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LOCAL CONTROL ROBOTIC SURGICAL DEVICES AND RELATED METHODS

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(54) **LOCAL CONTROL ROBOTIC SURGICAL DEVICES AND RELATED METHODS**

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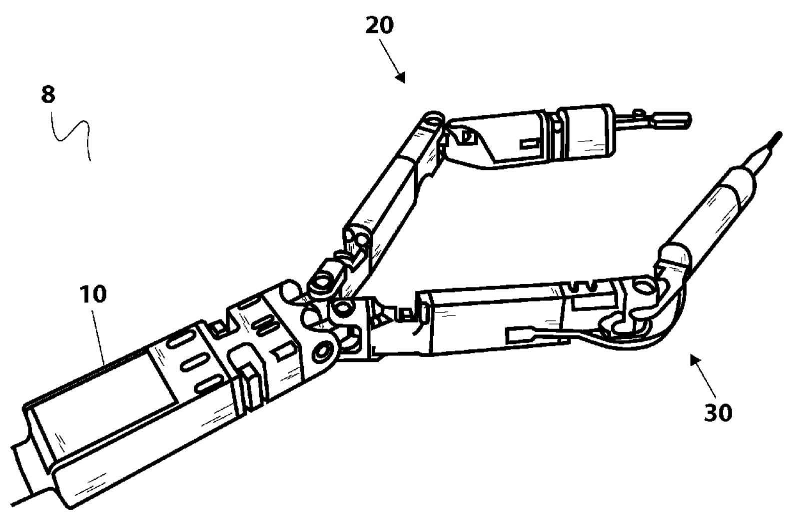
(57) **ABSTRACT**

The various robotic medical devices include robotic devices that are disposed within a body cavity and positioned using a support component disposed through an orifice or opening in the body cavity. Additional embodiments relate to devices having arms coupled to a device body wherein the device has a minimal profile such that the device can be easily inserted through smaller incisions in comparison to other devices without such a small profile. Further embodiments relate to methods of operating the above devices.

20 Claims, 49 Drawing Sheets



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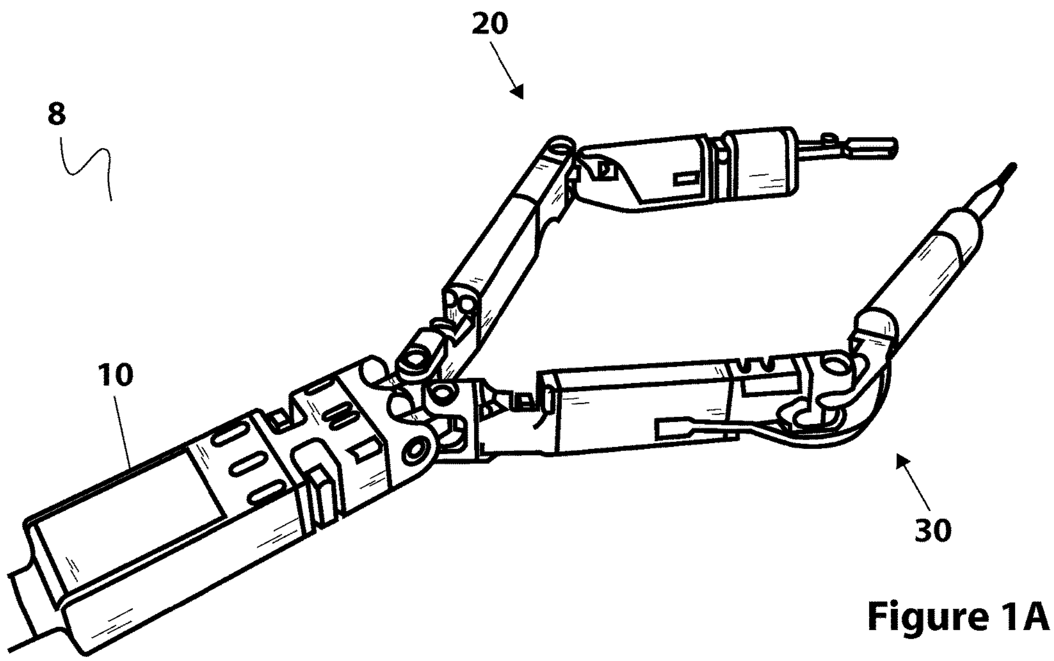

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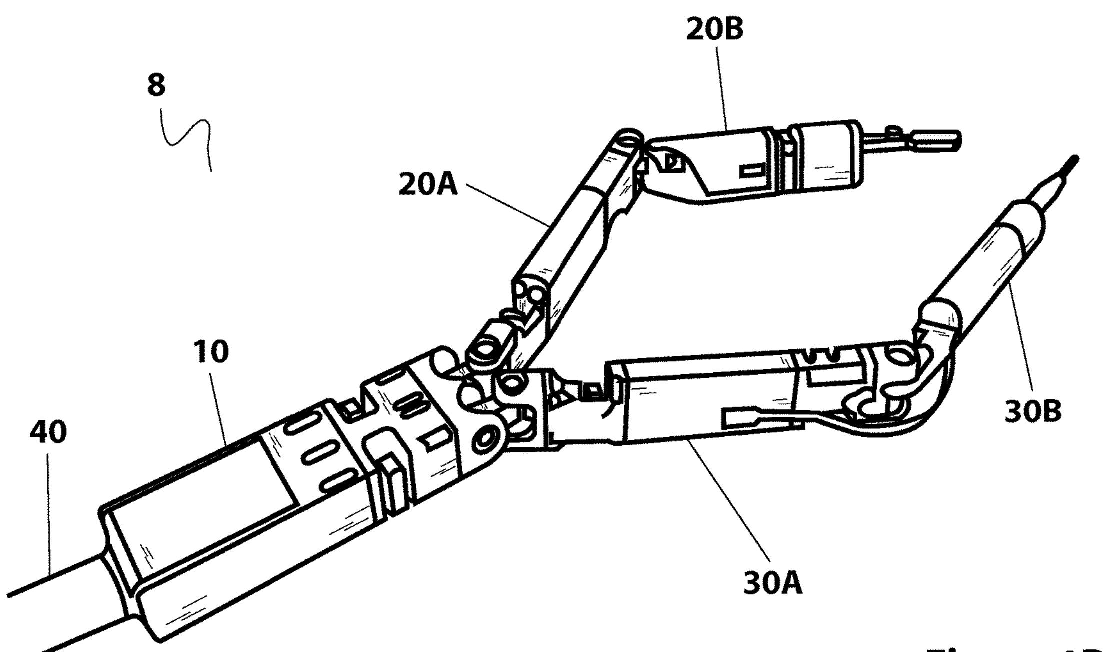

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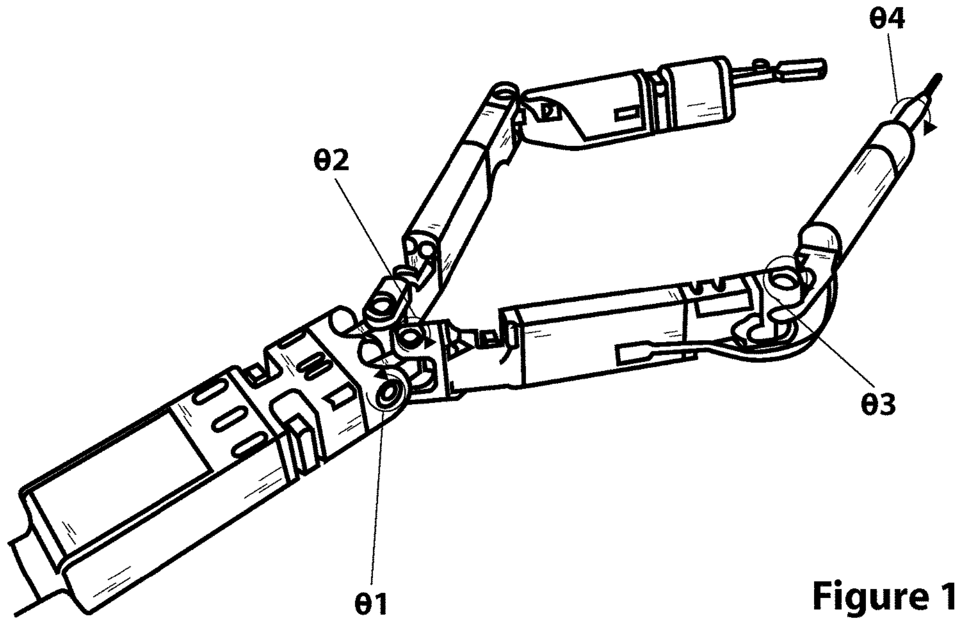

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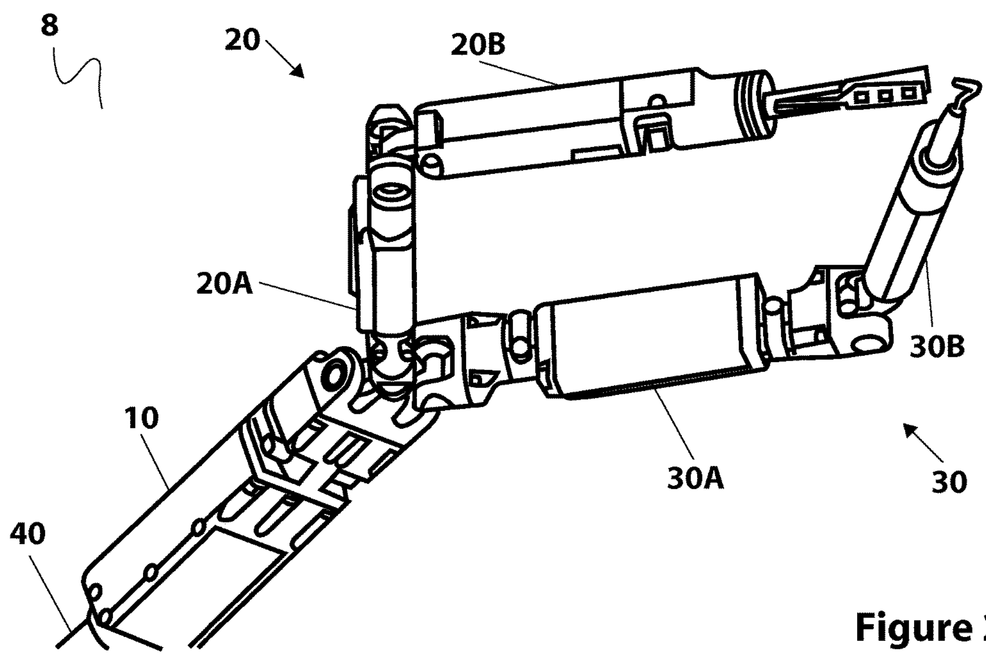

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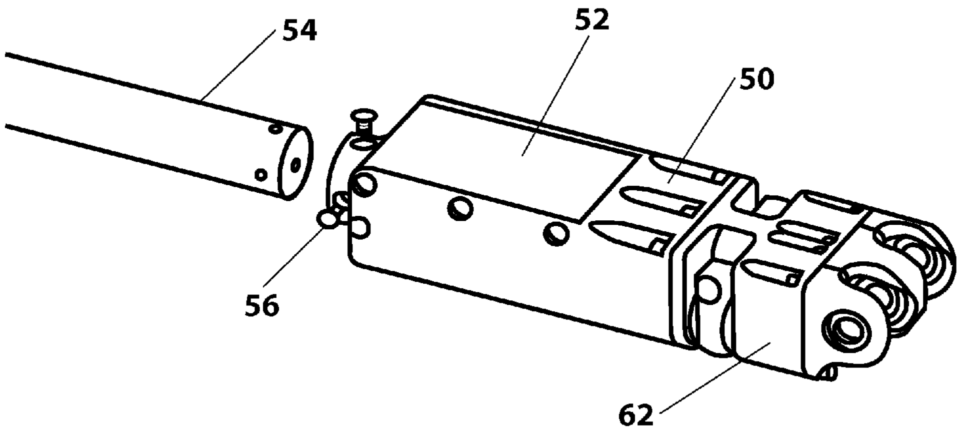

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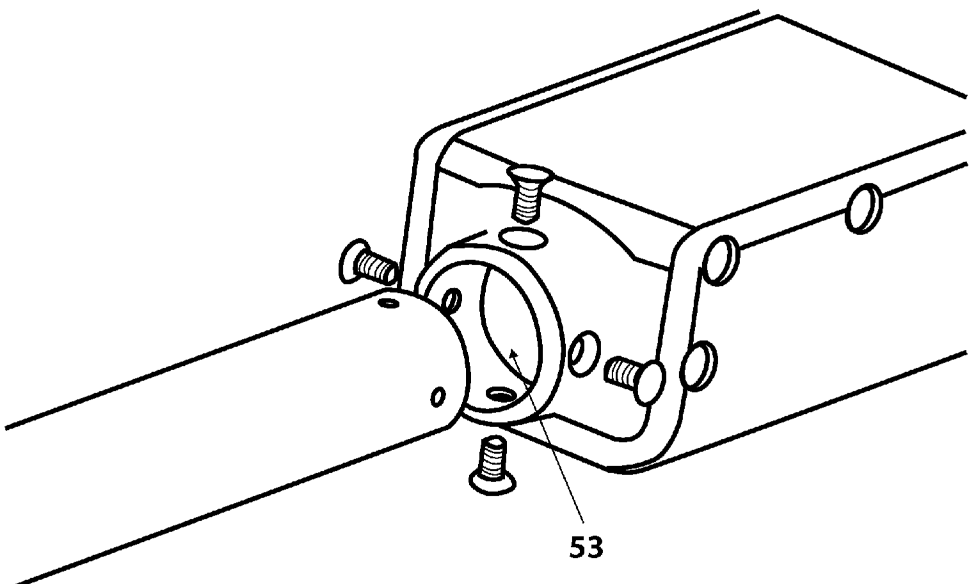

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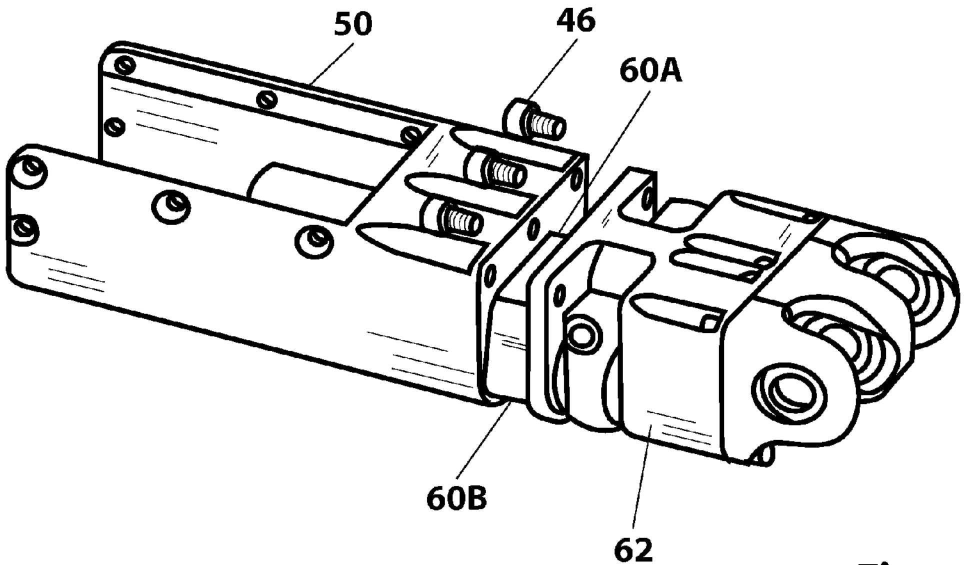

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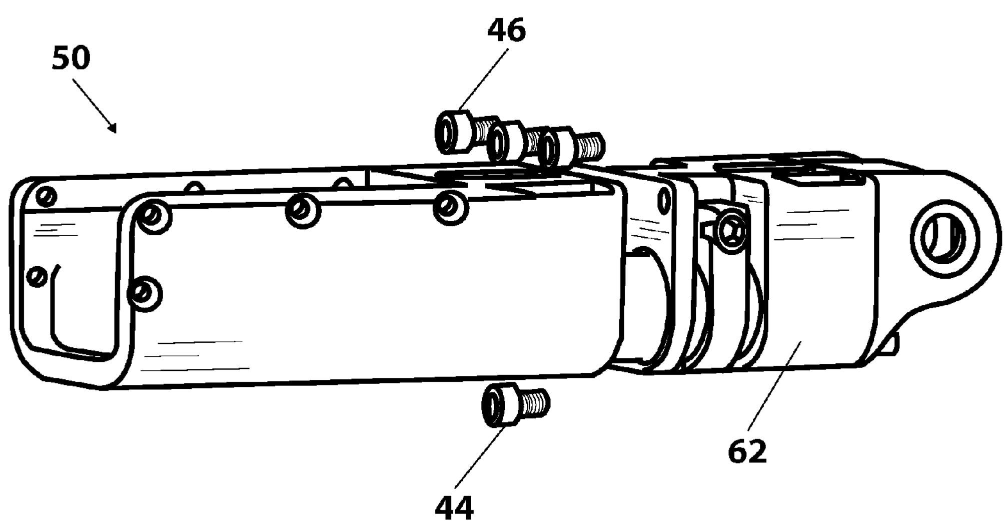

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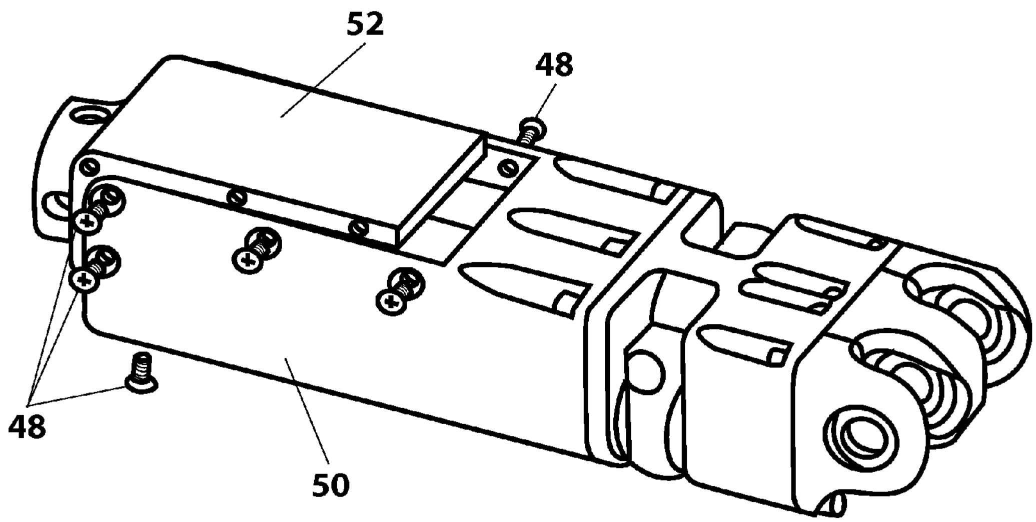

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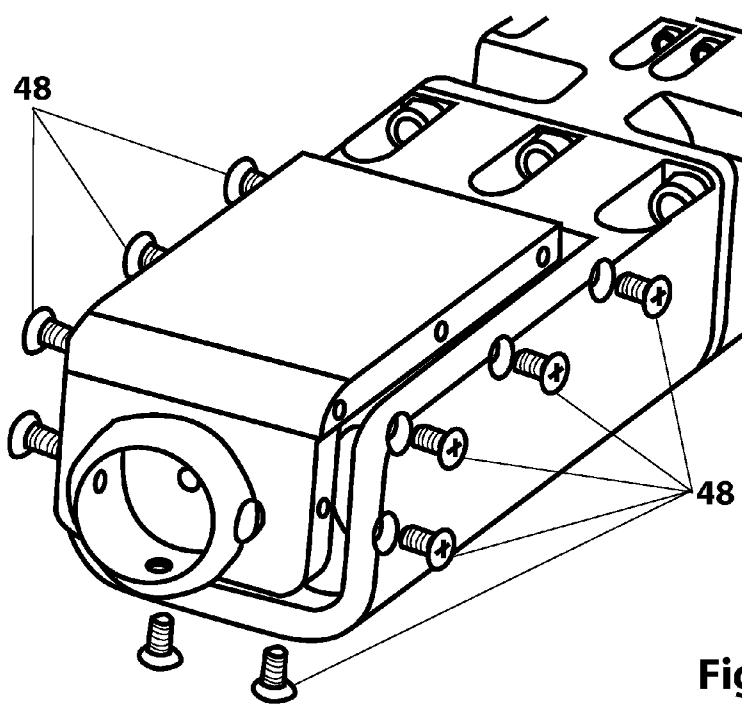

