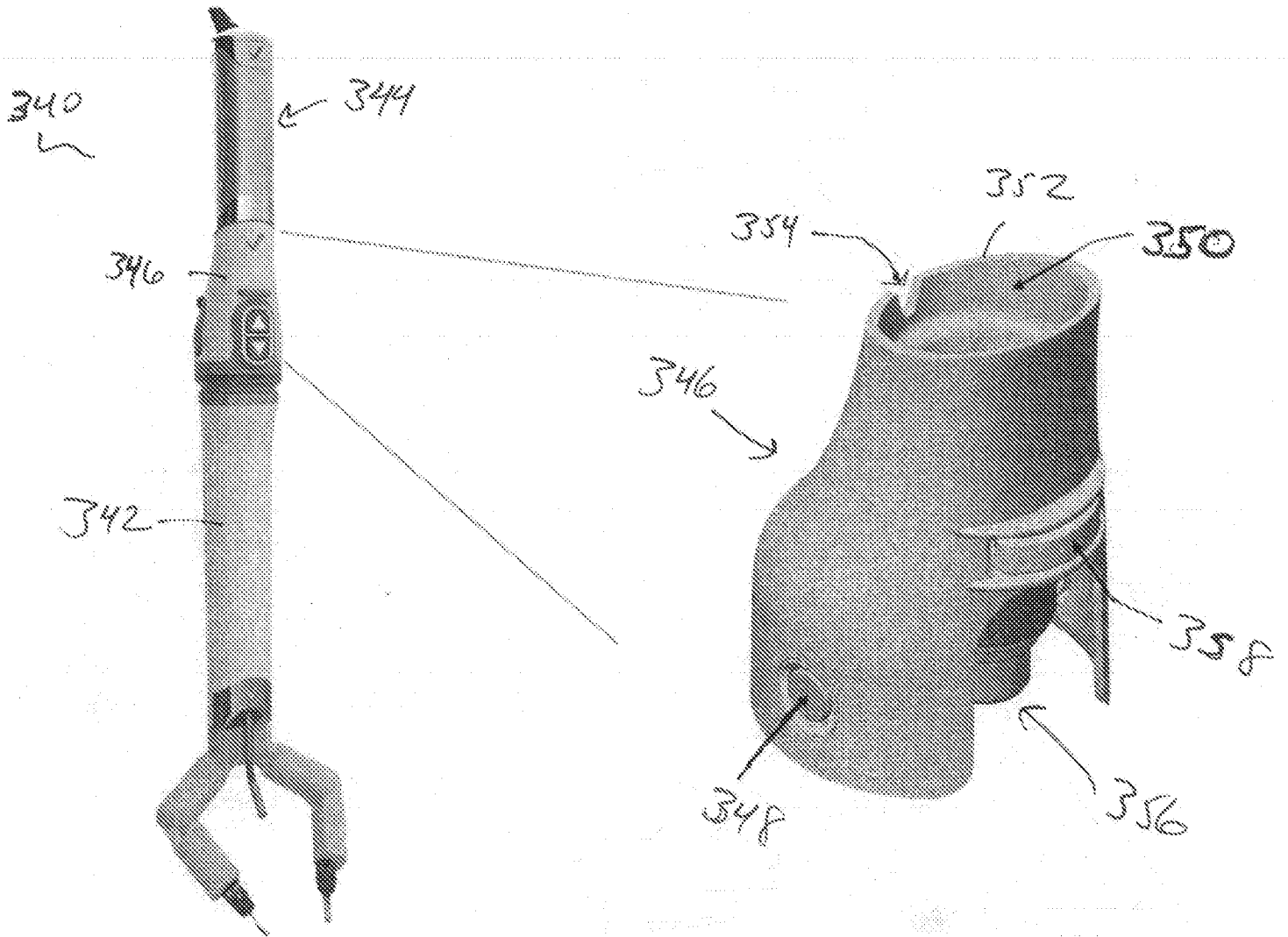


FIG. 11B

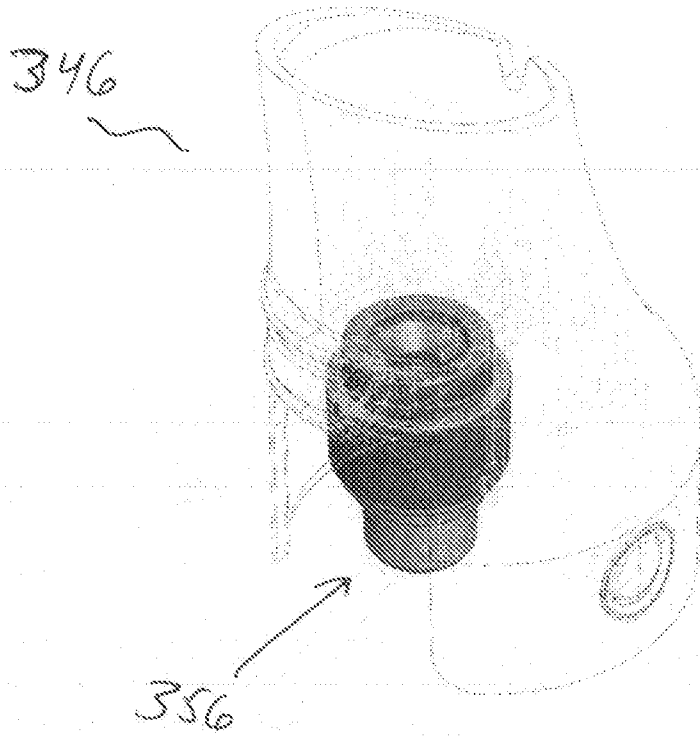


FIG. 12A

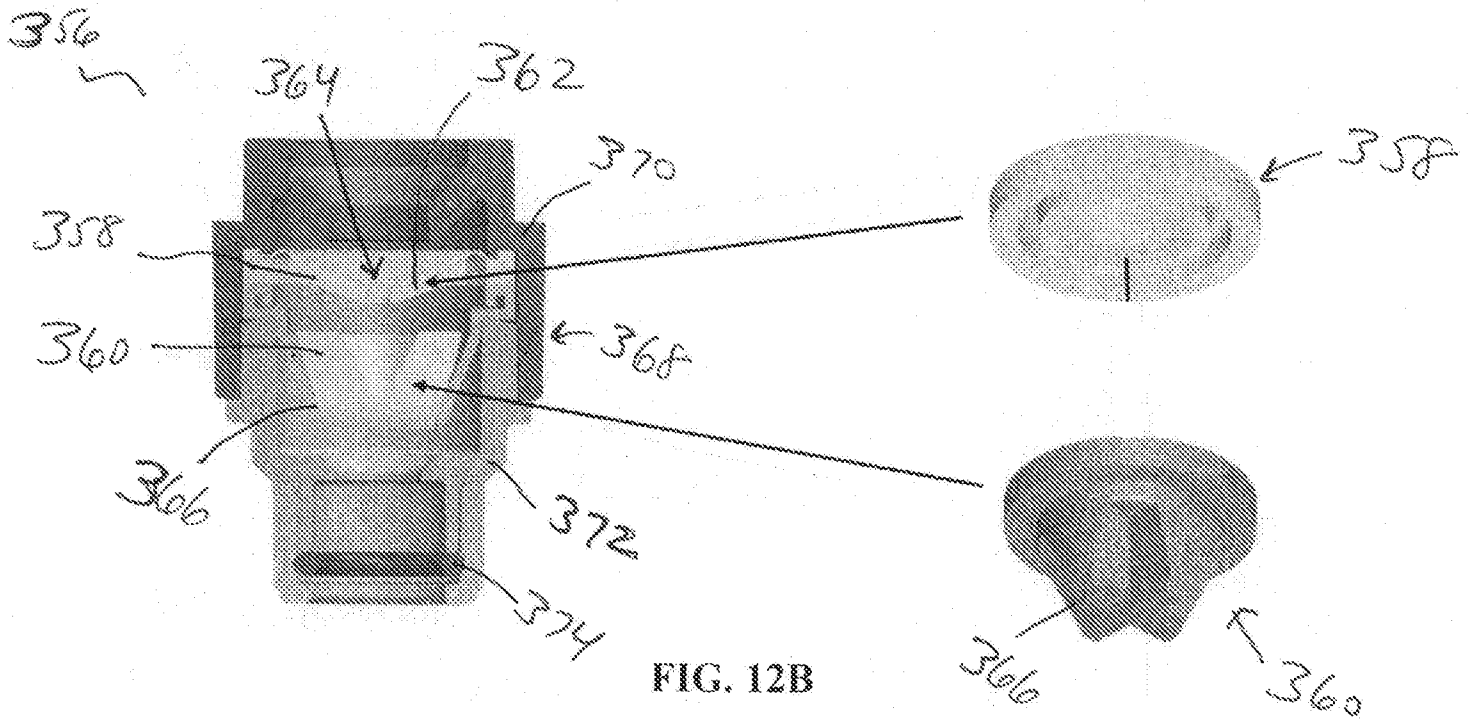


FIG. 12B

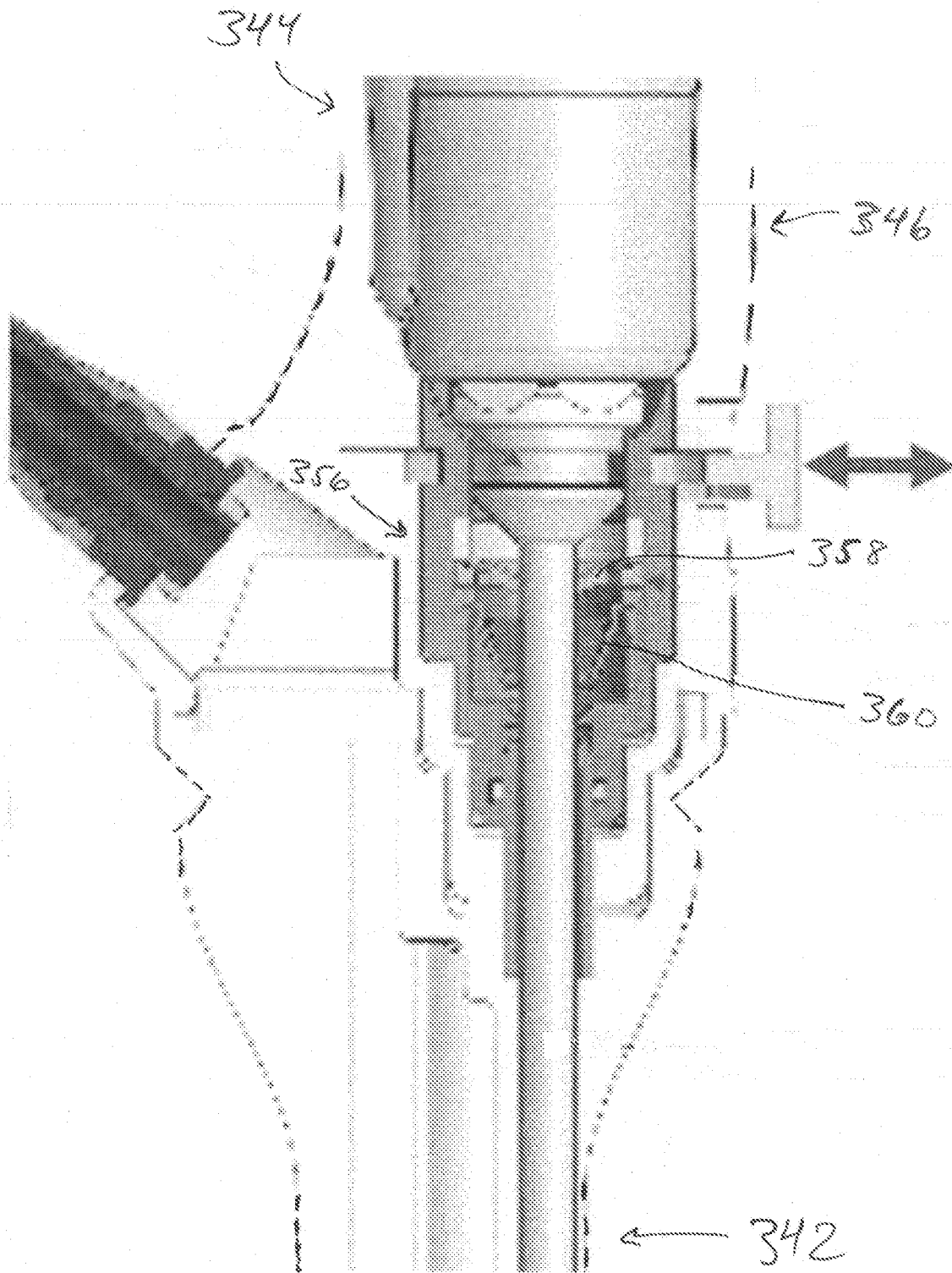


FIG. 13

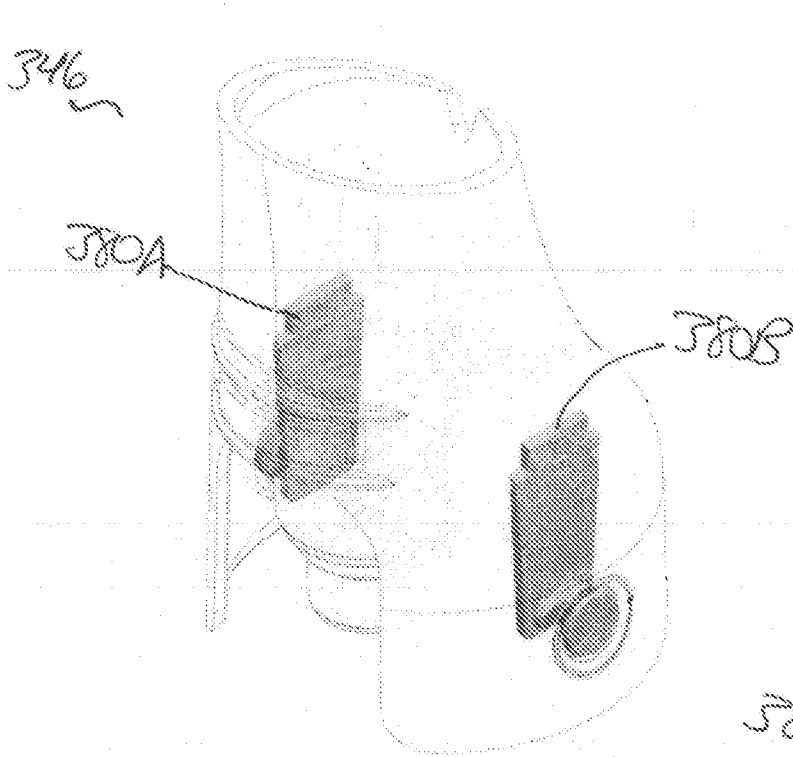


FIG. 14A

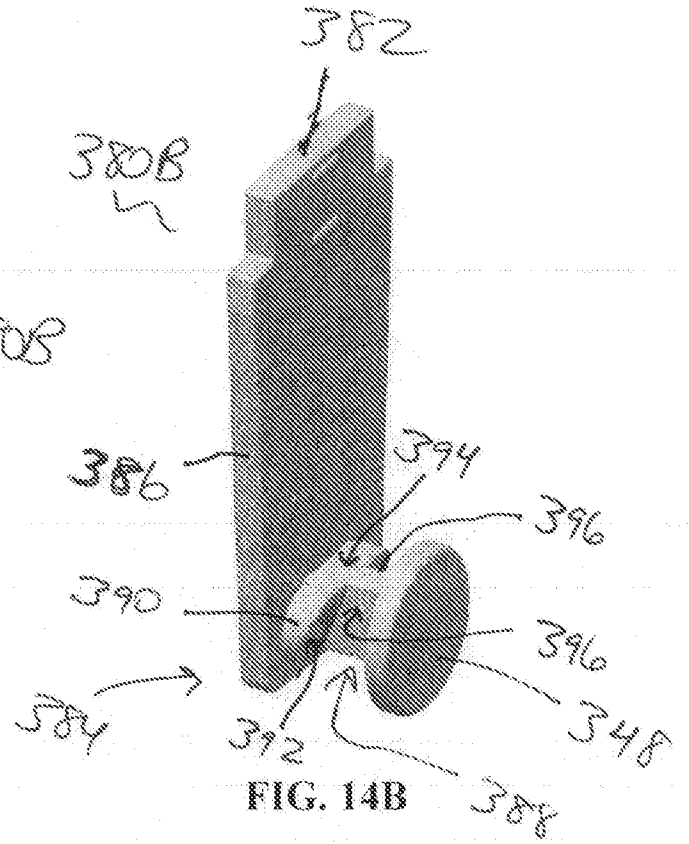