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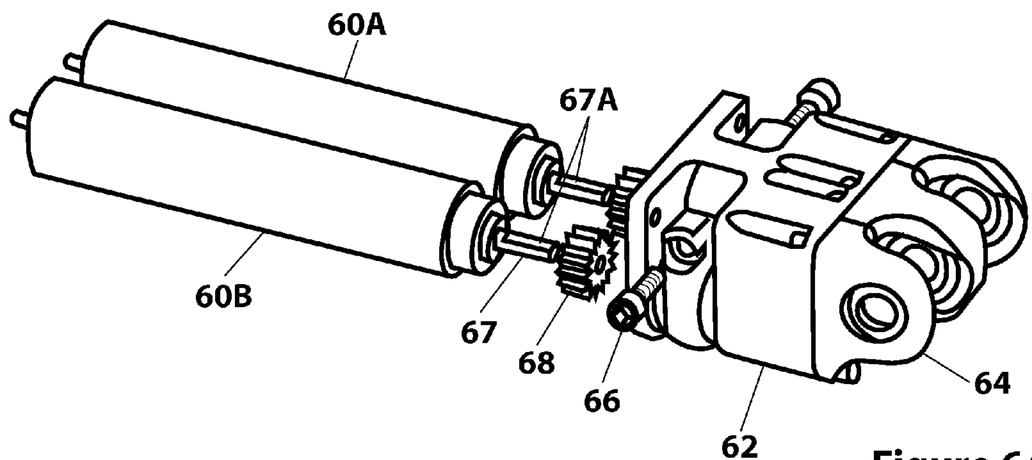

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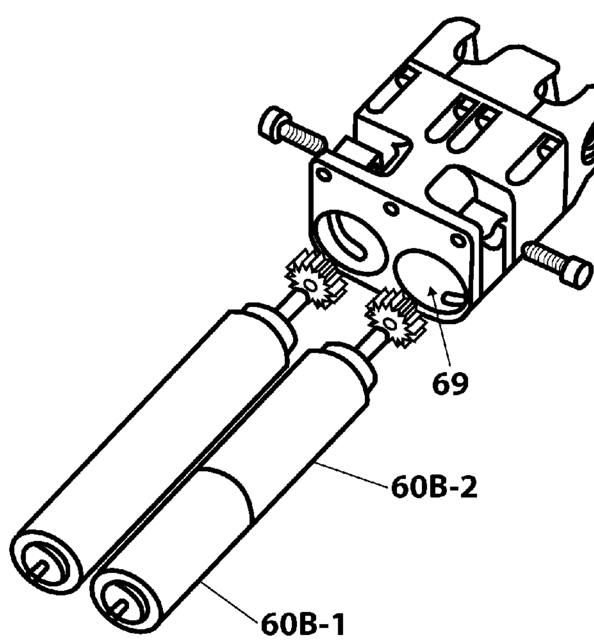

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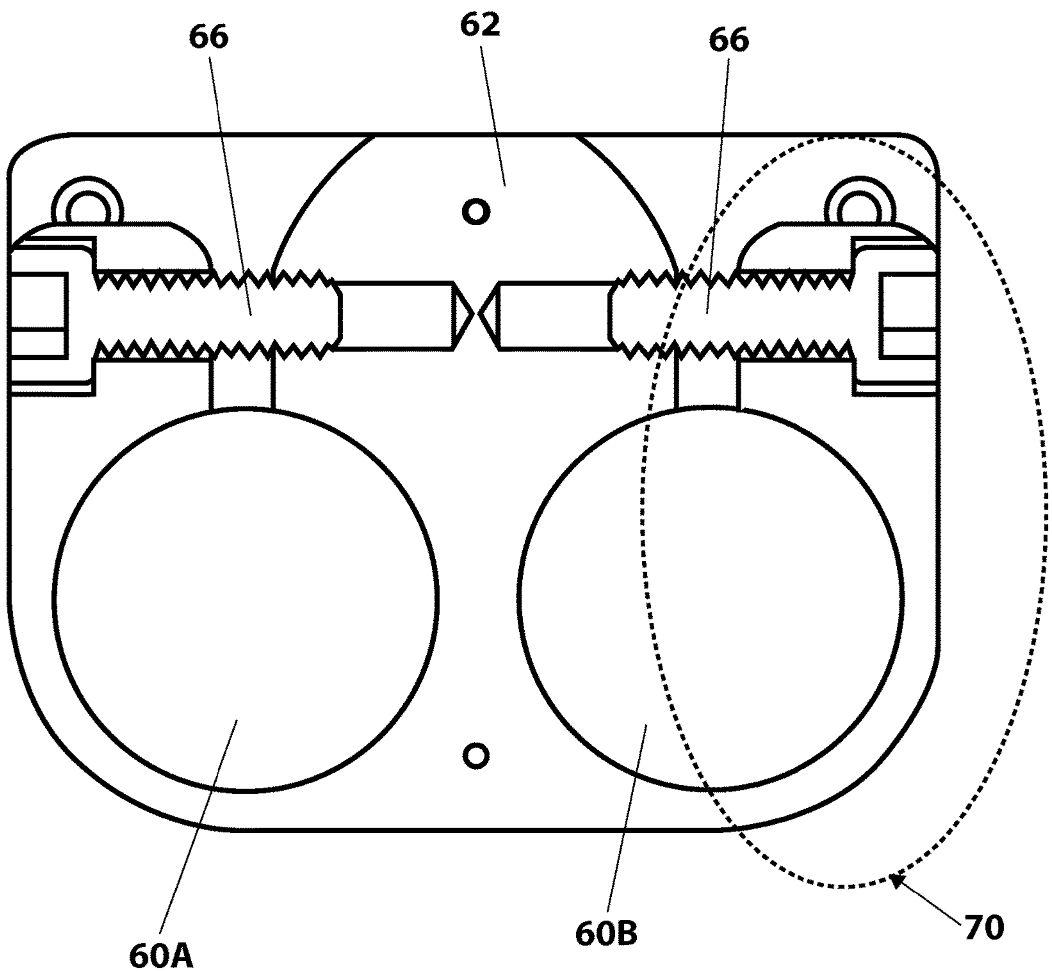

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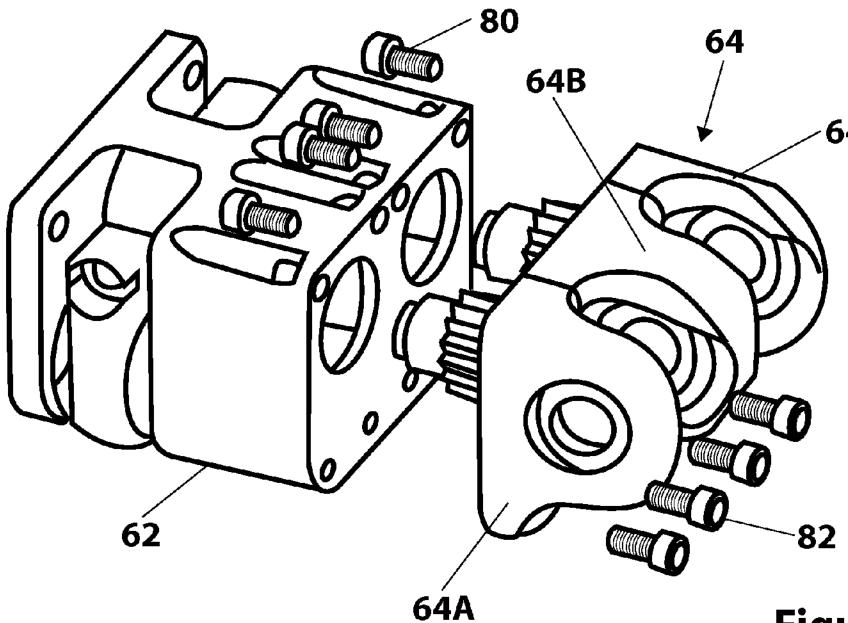

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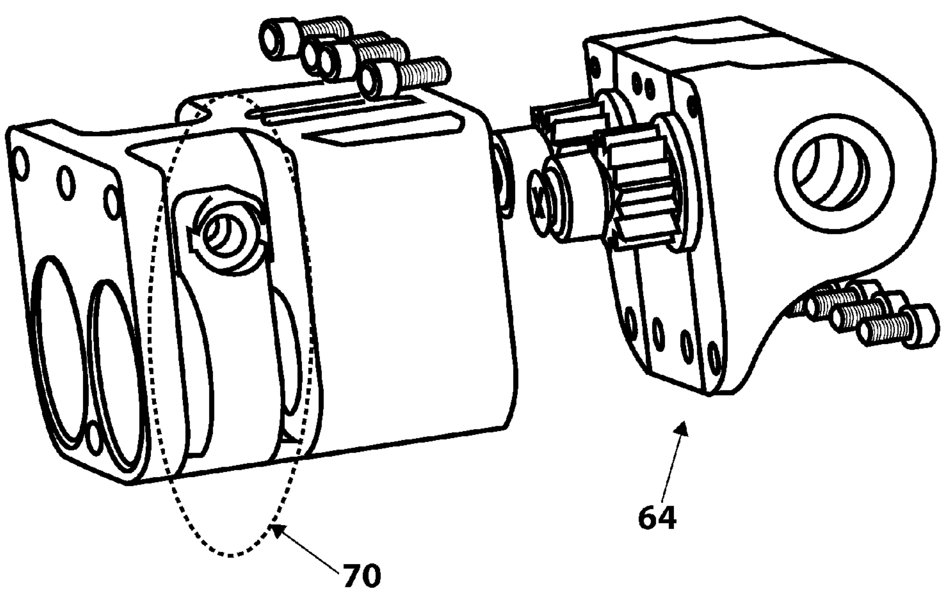

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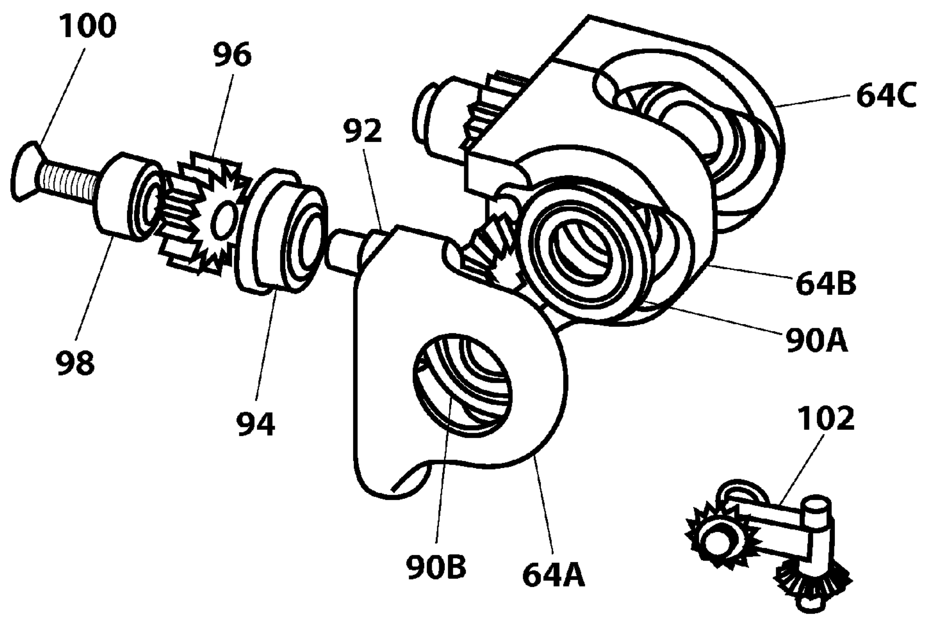

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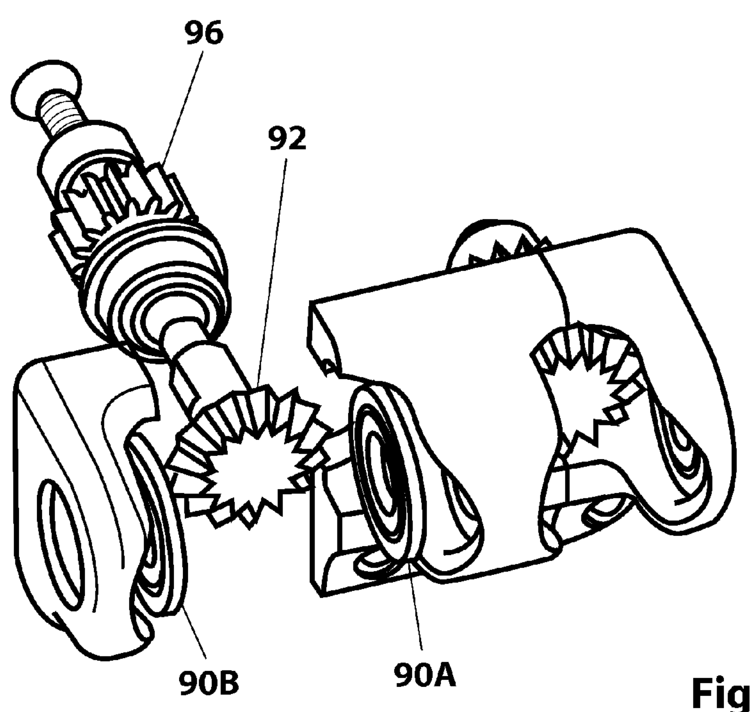

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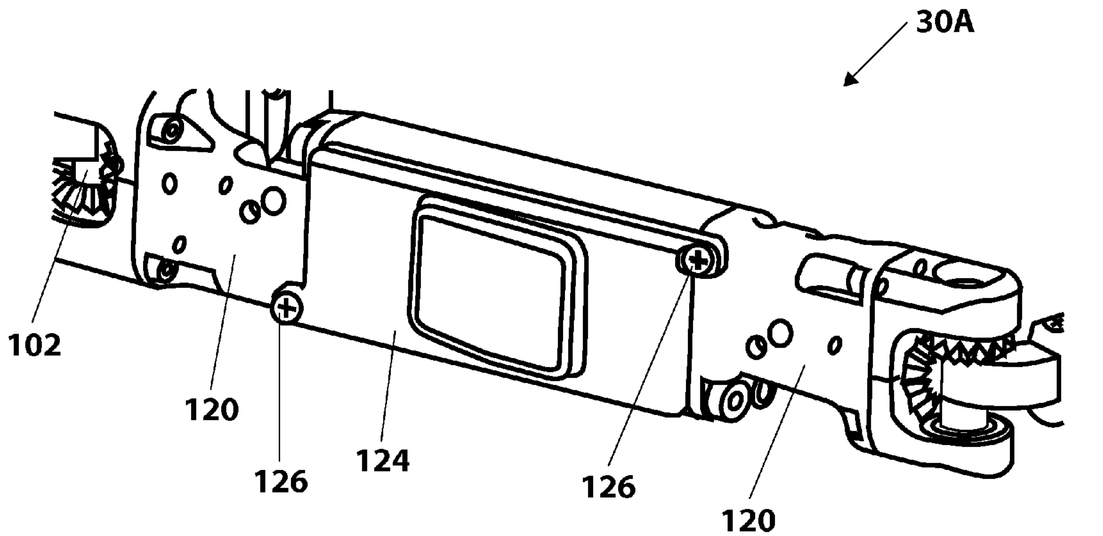

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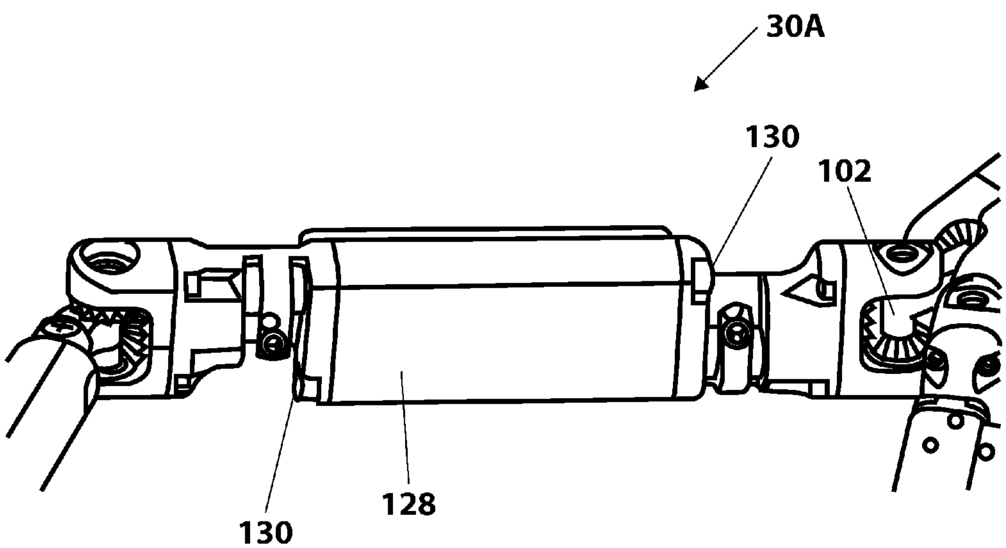

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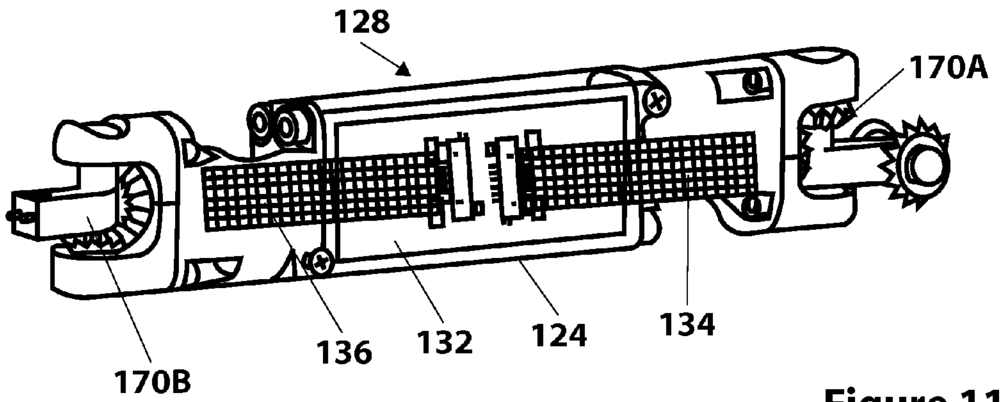

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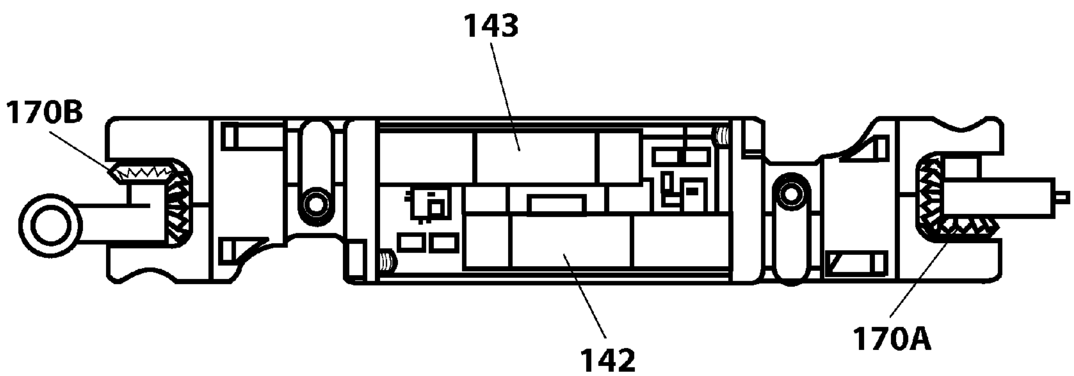