FIG. 14B

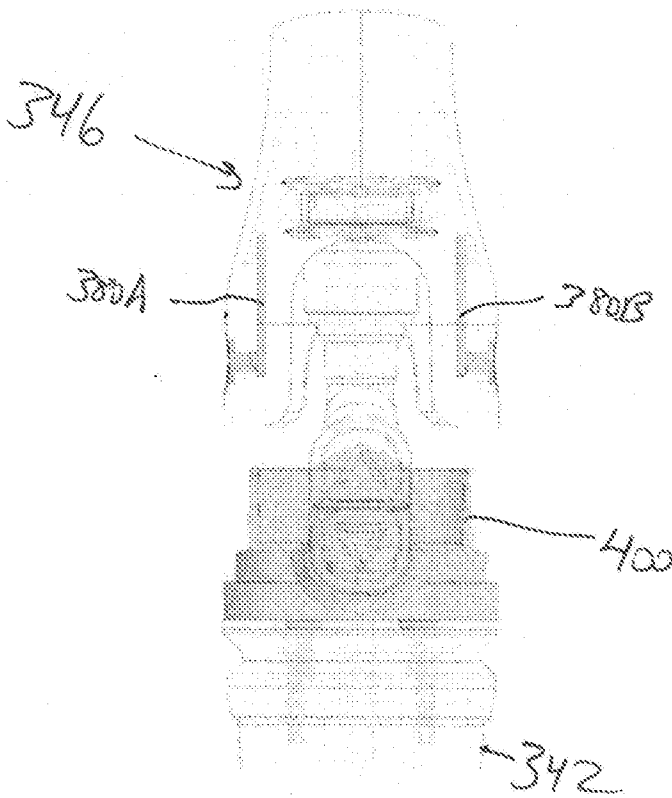


FIG. 15A

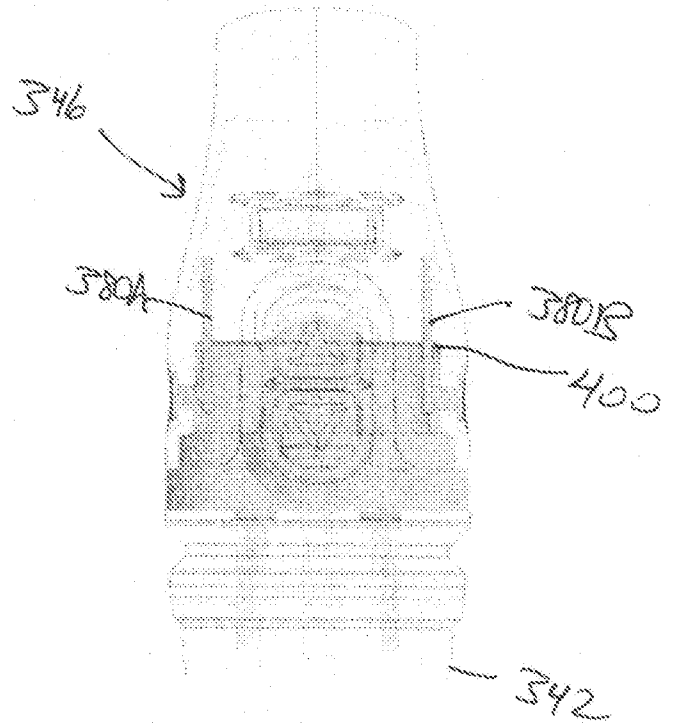


FIG. 15B