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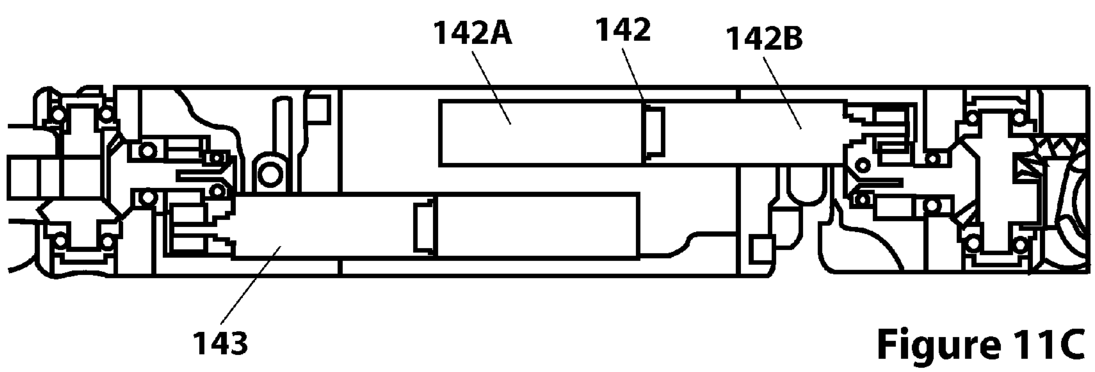

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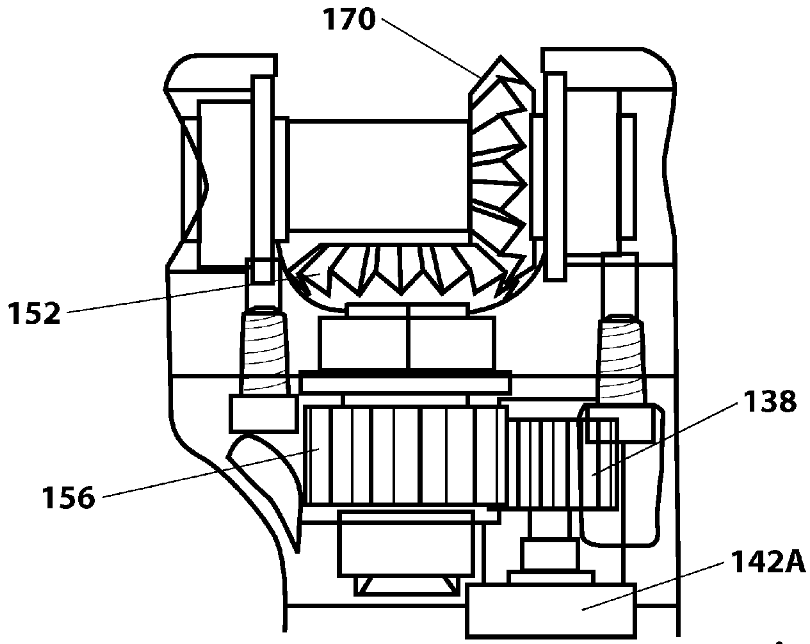

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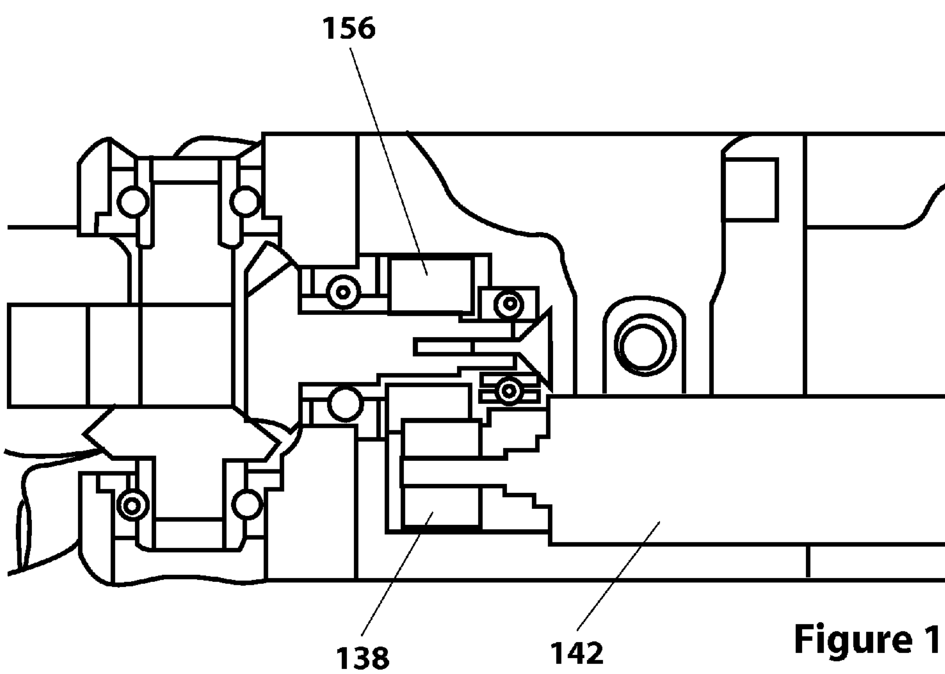

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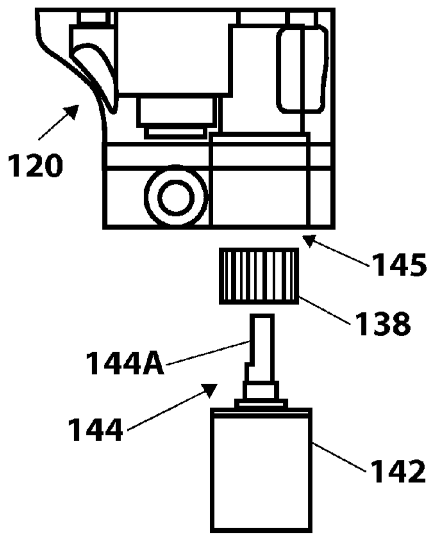

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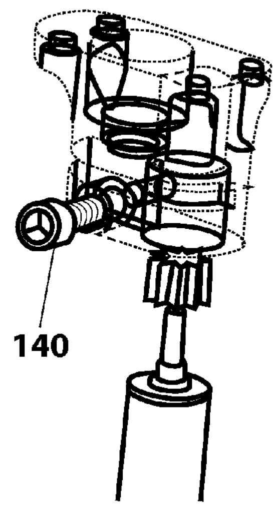

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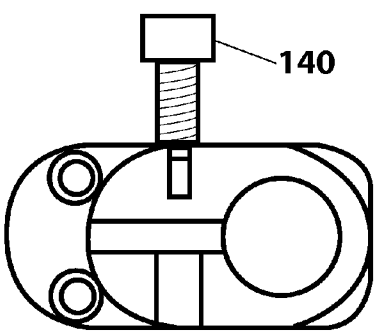

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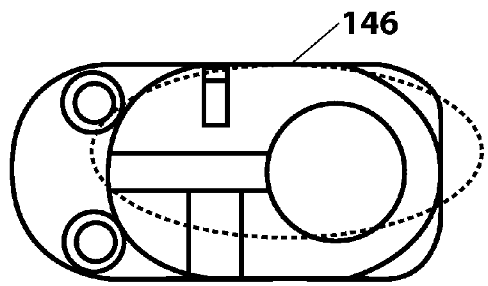

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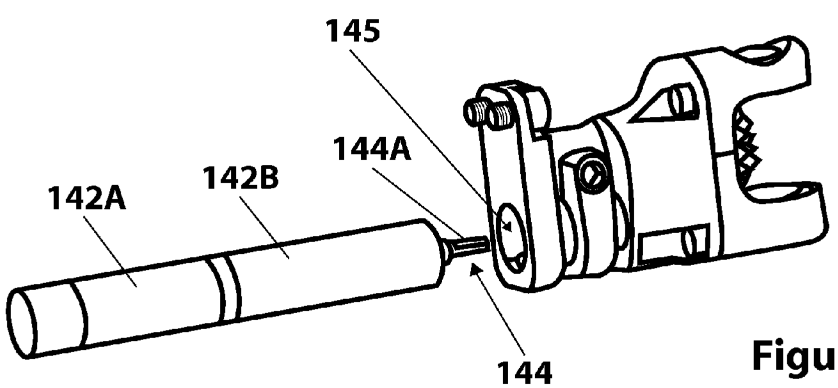

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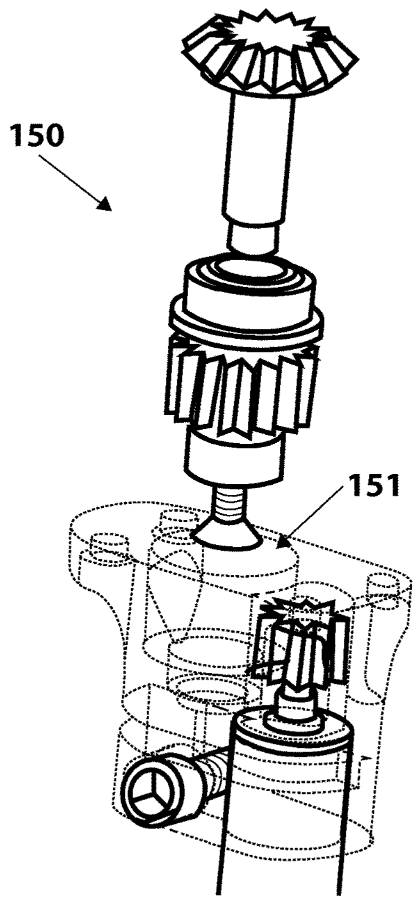

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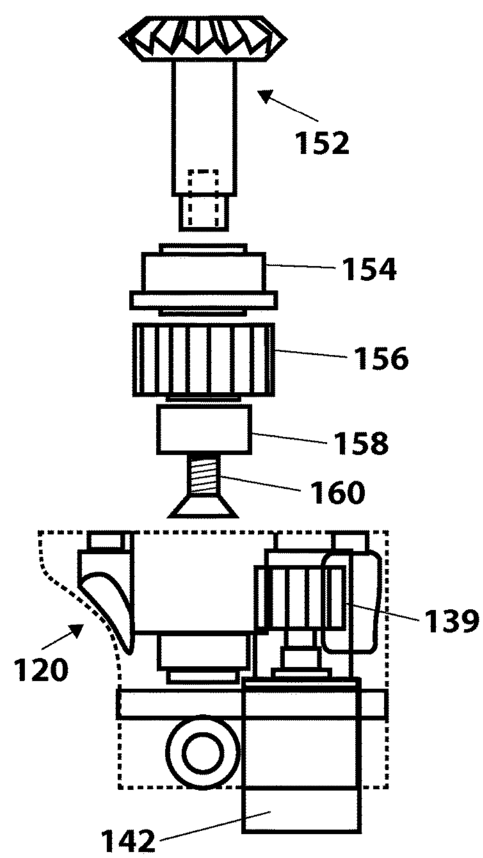

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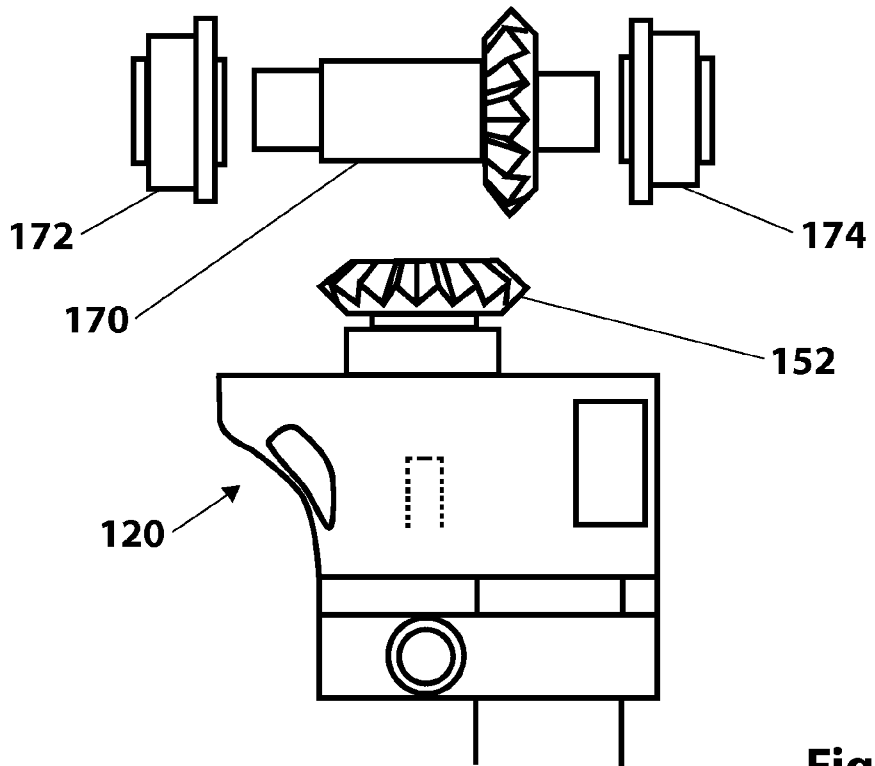

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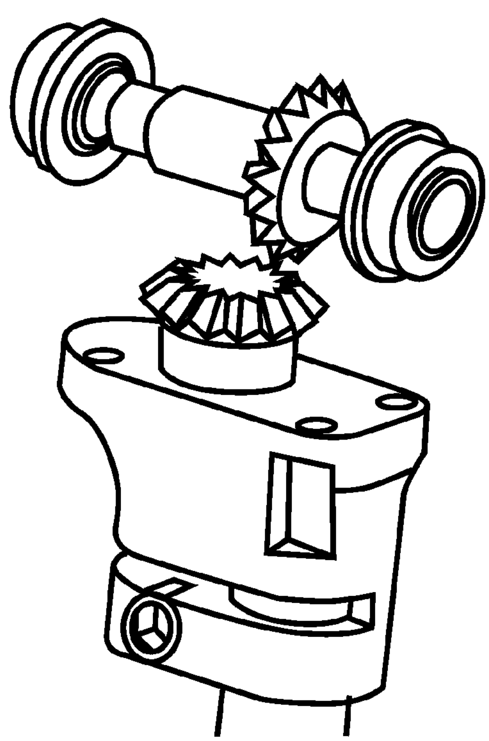

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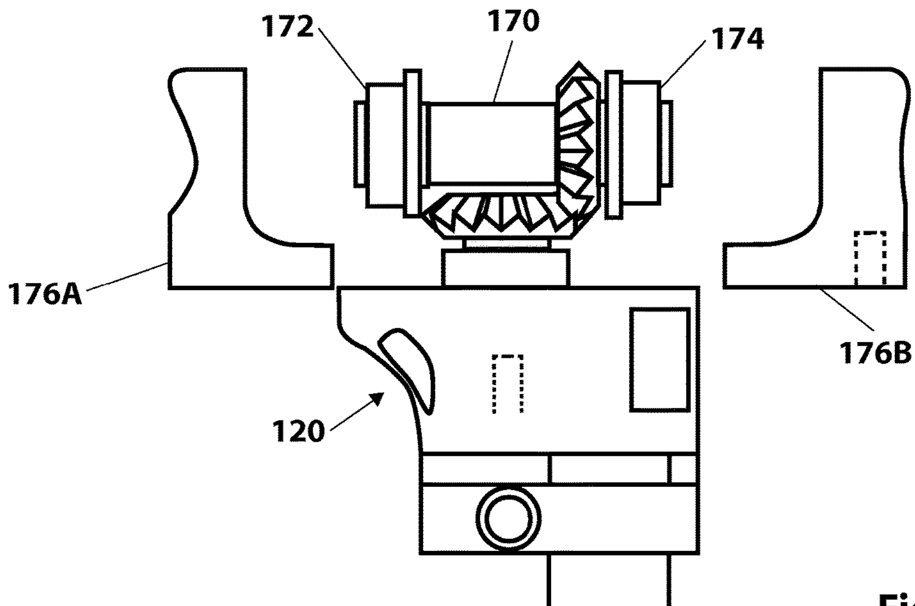

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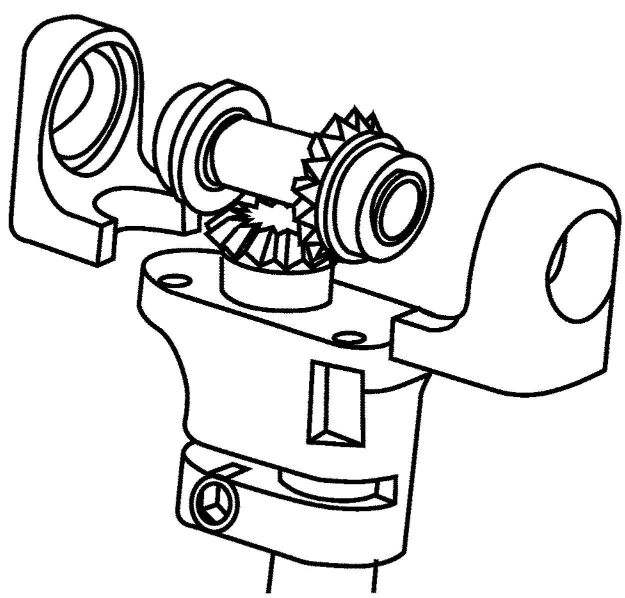

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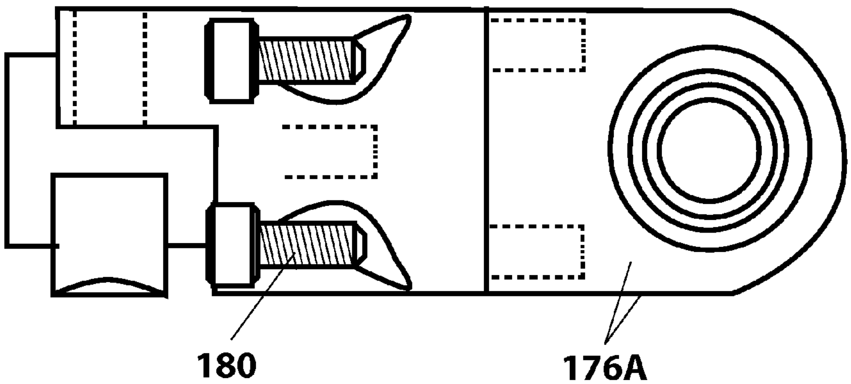

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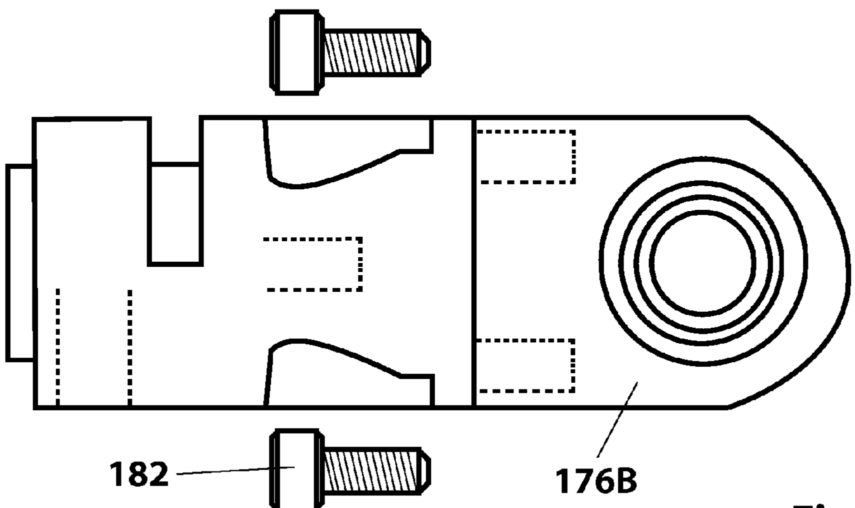