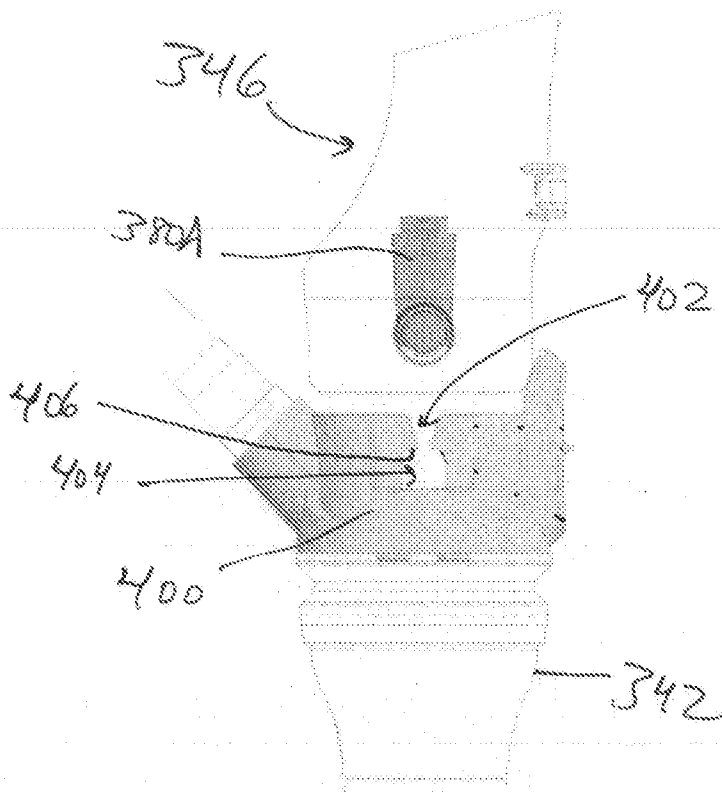


FIG. 16A

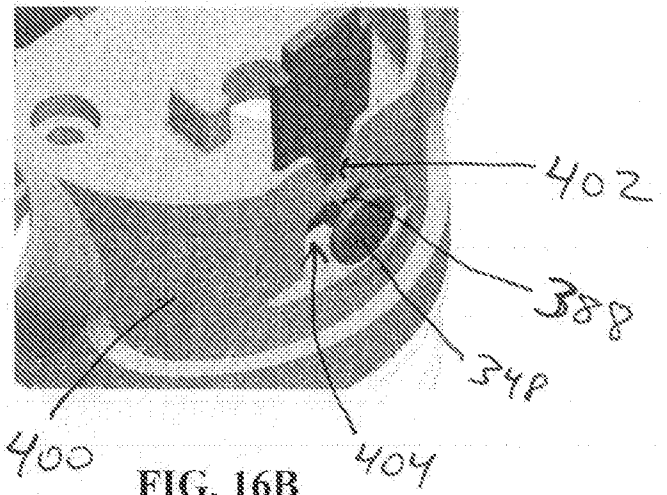


FIG. 16B

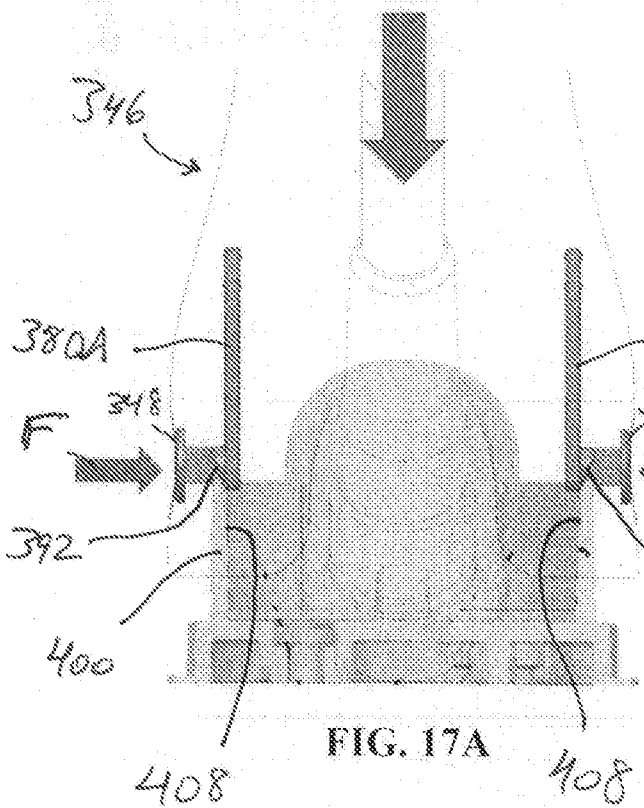


FIG. 17A

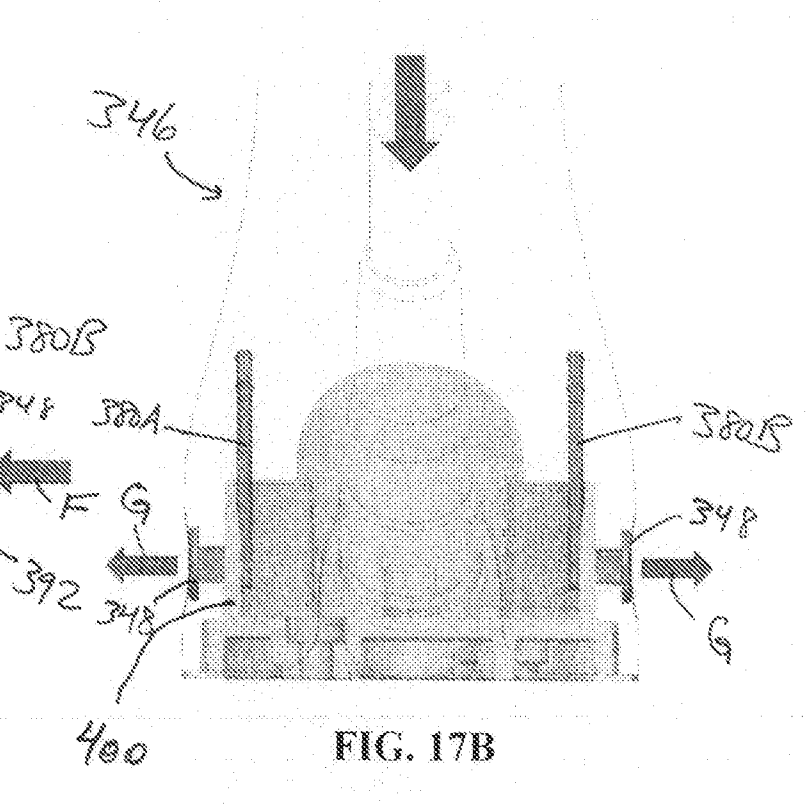


FIG. 17B

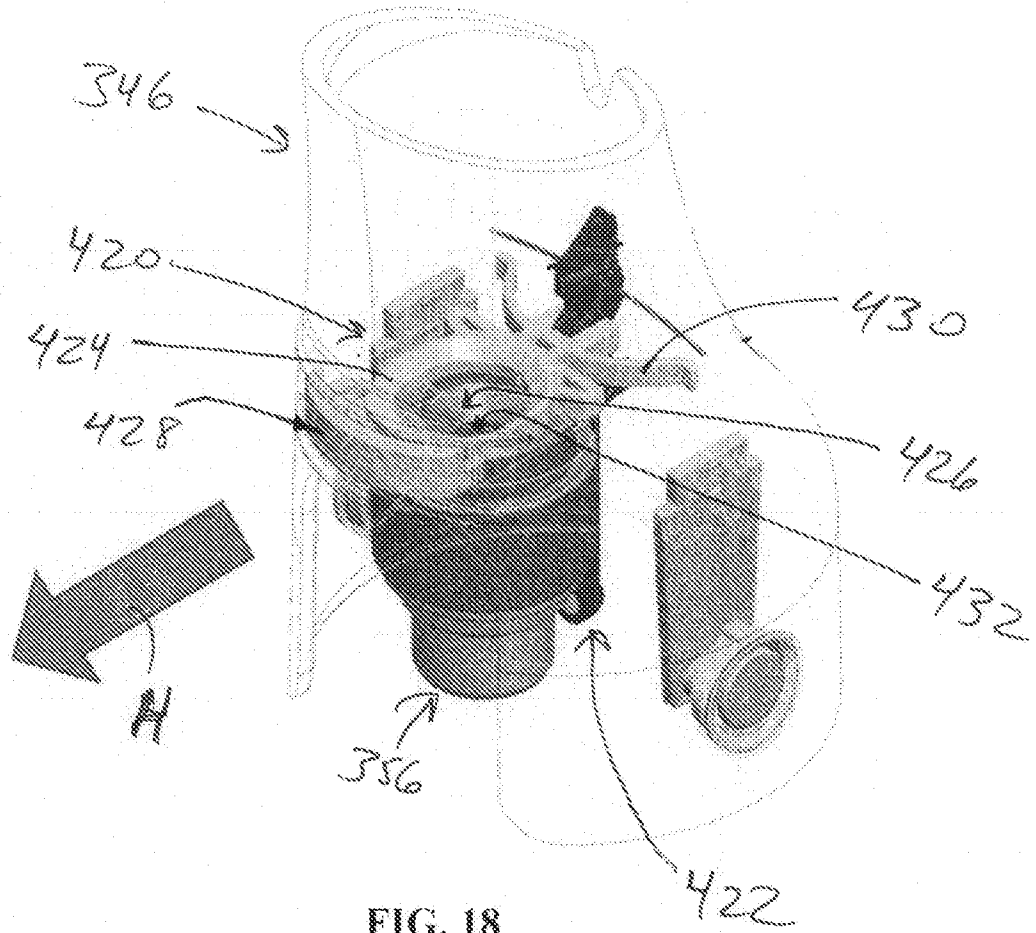


FIG. 18

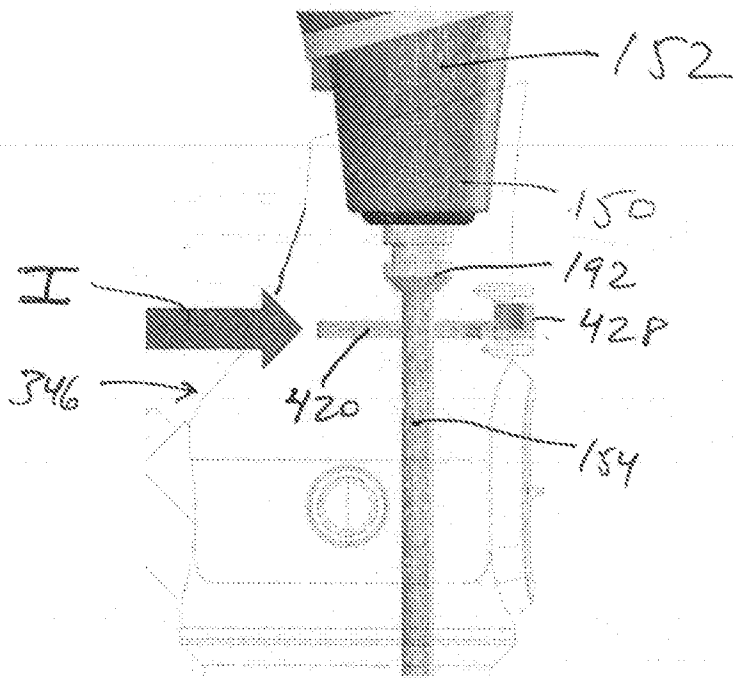