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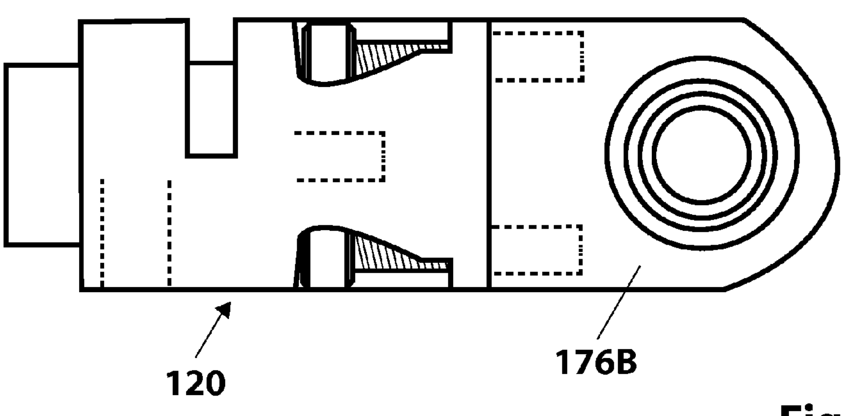

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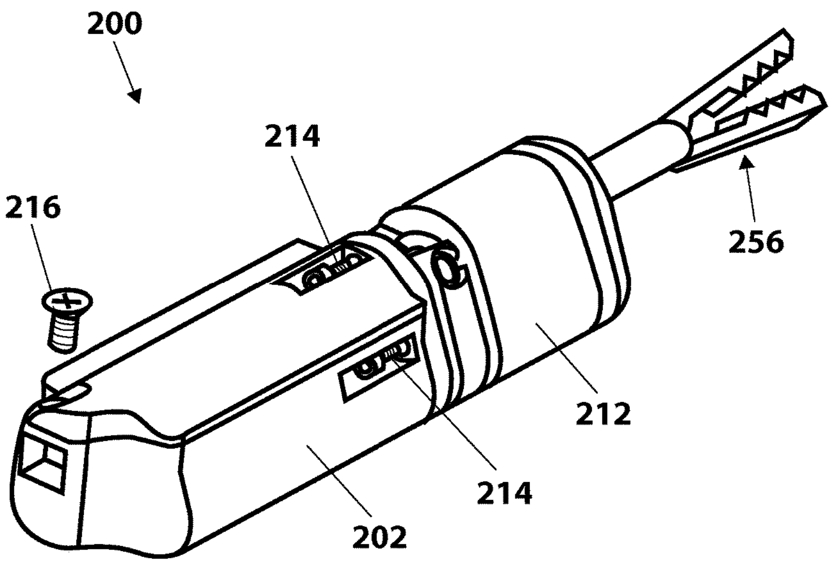

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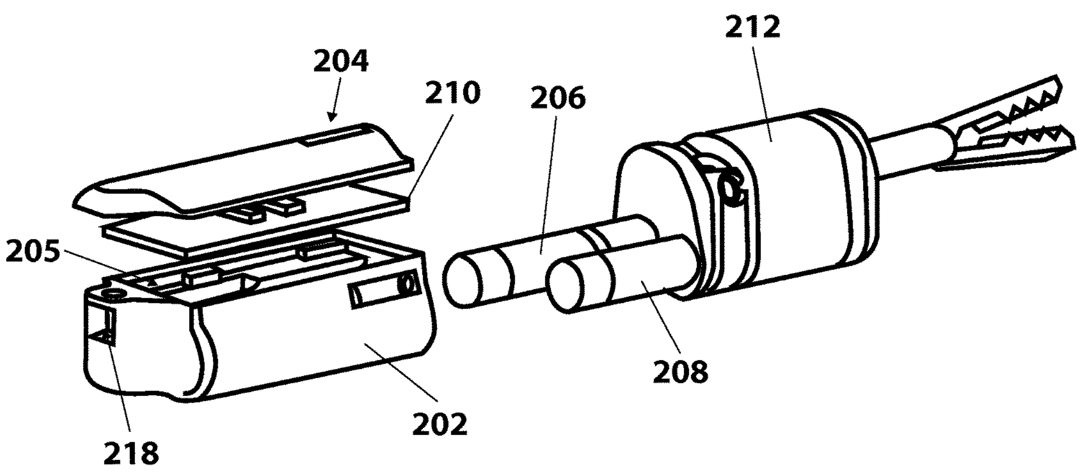

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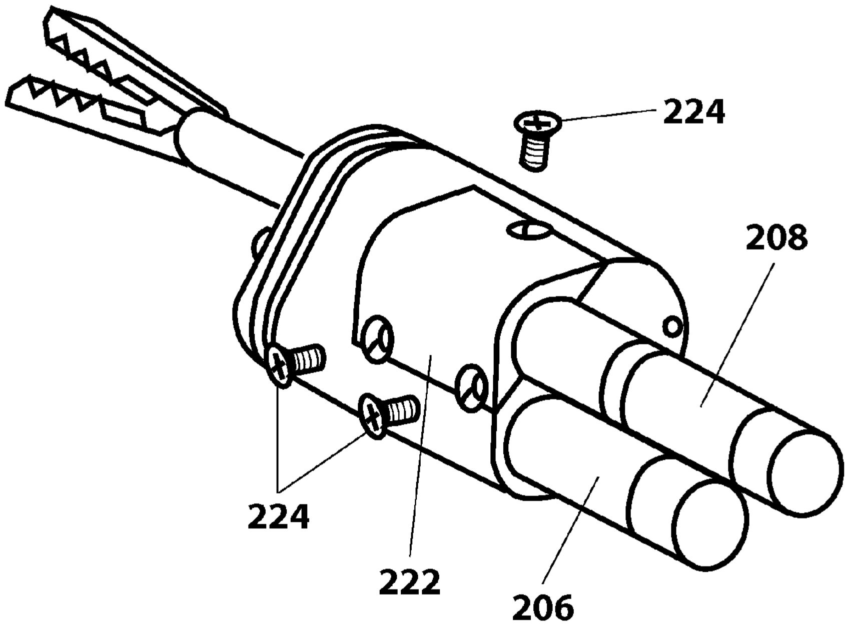

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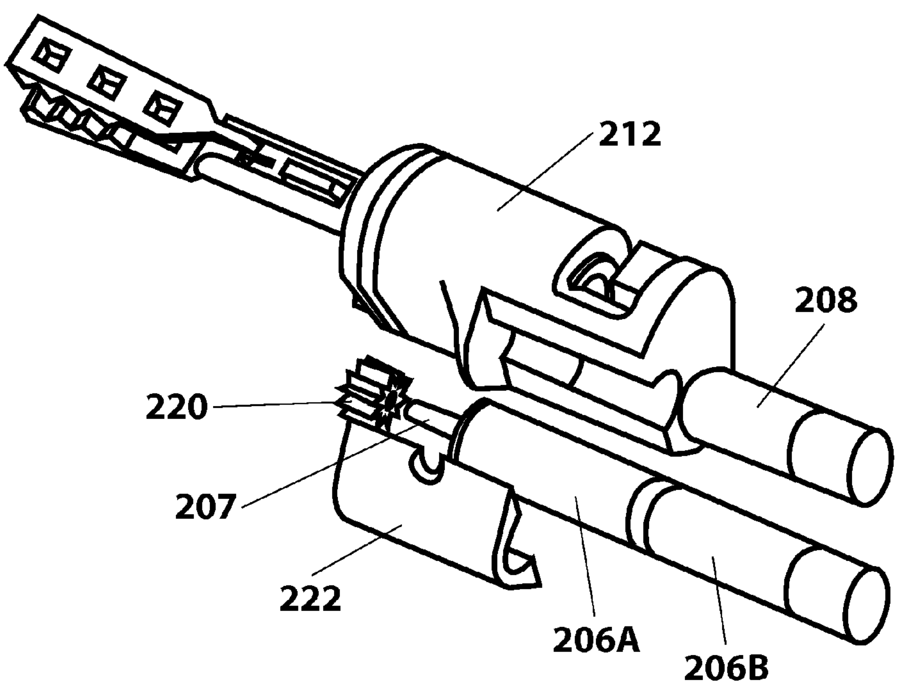

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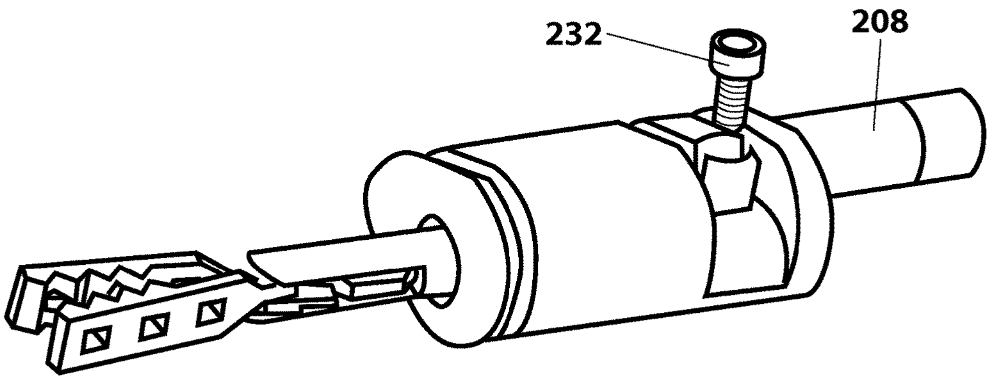

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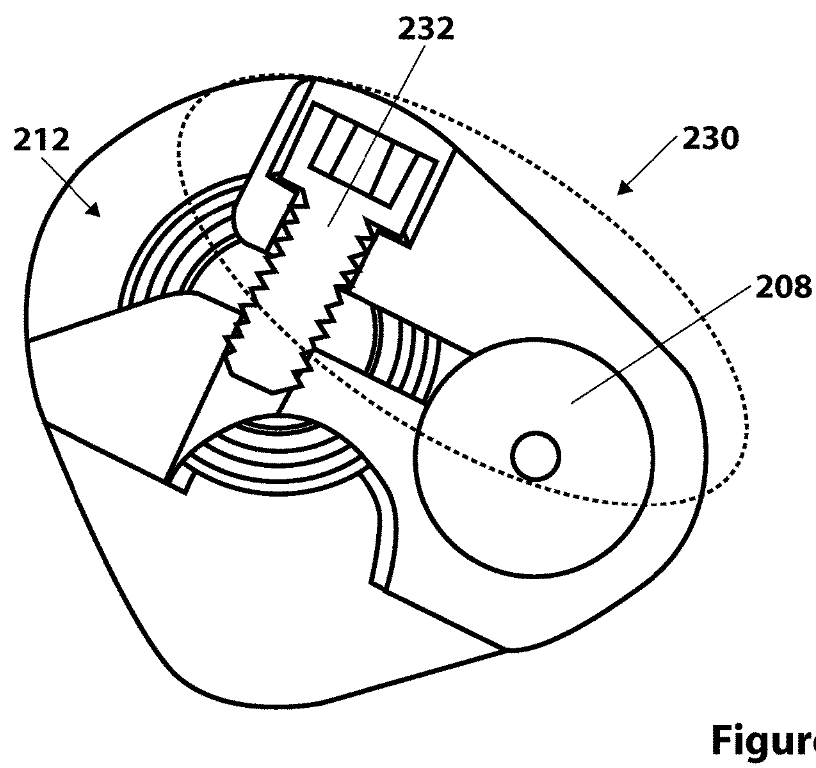

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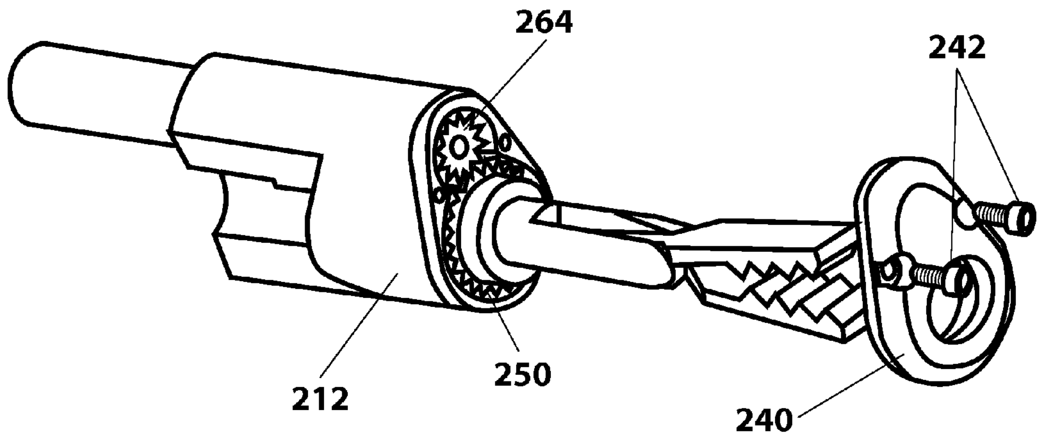

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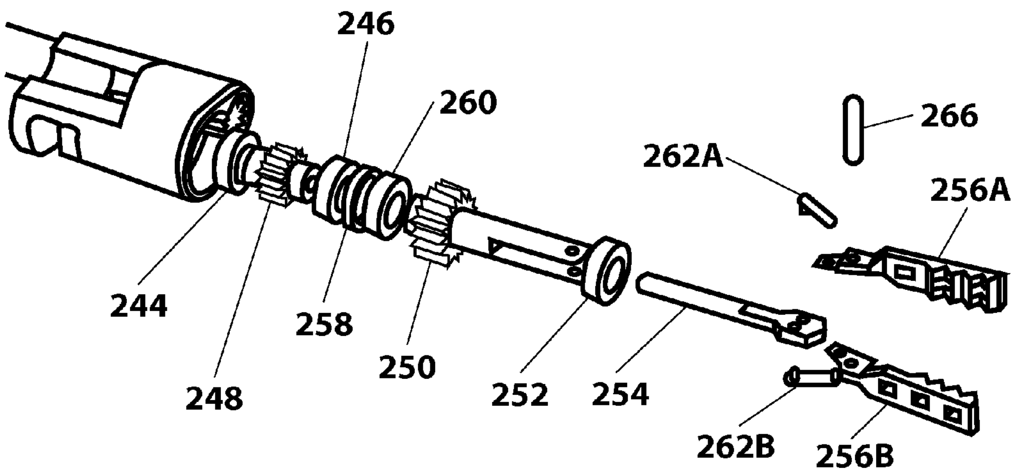

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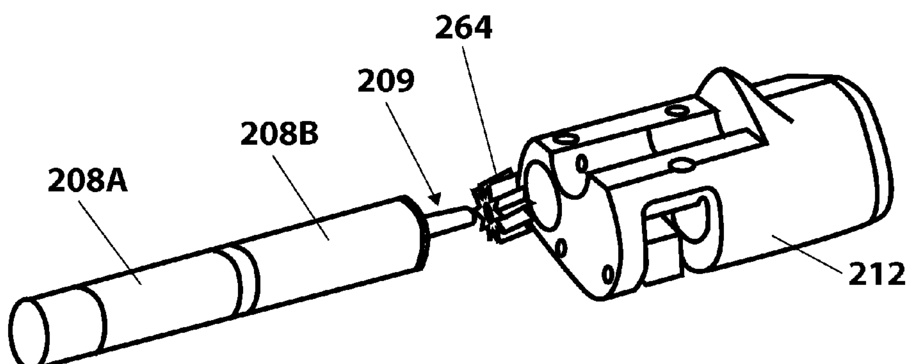

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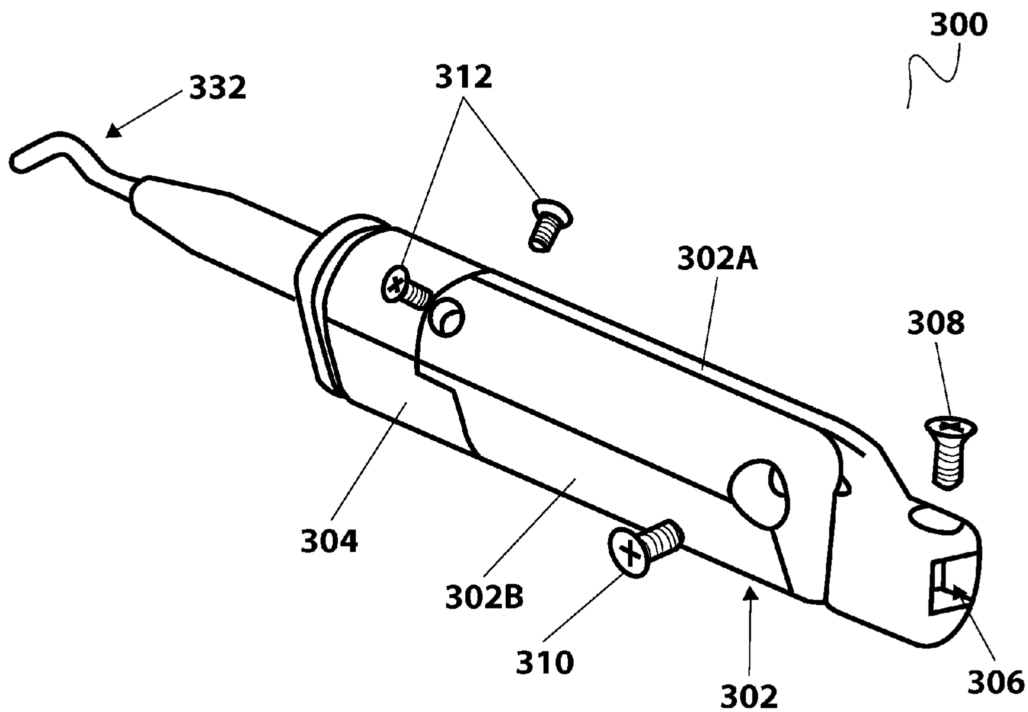

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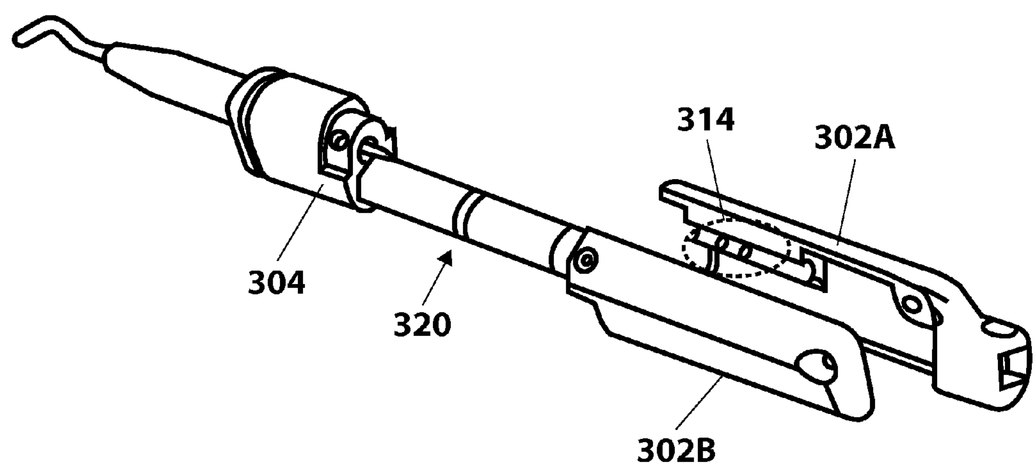

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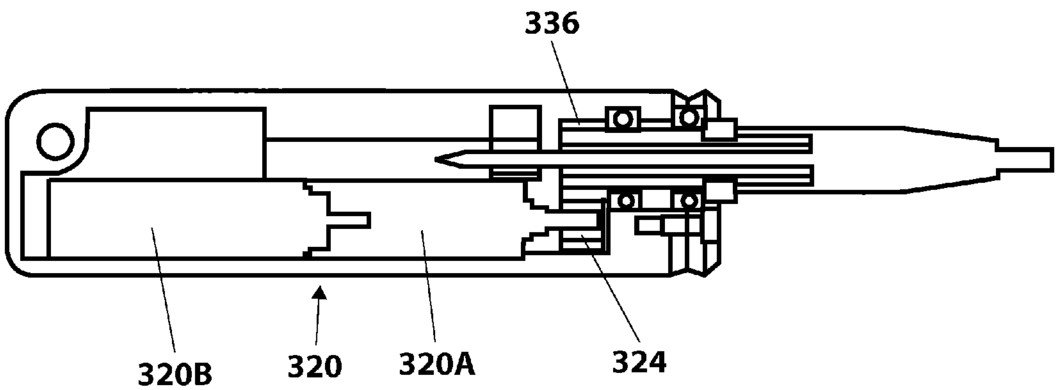