FIG. 19A

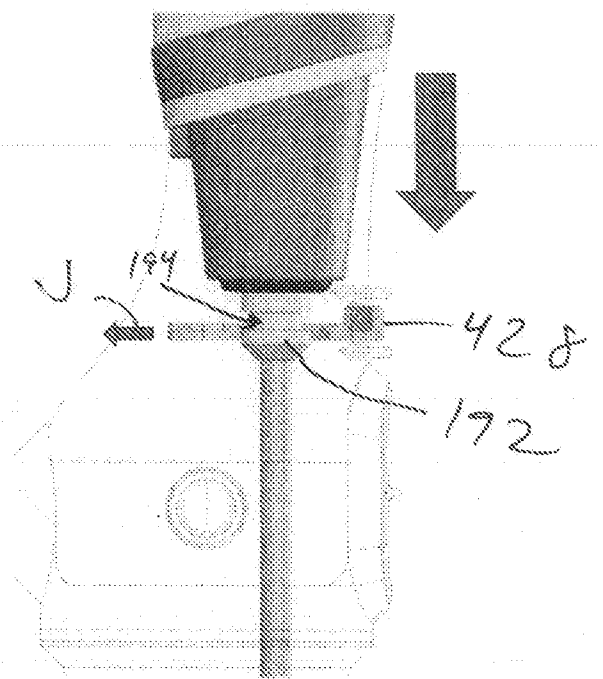


FIG. 19B

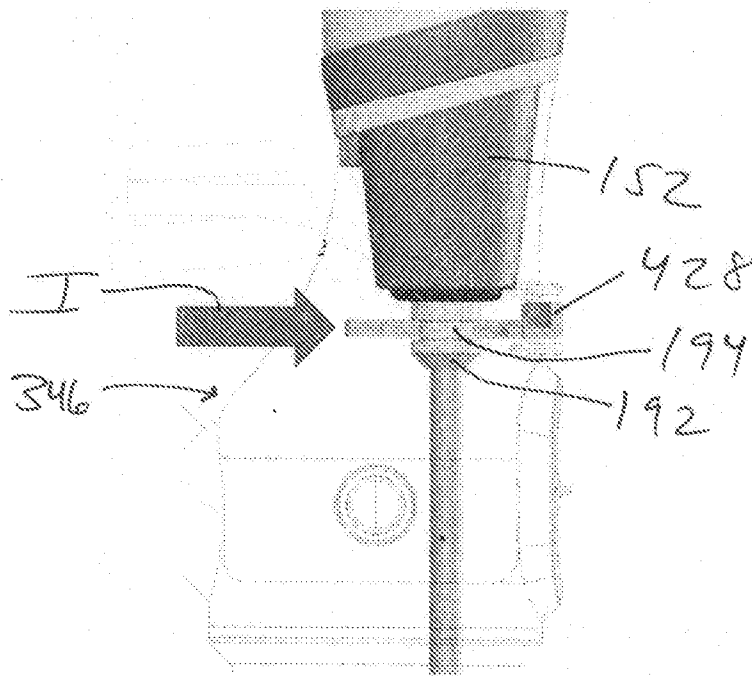


FIG. 19C



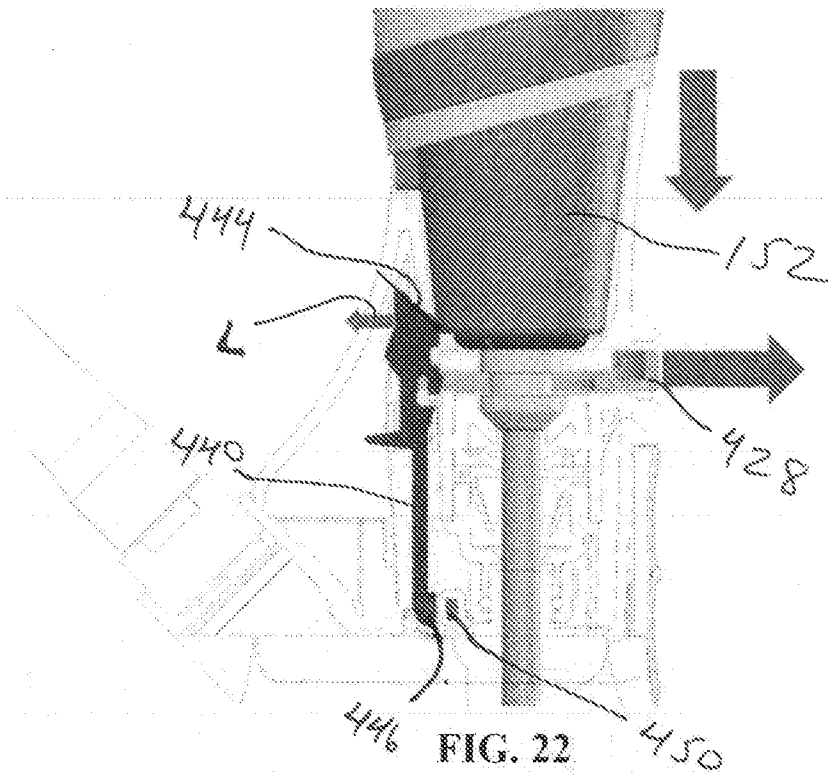


FIG. 22

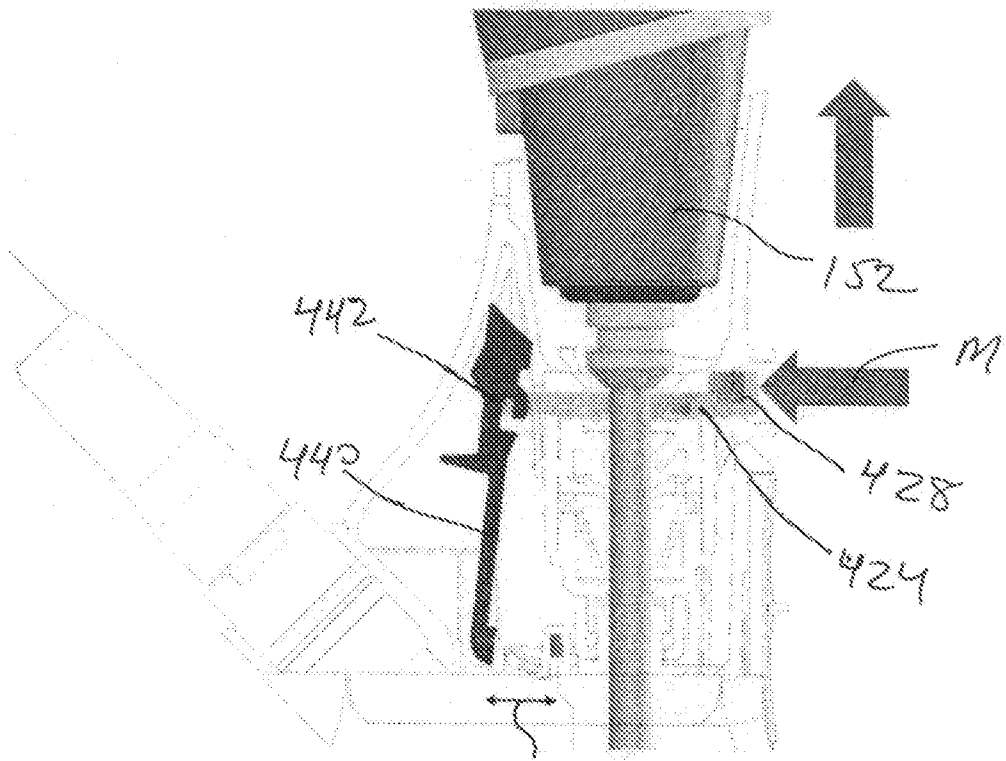
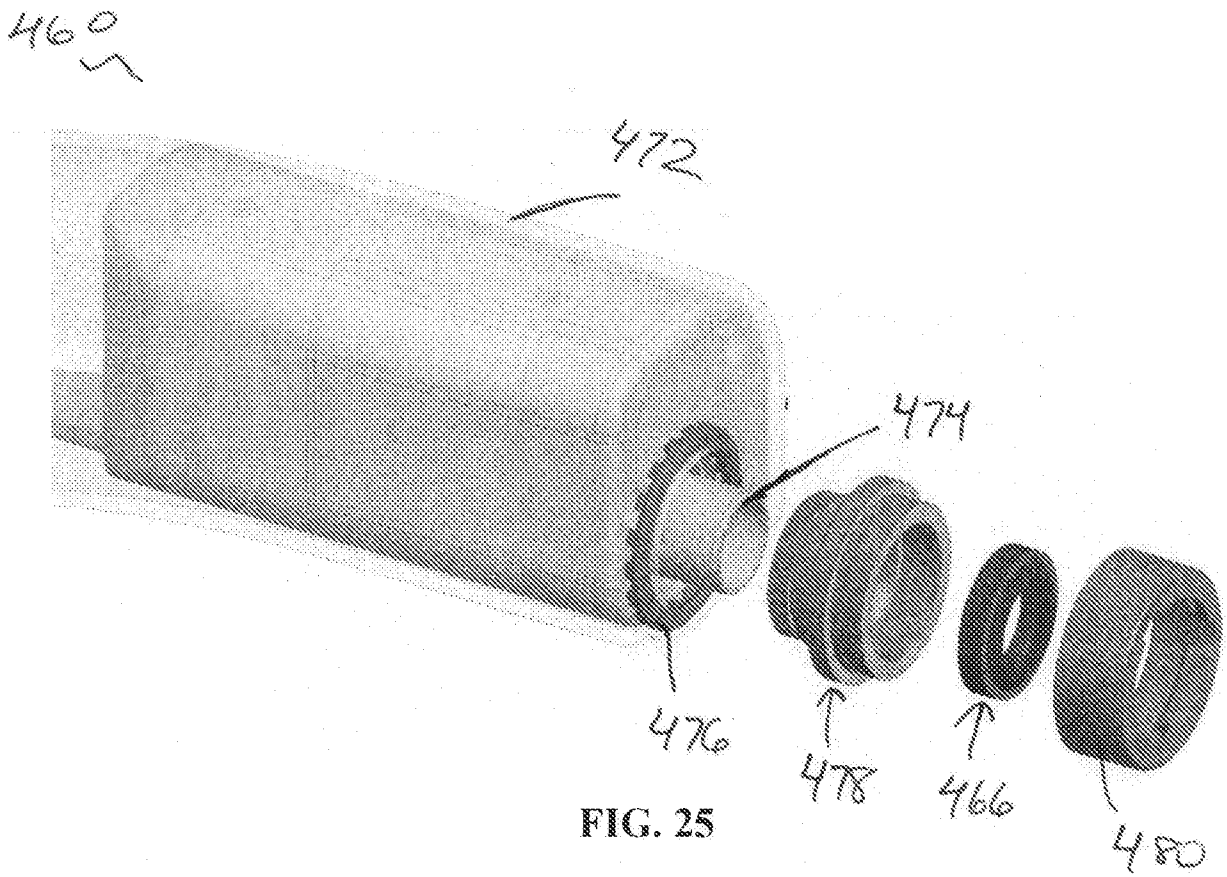
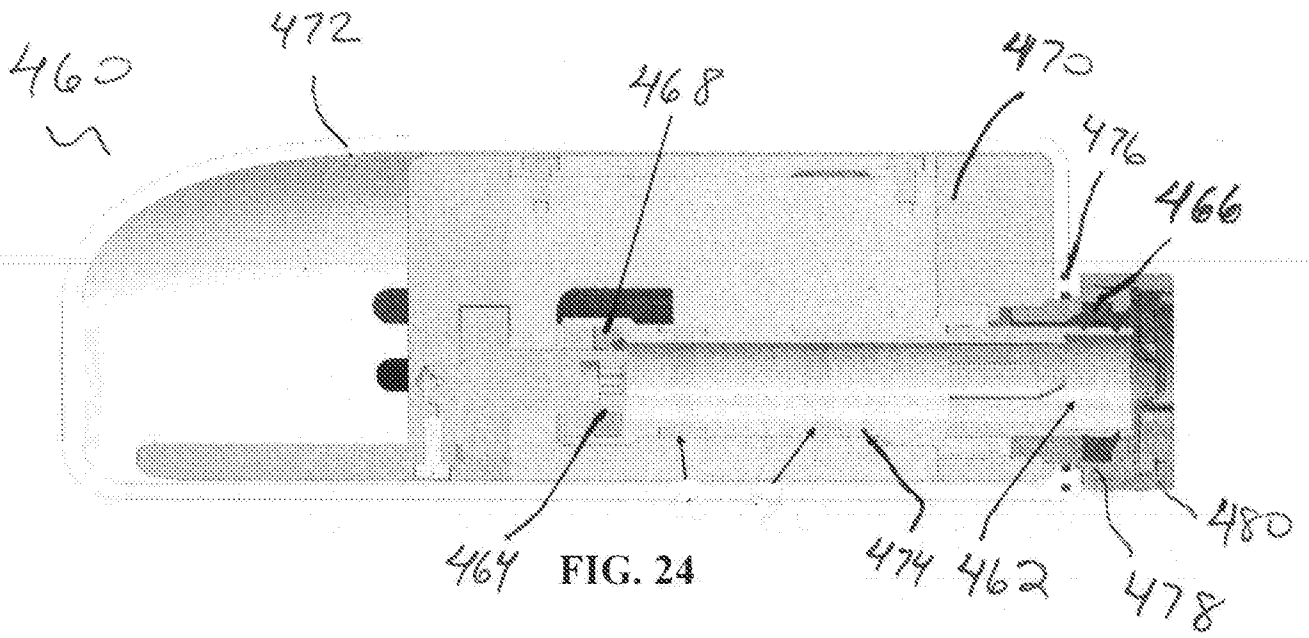