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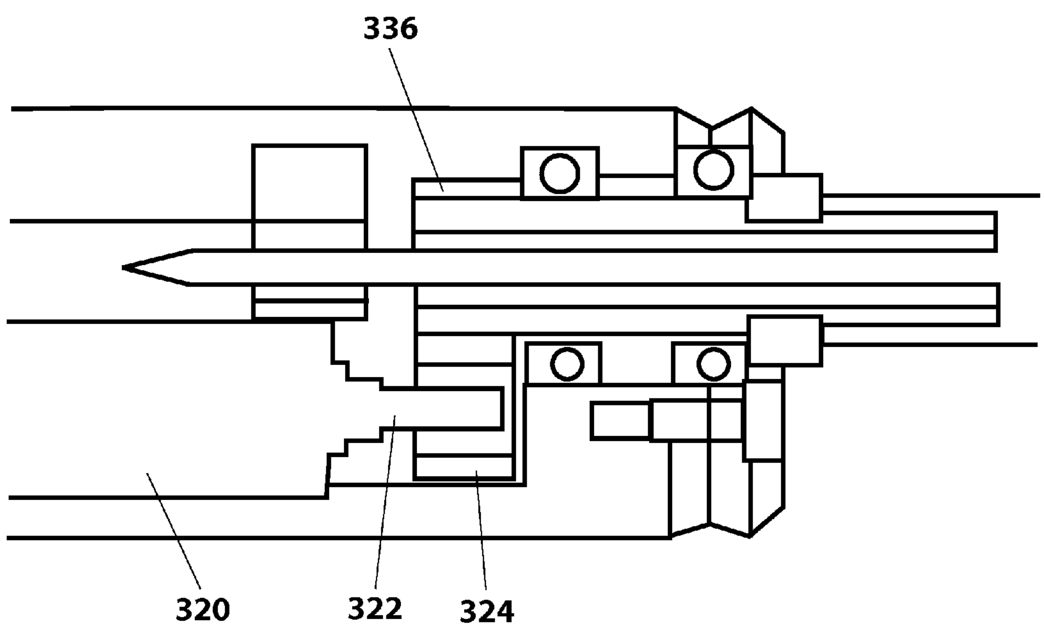

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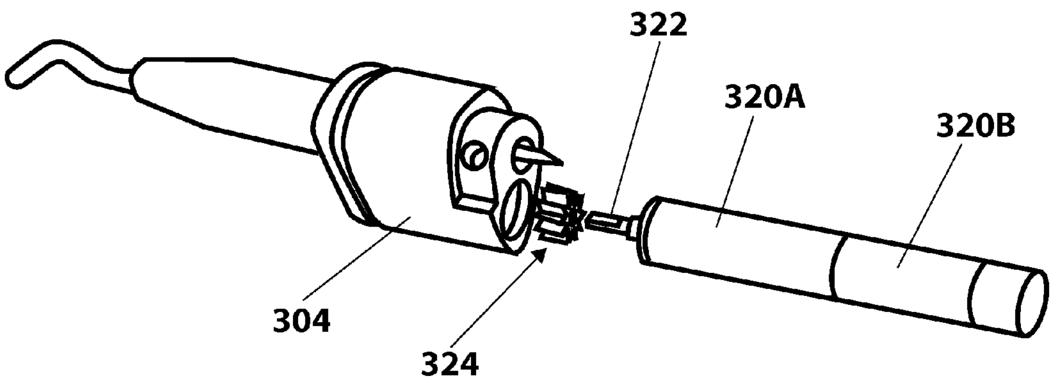

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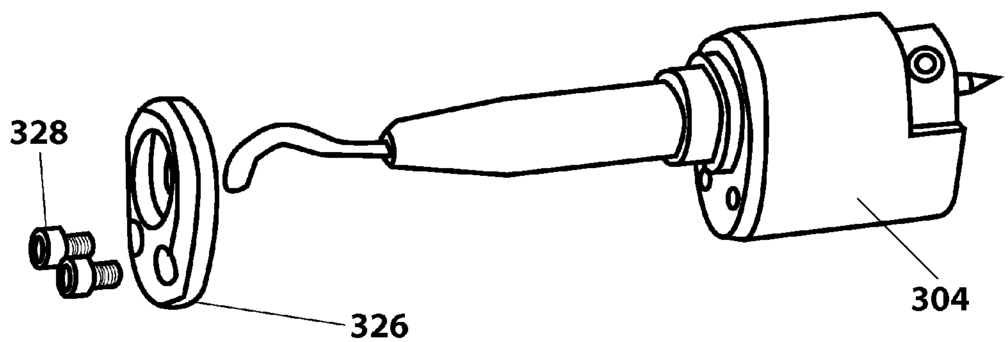

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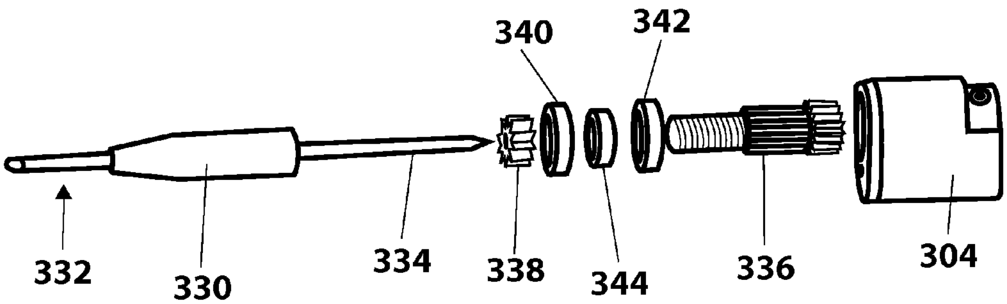

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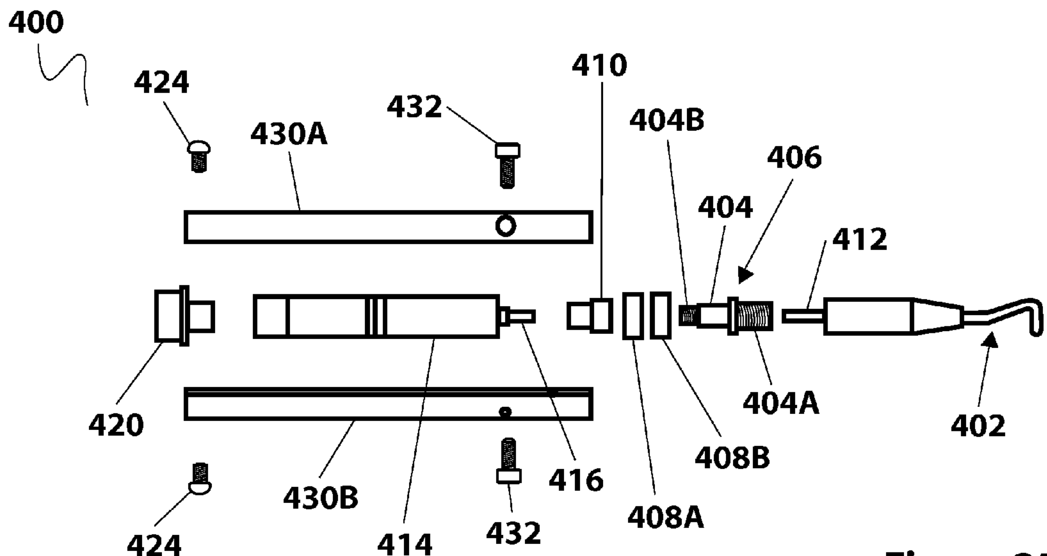

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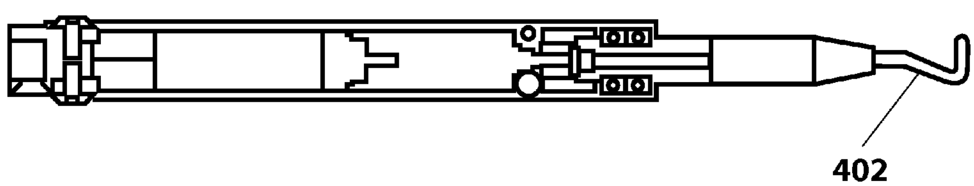

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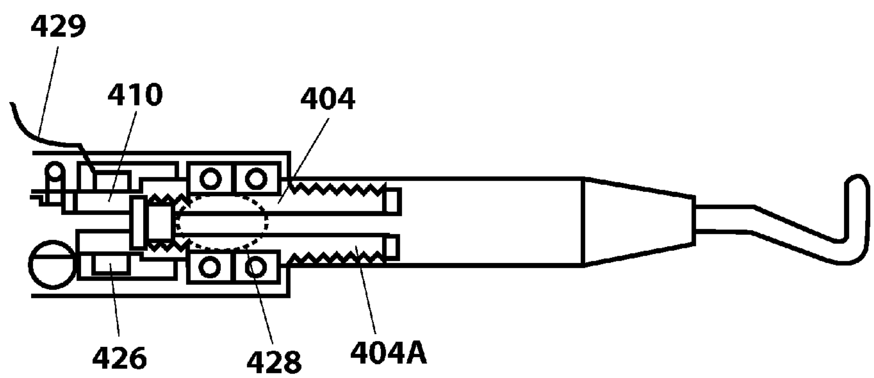

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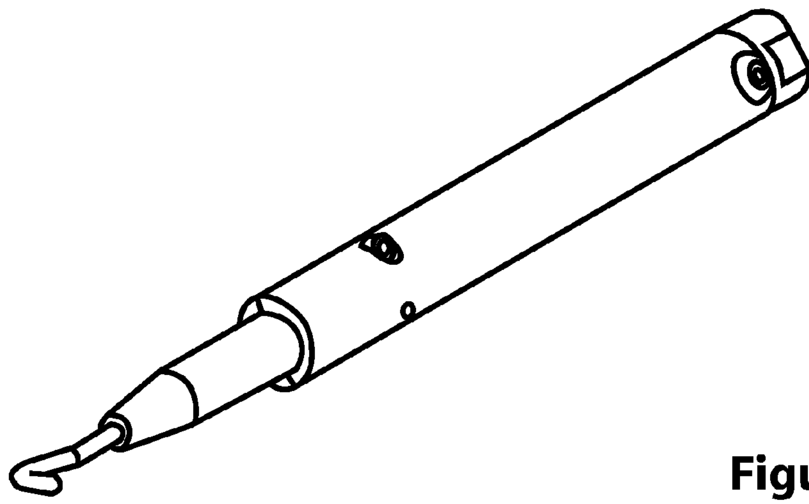

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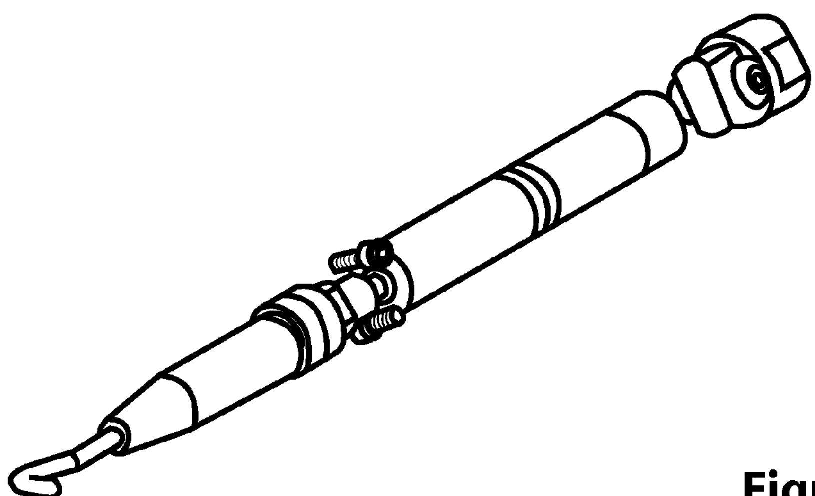

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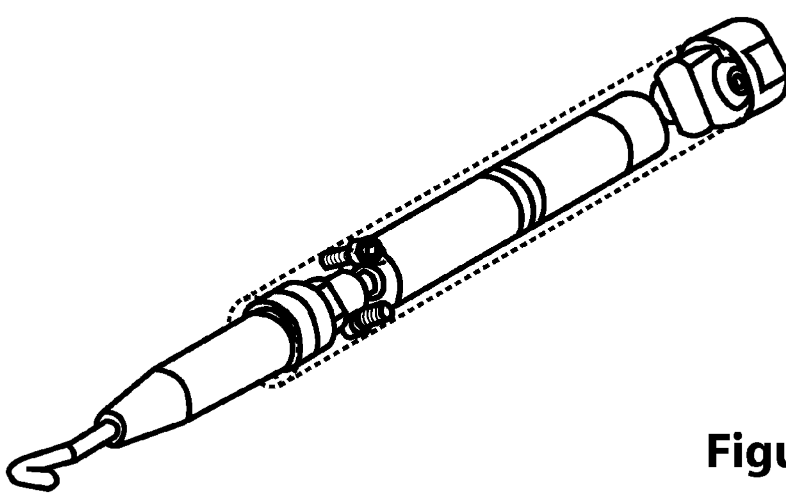