FIG. 23



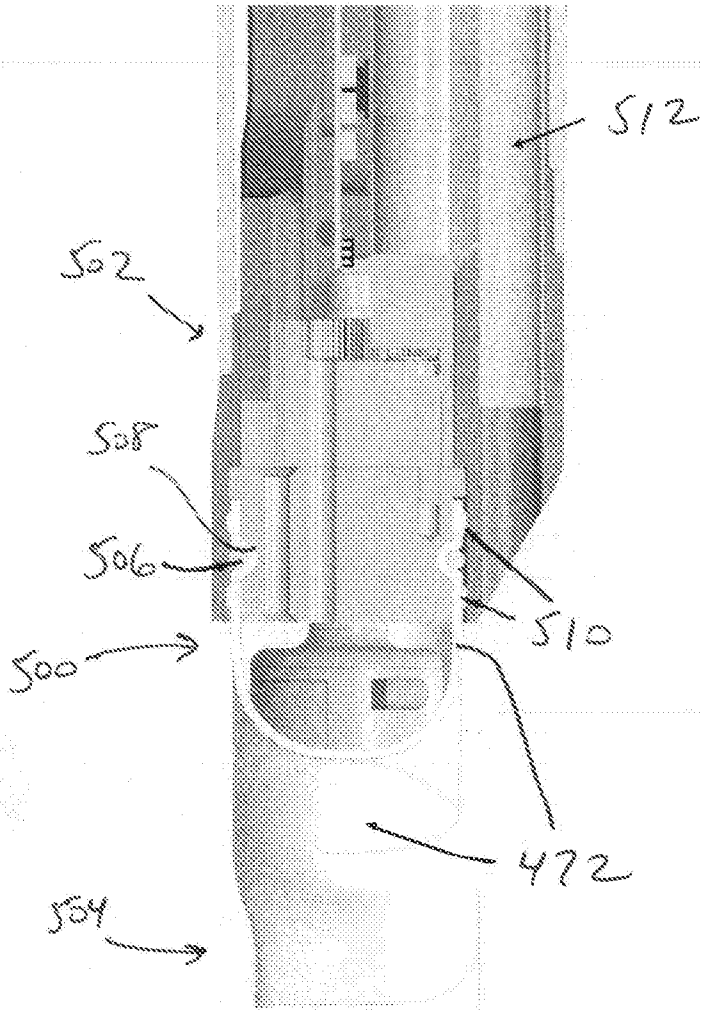


FIG. 26

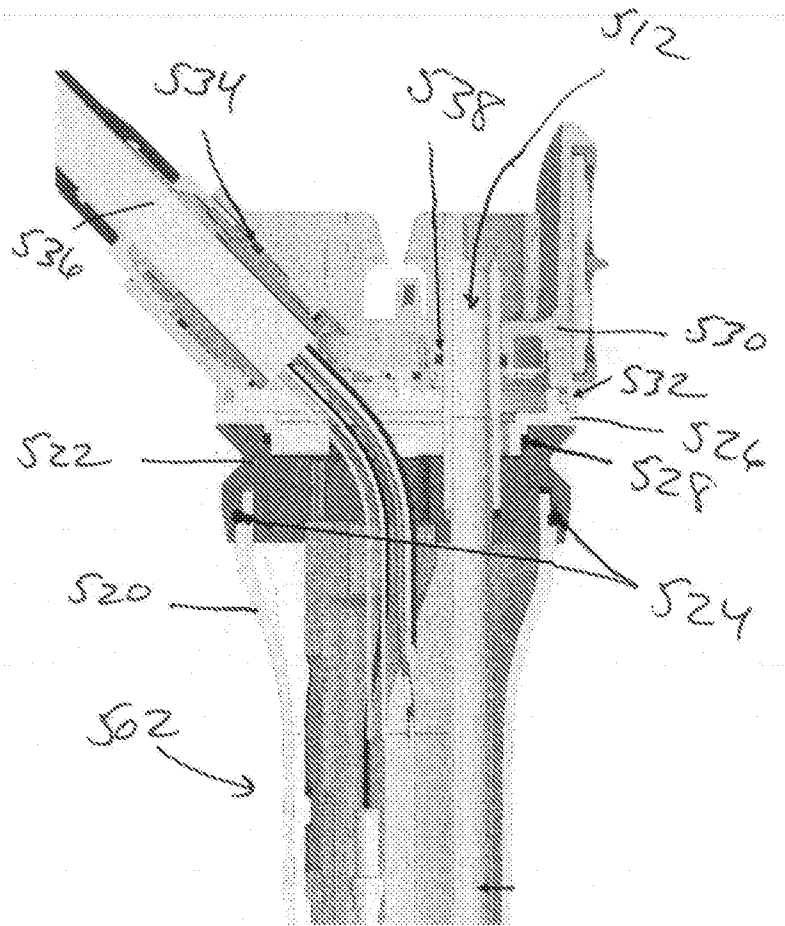


FIG. 27

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 20/12533

## A. CLASSIFICATION OF SUBJECT MATTER

IPC - A61B 1/05 (2020.01)

CPC - A61B 34/30, A61B 90/361, A61B 1/00128, A61B 1/045, A61B 1/051

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)*

See Search History document

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

See Search History document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History document

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2018/0338777 A1 (Atropos Limited) 29 November 2018 (29.11.2018), entire document, especially Fig. 1, 6a, abstract, para [0136]	1-22
A	US 2017/0354470 A1 (Virtual Incision Corporation) 14 December 2017 (14.12.2017), entire document, especially Fig. 2, 4, para [0145], [0148], [0149], [0150]	1-22
A	US 2018/0153578 A1 (Intuitive Surgical Operations, Inc.) 7 June 2018 (07.06.2018), entire document, especially Fig. 1-3, para [0009], [0031], [0038]	1-22
A	WO 2017/201310 A1 (Virtual Incision Corporation) 18 May 2016 (18.05.2016), entire document	1-22
A	US 2013/0131695 A1 (Scarfoglio et al.) 23 May 2013 (23.05.2013), entire document	1-22
A	US 2016/0066999 A1 (Valuebiotech S.R.L) 10 March 2016 (10.03.2016), entire document	1-22
A	US 2015/0297299 A1 (Bio-Medical Engineering (HK)) 22 October 2015 (22.10.2015), entire document	1-22

 Further documents are listed in the continuation of Box C. See patent family annex.

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"&amp;" document member of the same patent family

Date of the actual completion of the international search

28 February 2020

Date of mailing of the international search report

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