Figure 27C

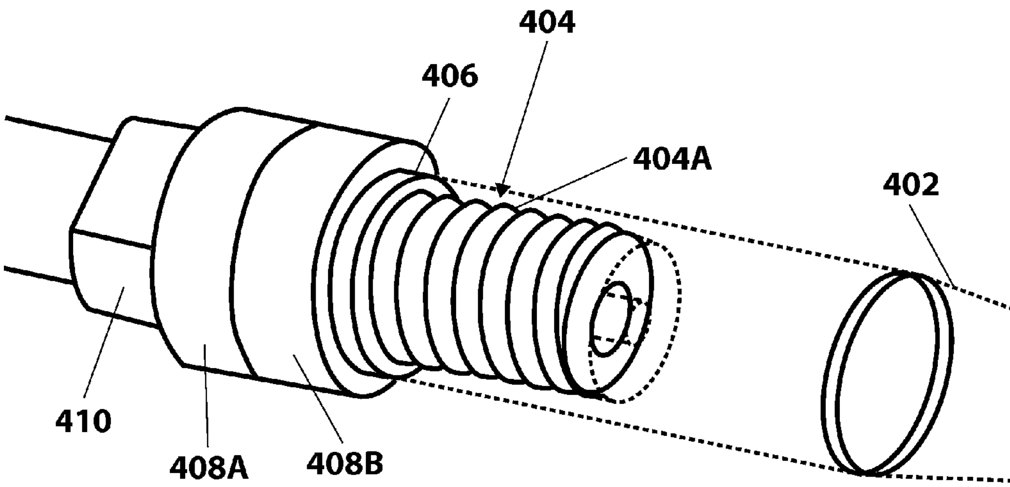


Figure 28A

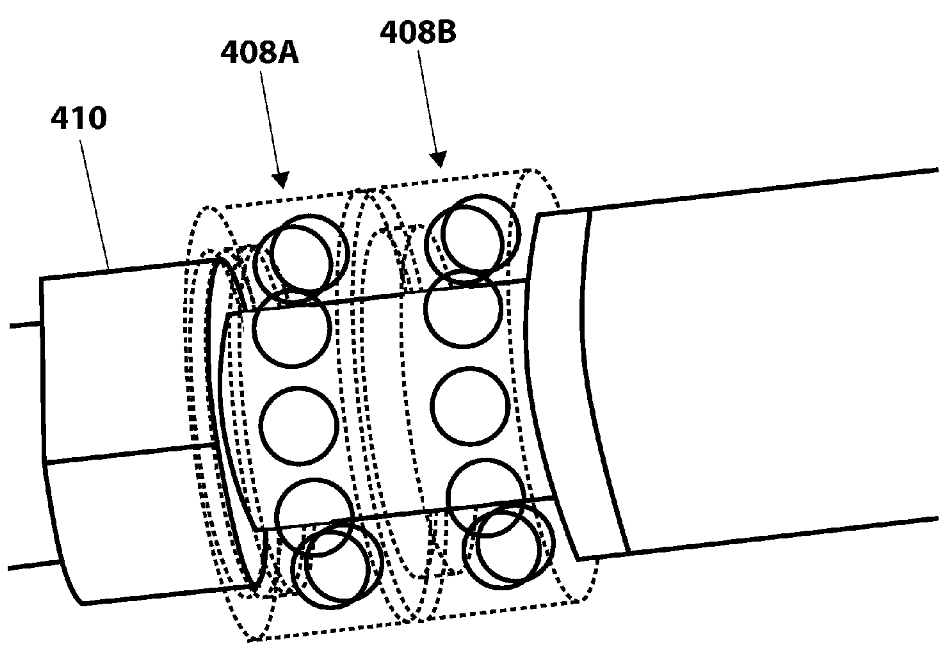


Figure 28B

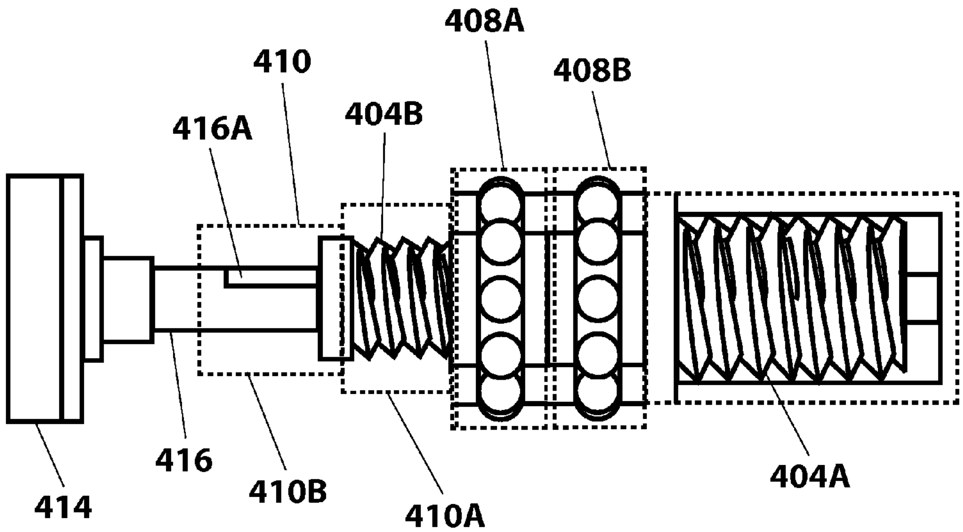


Figure 28C

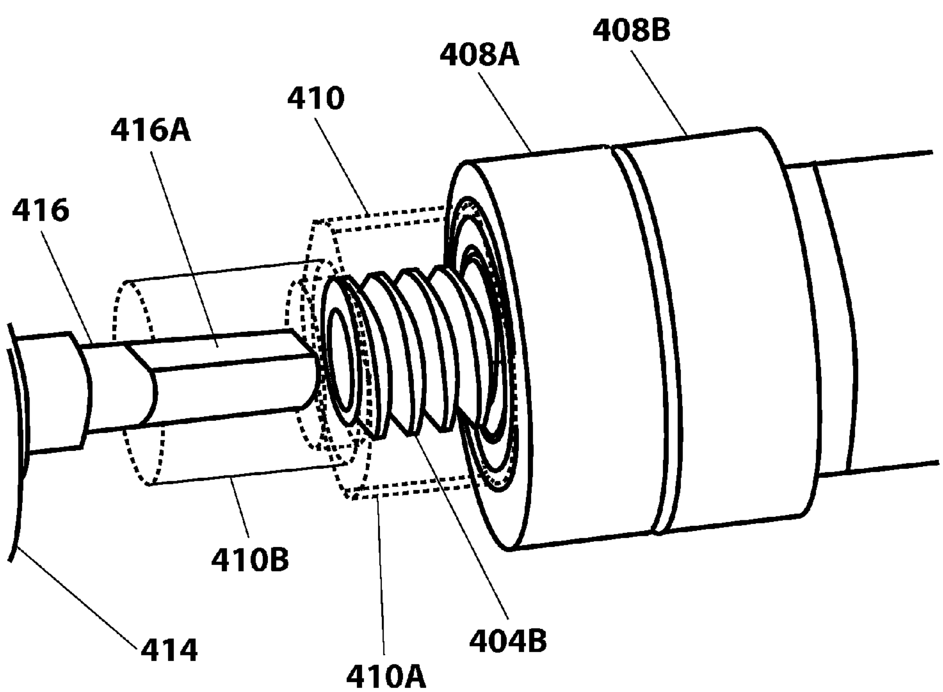


Figure 28D

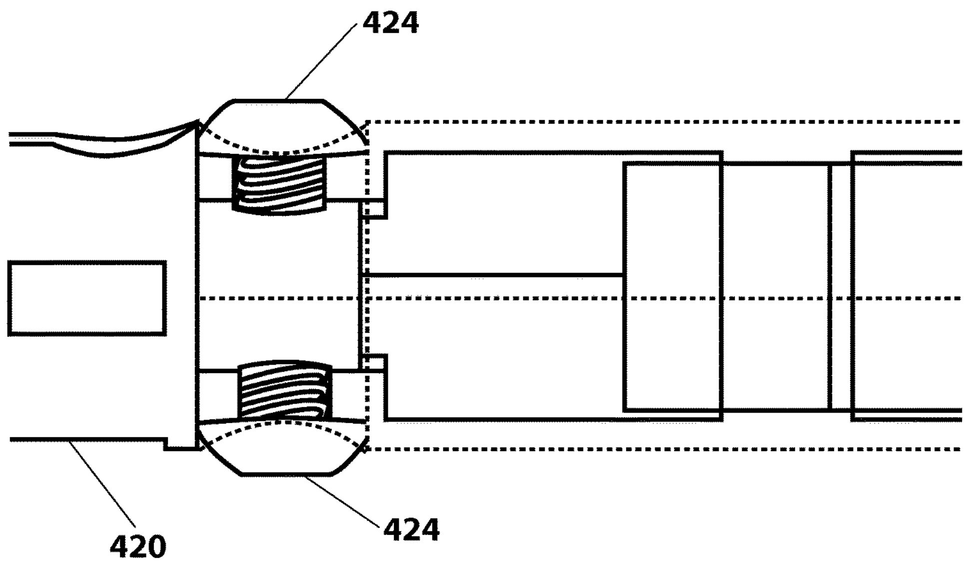


Figure 29A

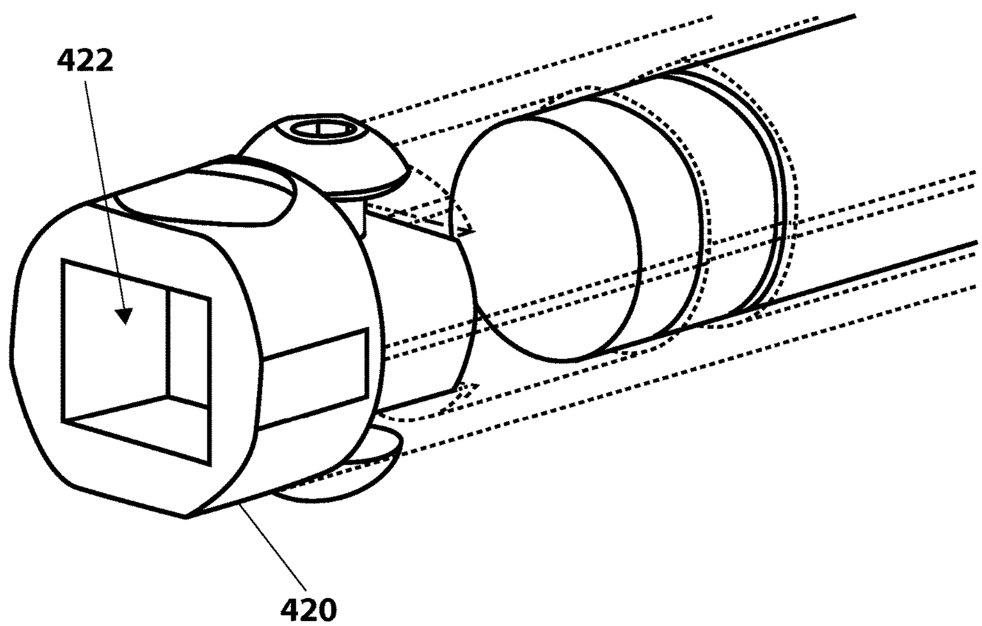


Figure 29B

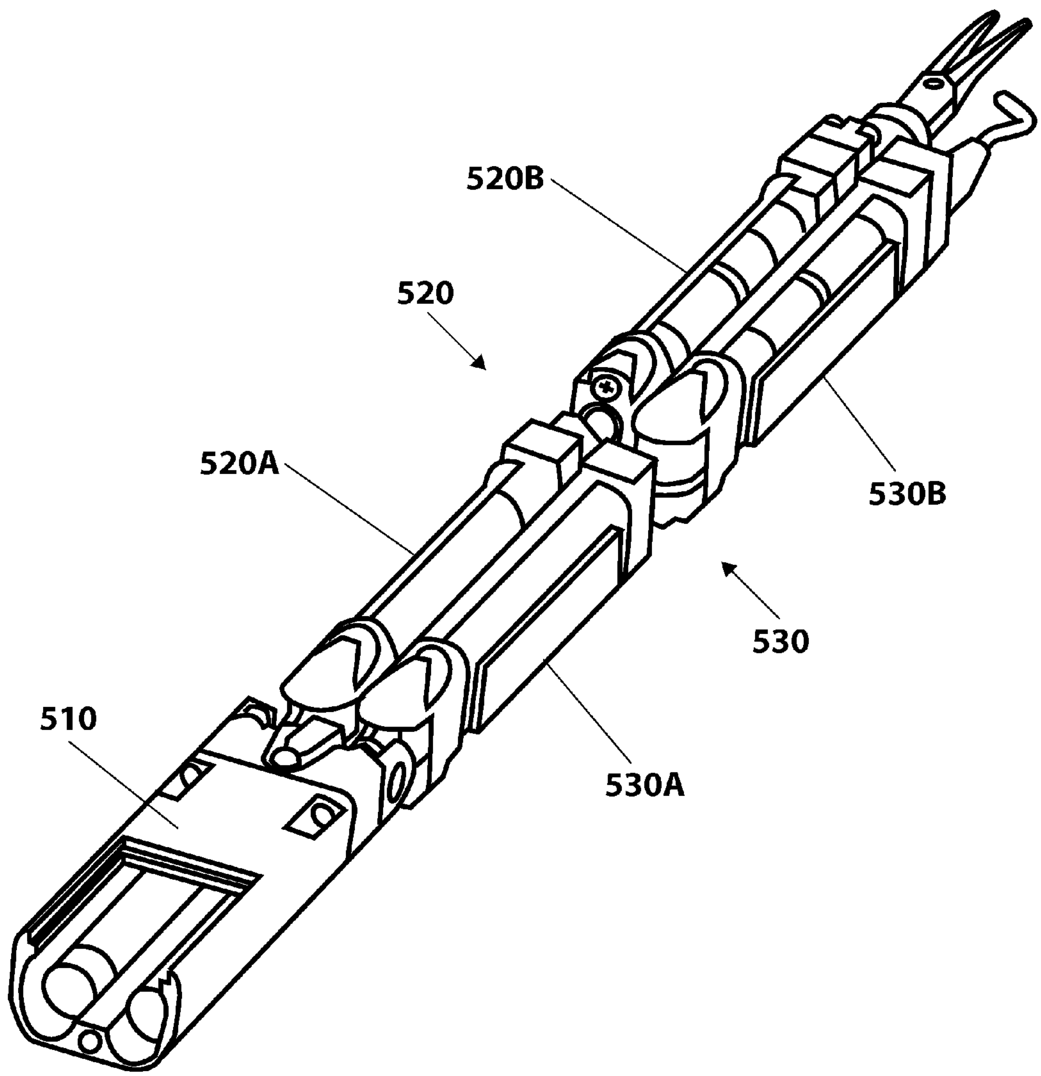


Figure 30

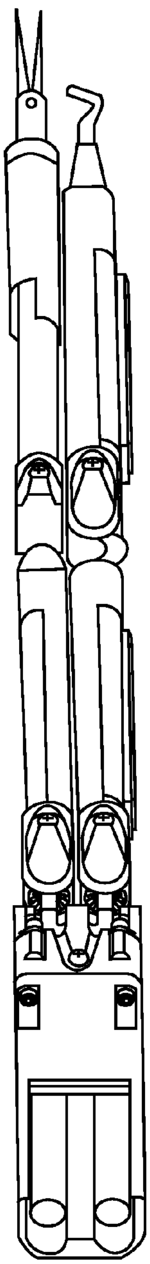


Figure 31A

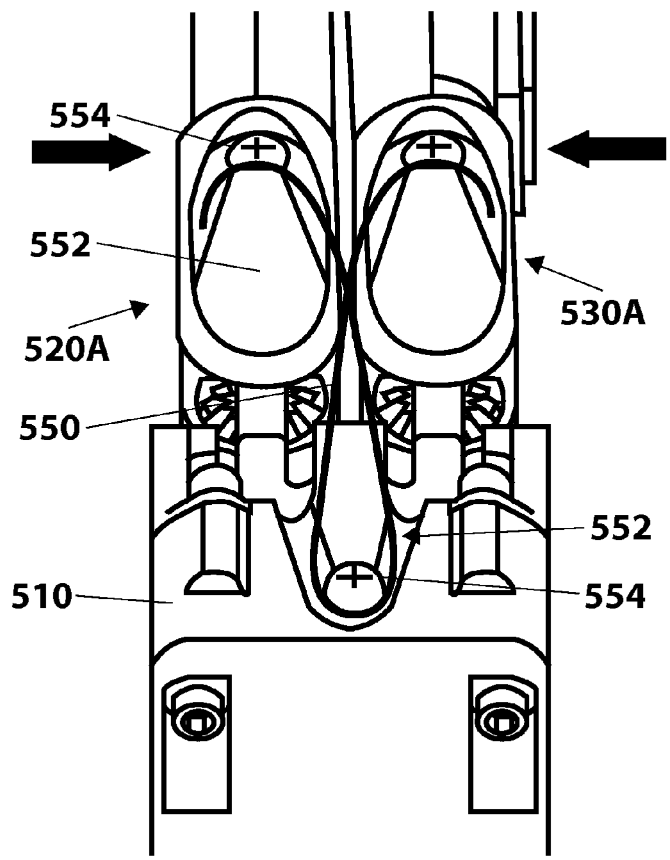


Figure 31B

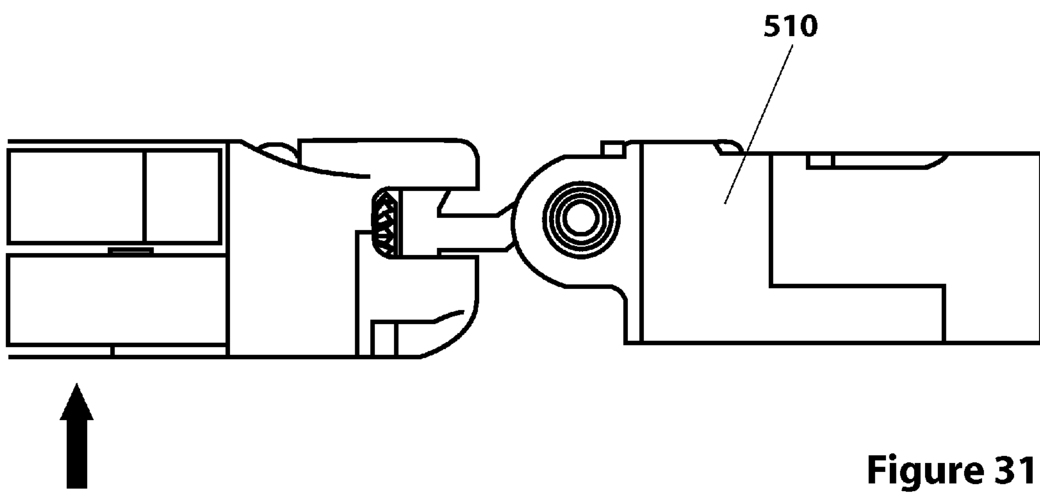


Figure 31C

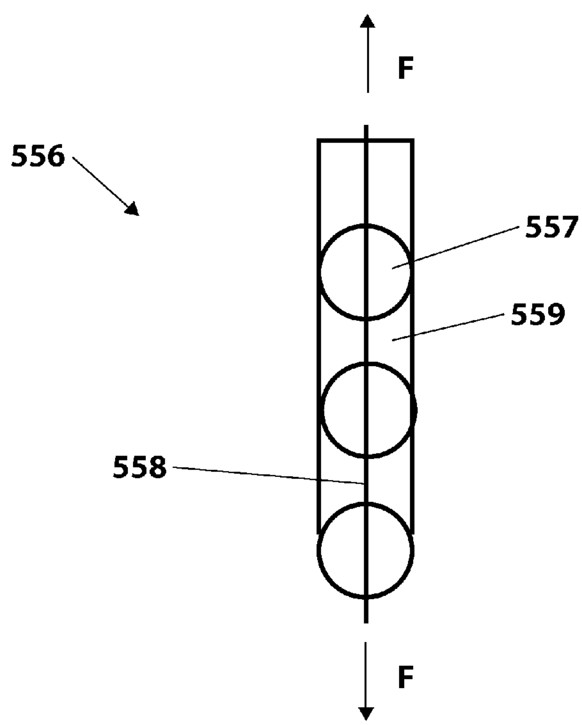


Figure 31D

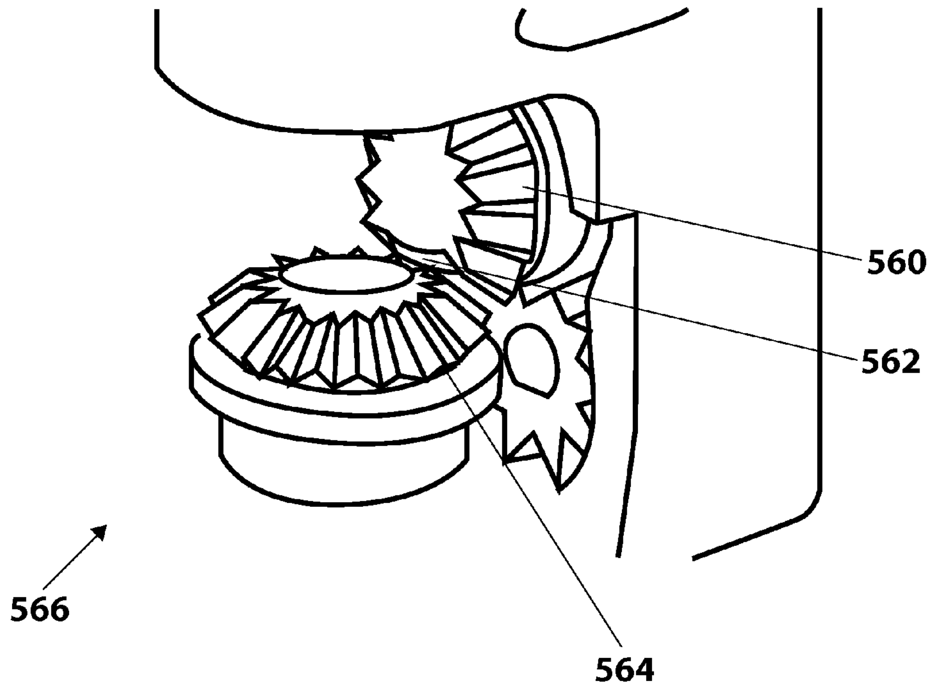


Figure 32A

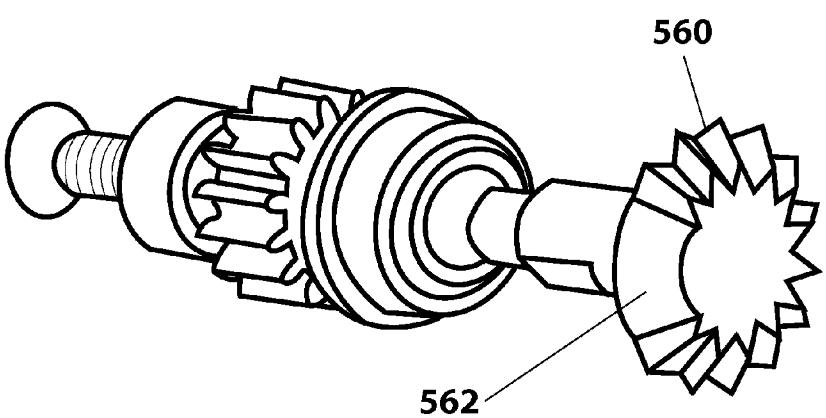


Figure 32B

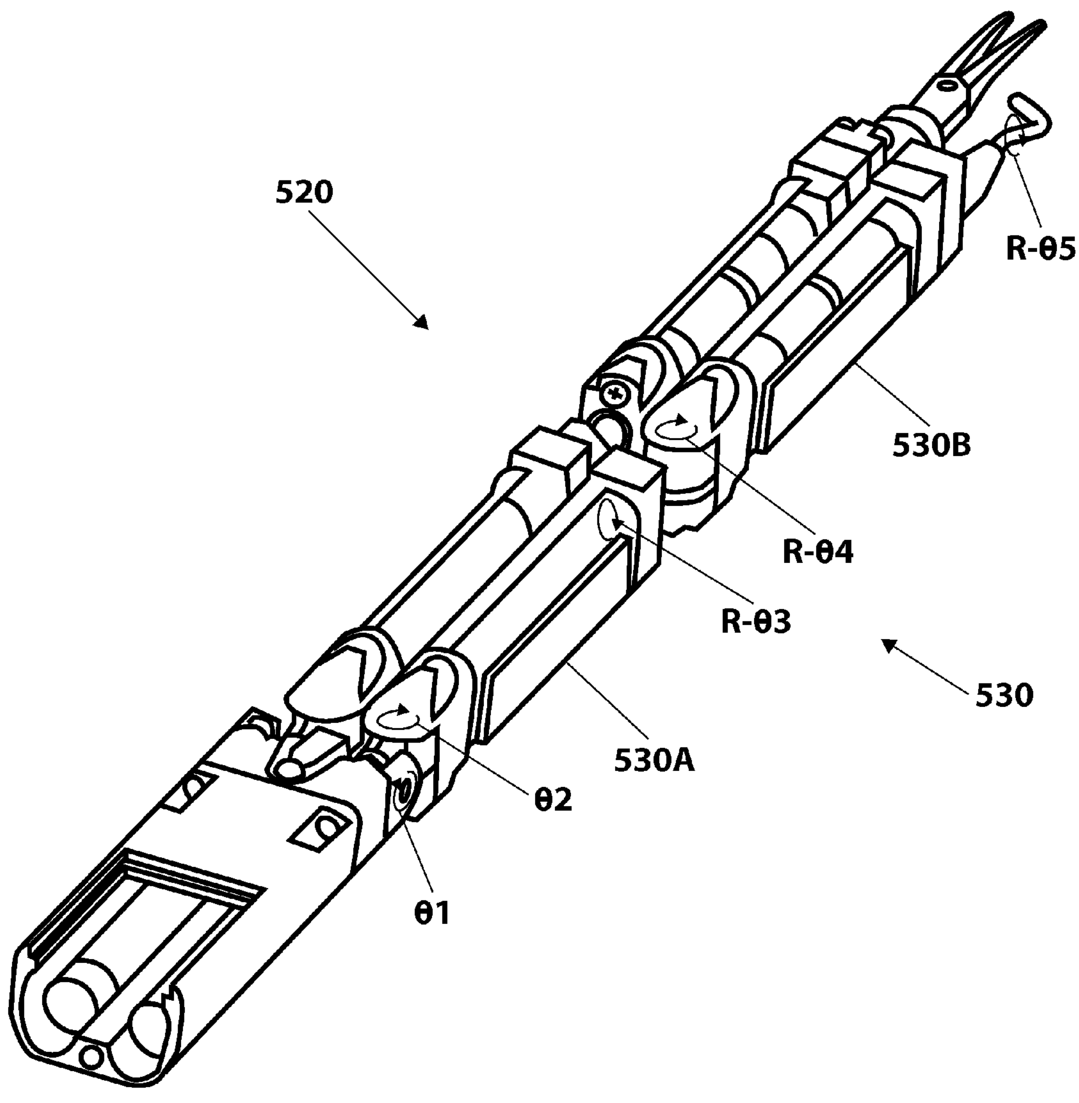


Figure 33

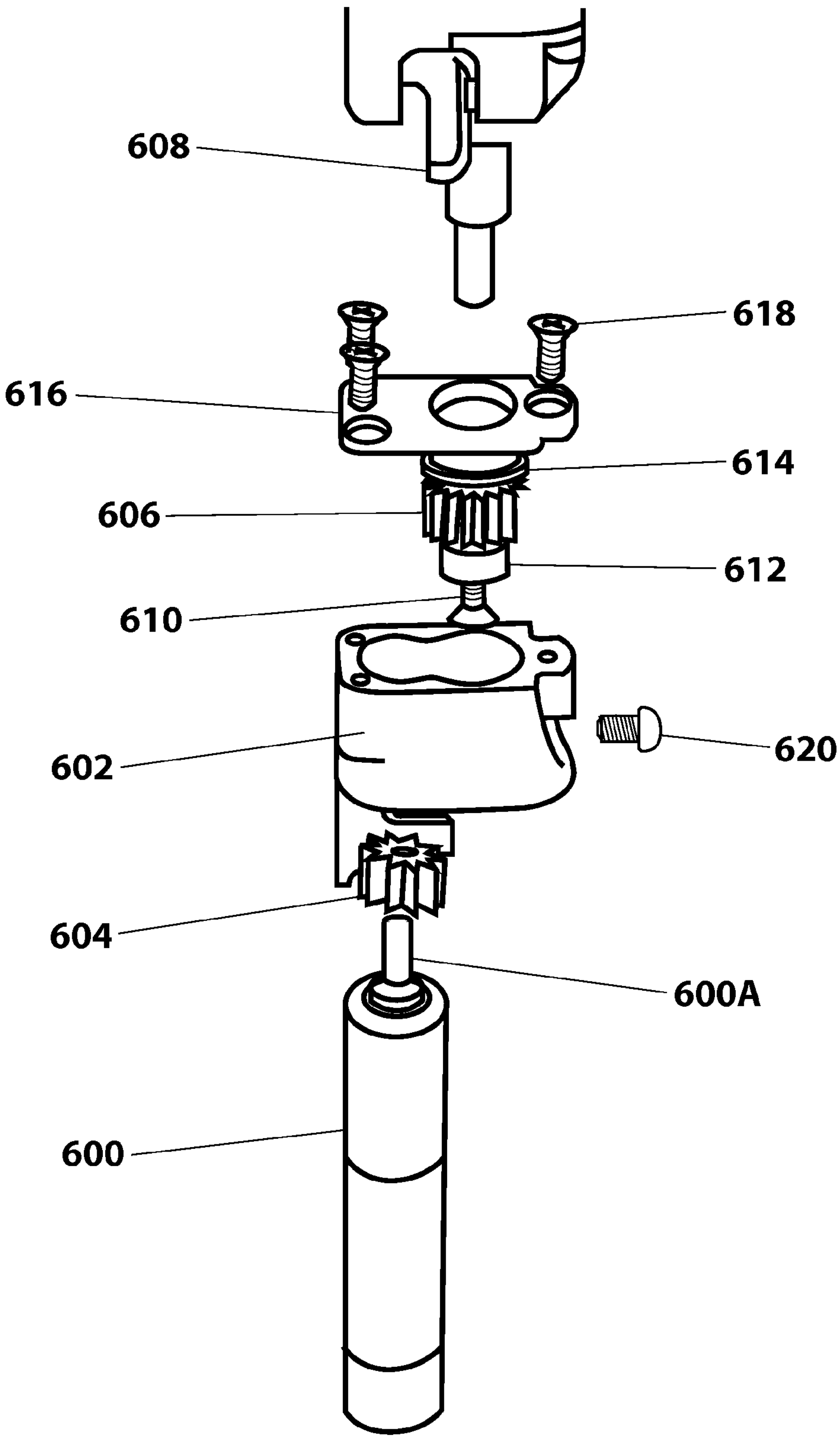


Figure 34

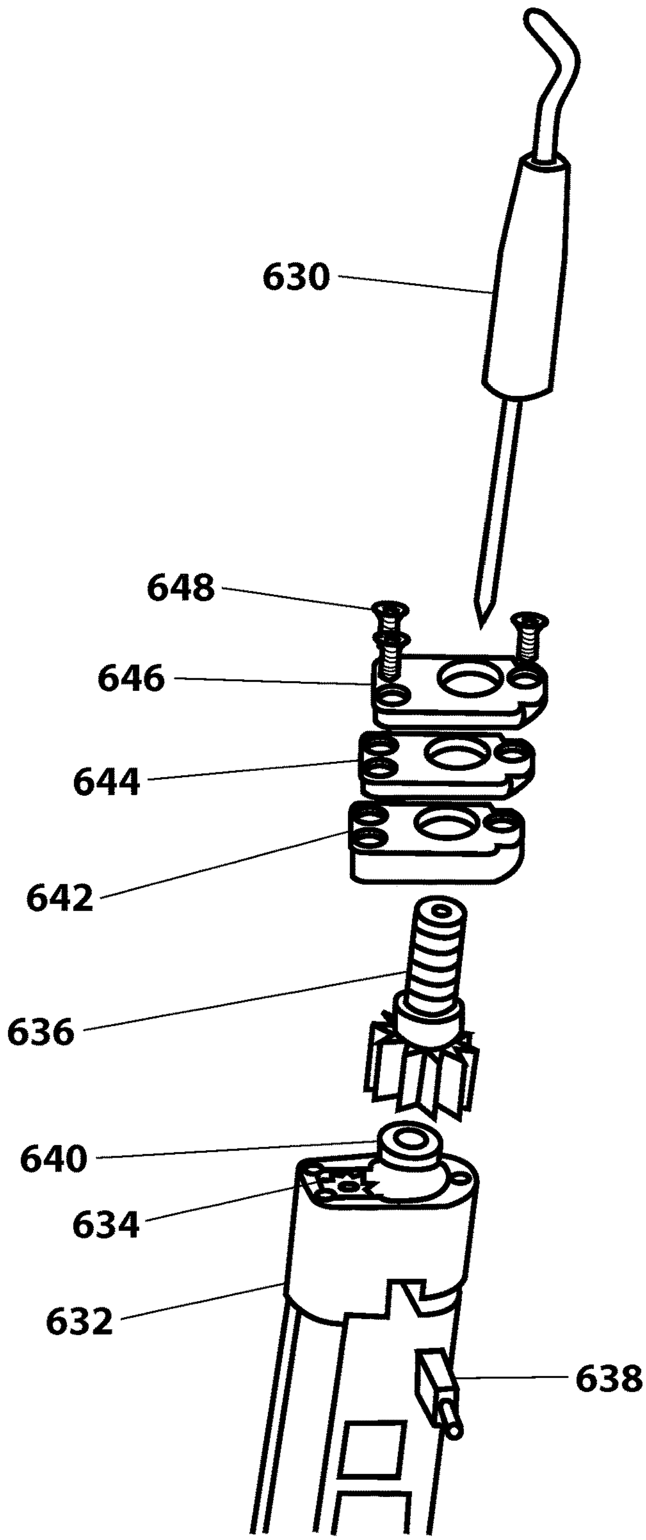
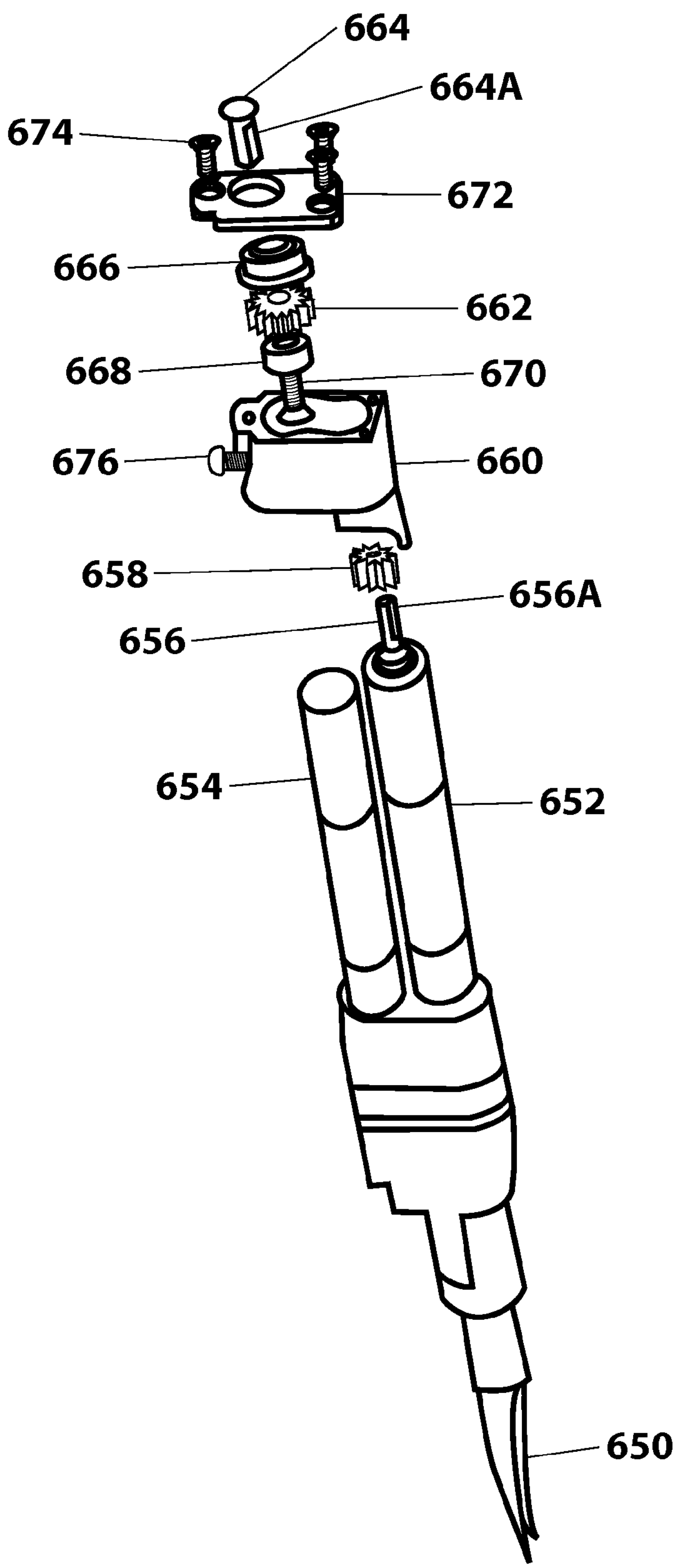


Figure 35


664
664A
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672
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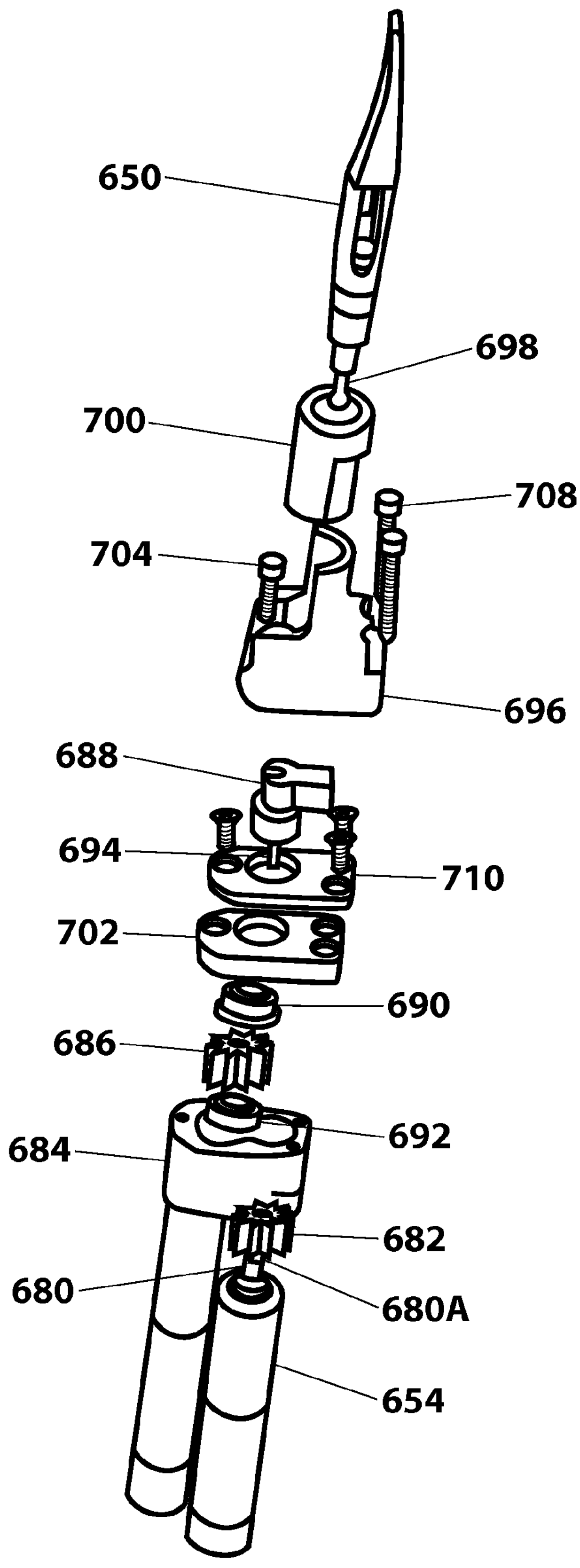
662
668
670
676
660
658
656A
656
654
652
650

Figure 36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702
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682
680
680A
654

Figure 37

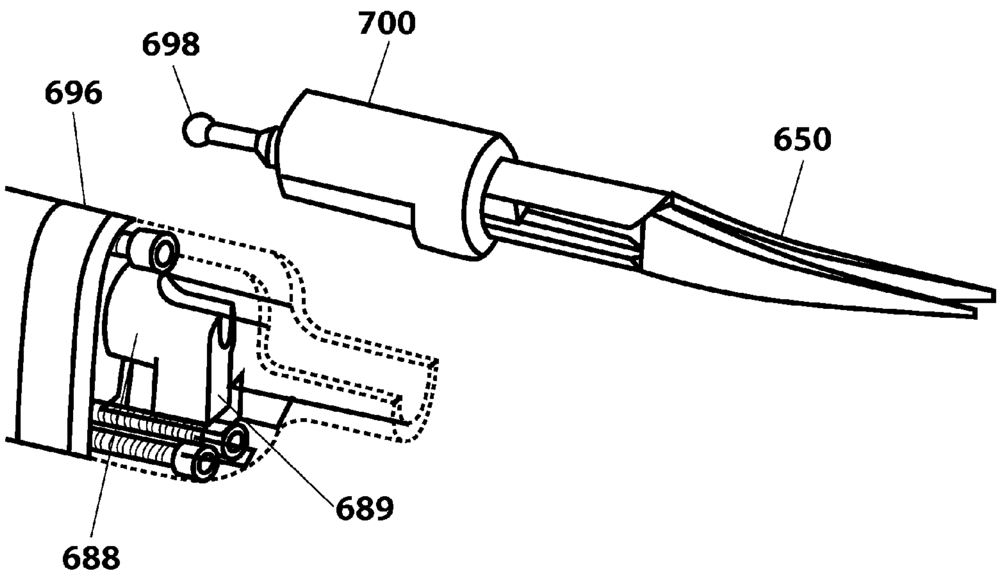

Figure 38A

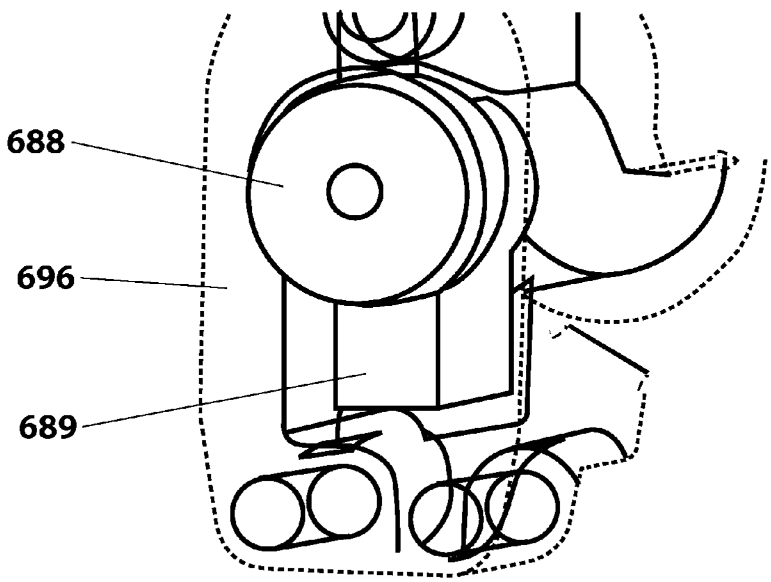

Figure 38B

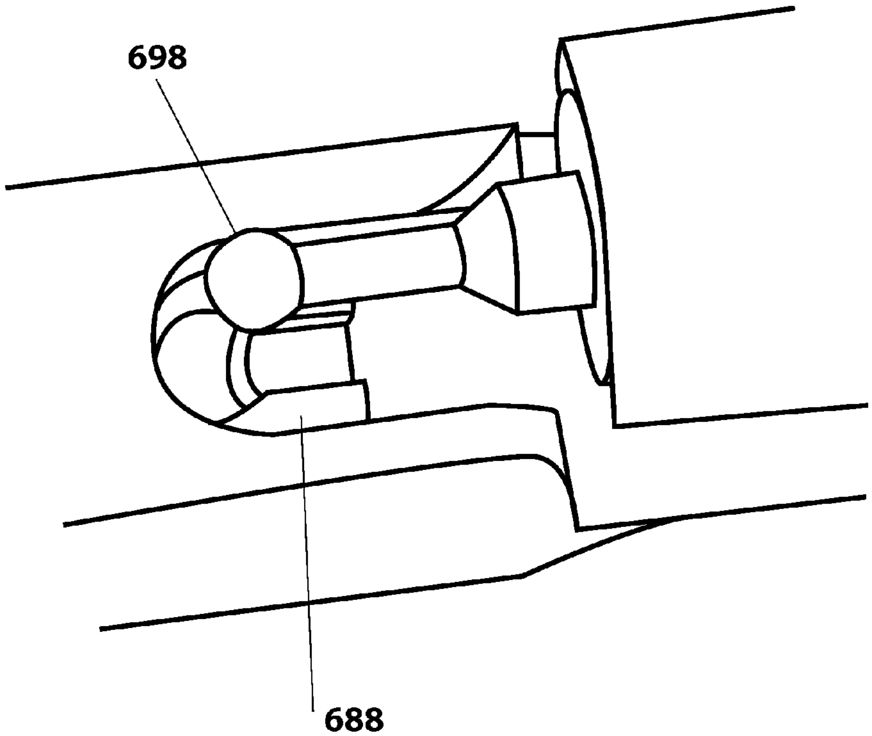

Figure 39A

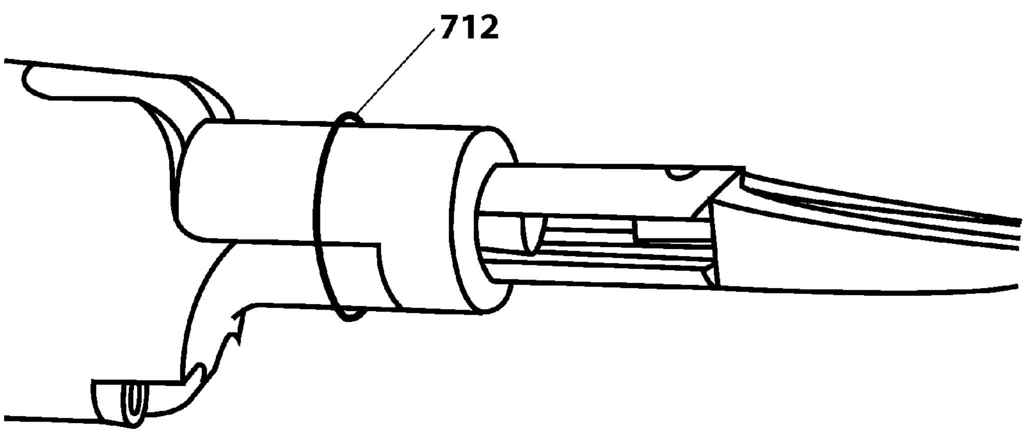

Figure 39B

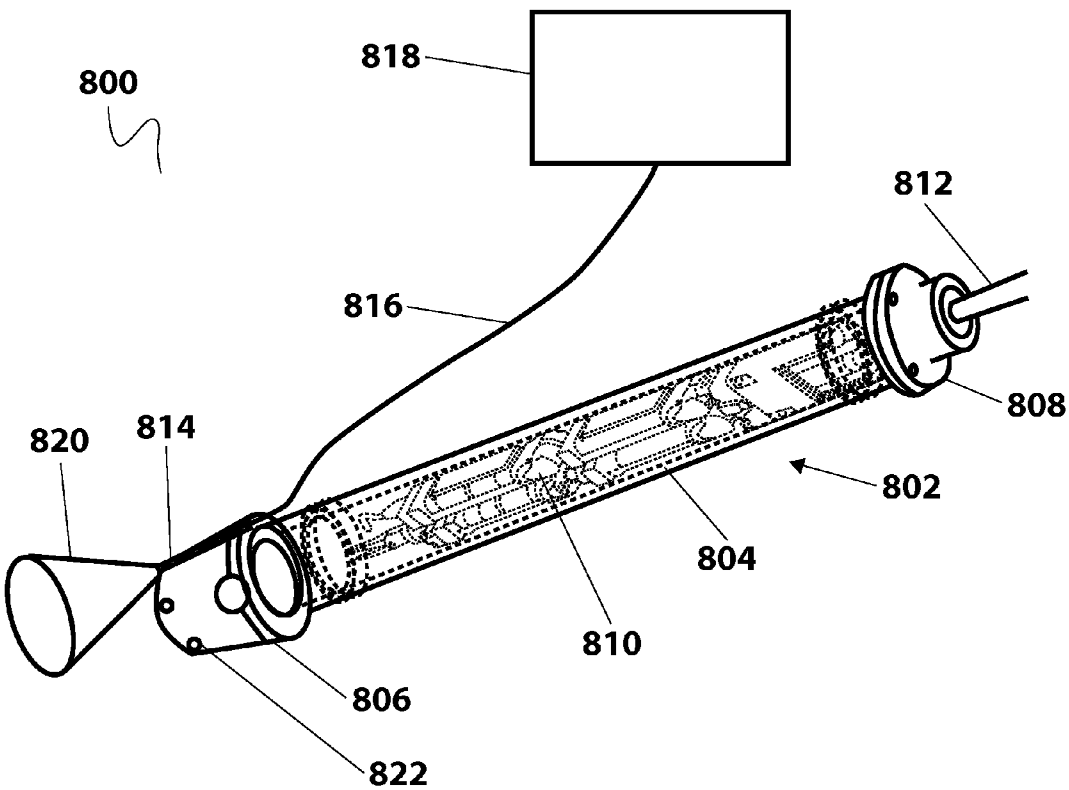

Figure 40A

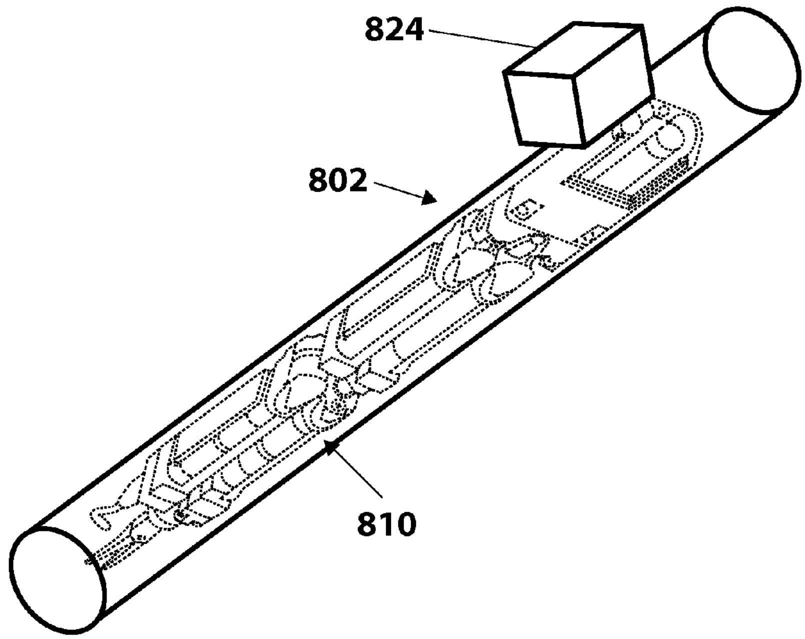

Figure 40B-1

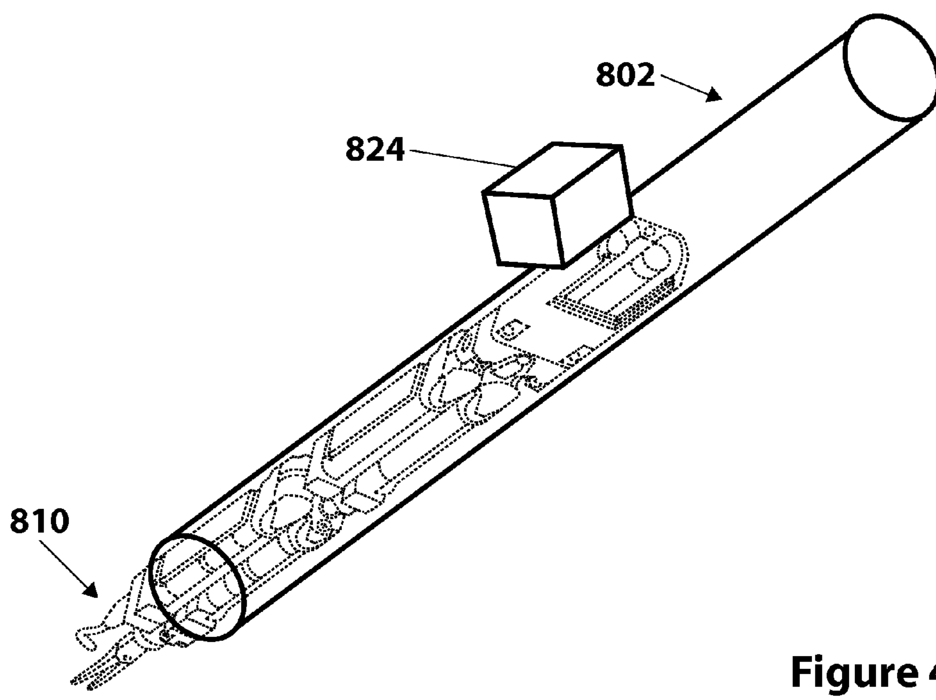

Figure 40B-2

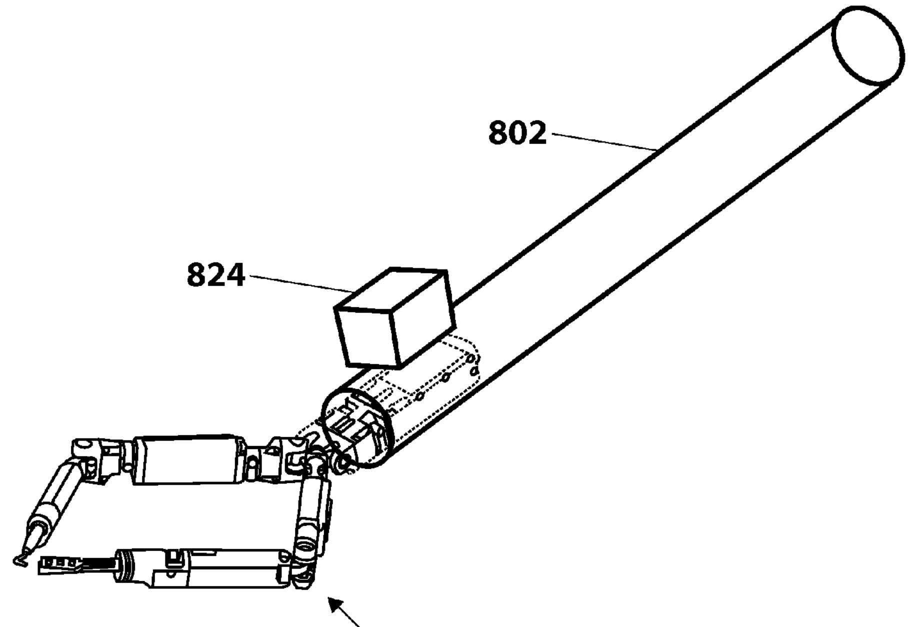

Figure 40B-3

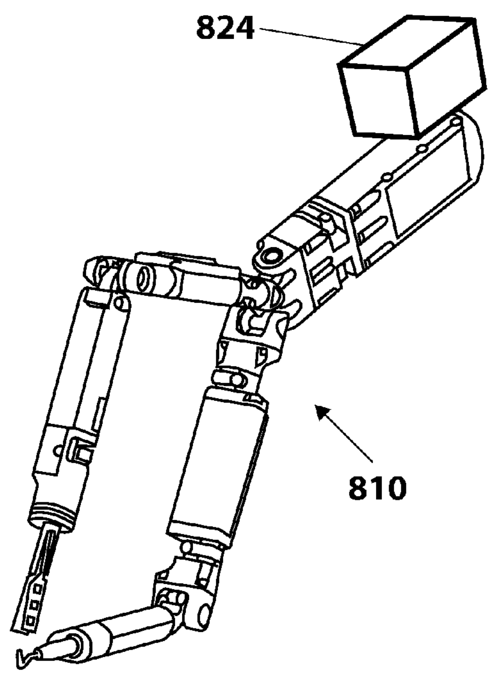

Figure 40B-4

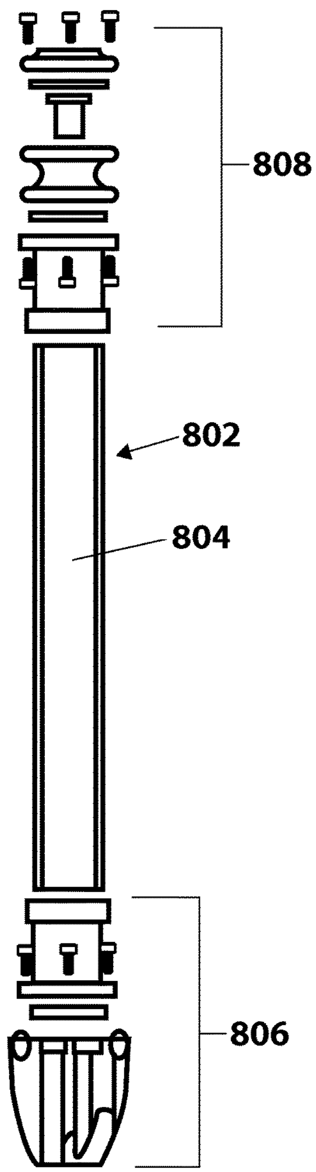

Figure 41A

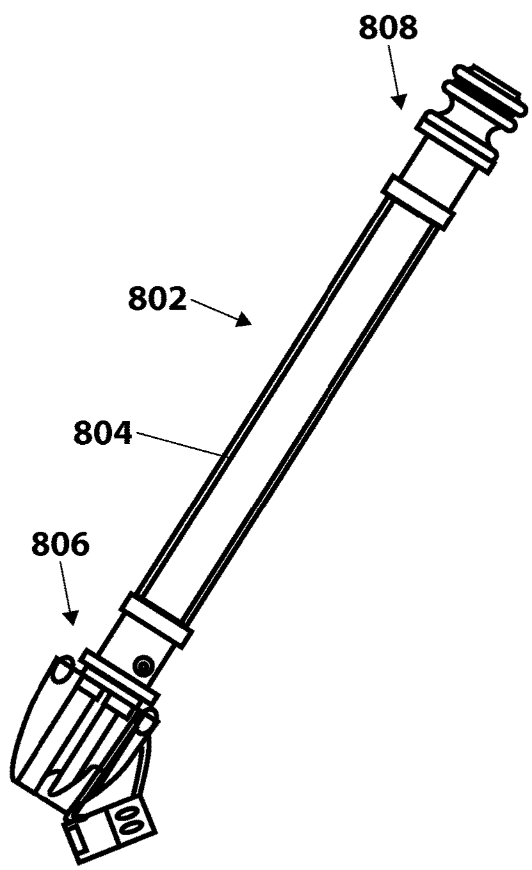

Figure 41B

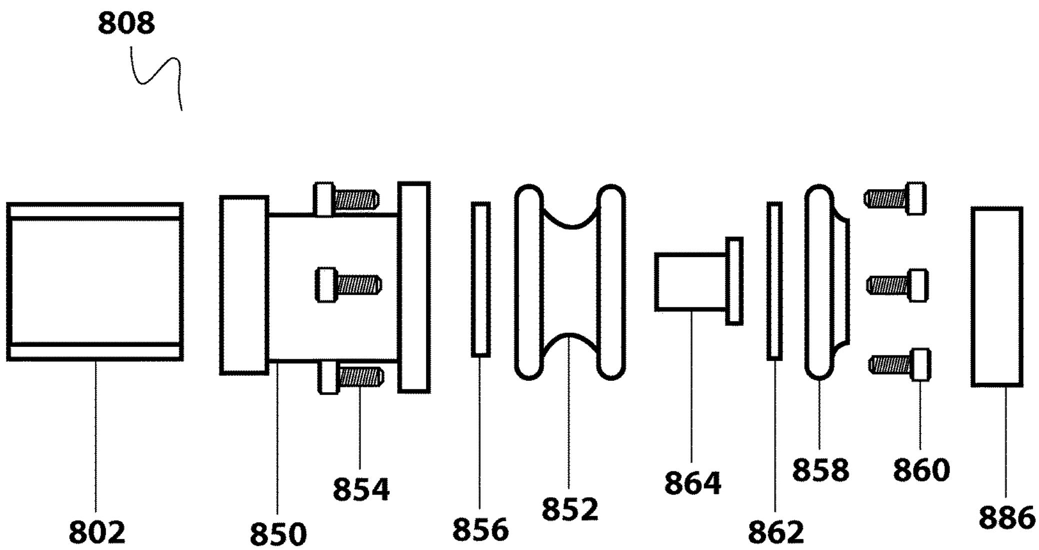

Figure 42A

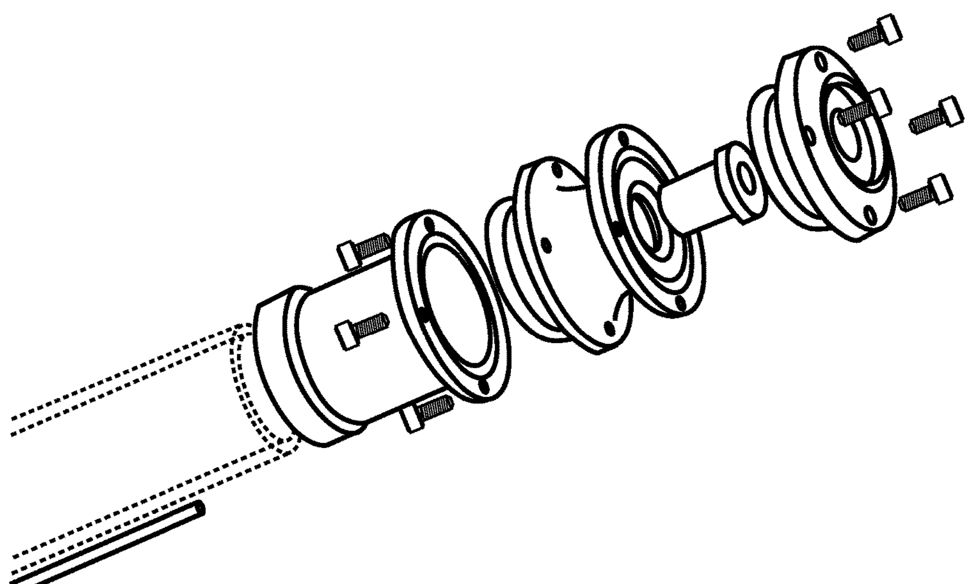

Figure 42B

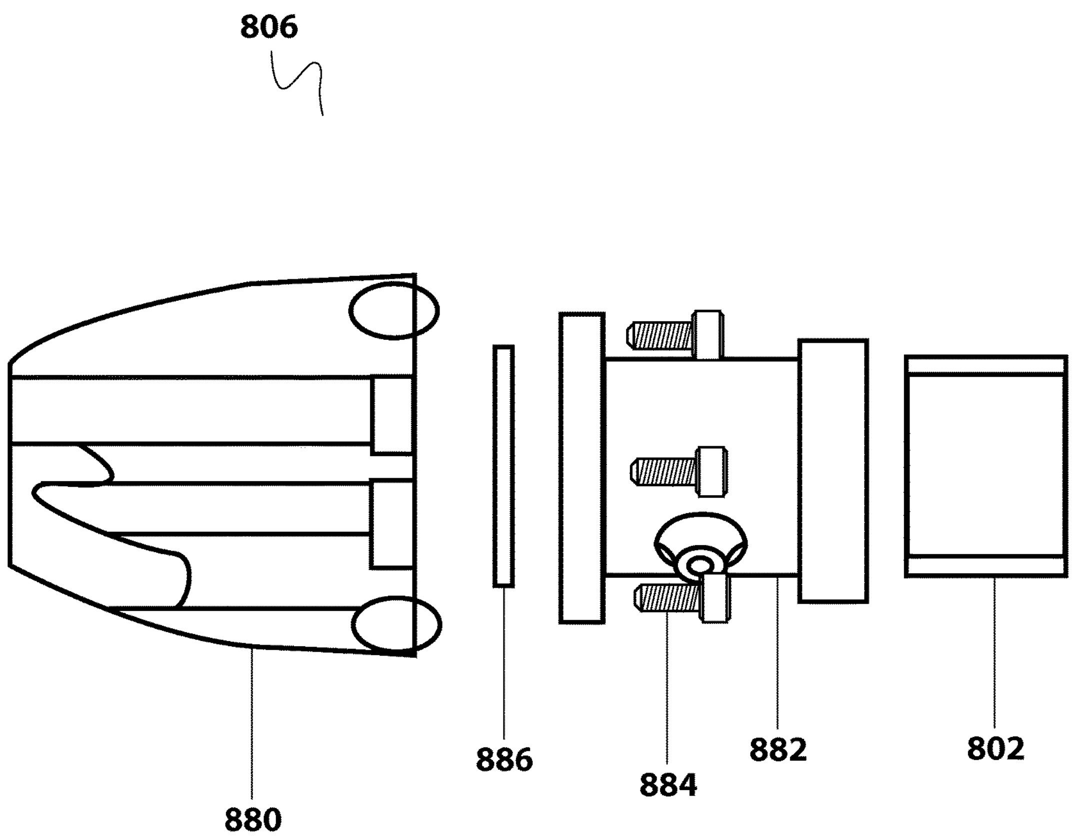

Figure 43

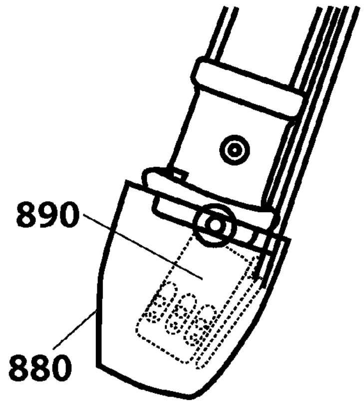

Figure 44A

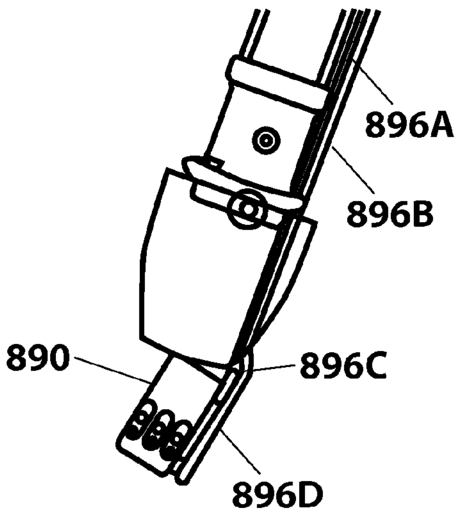

Figure 44B

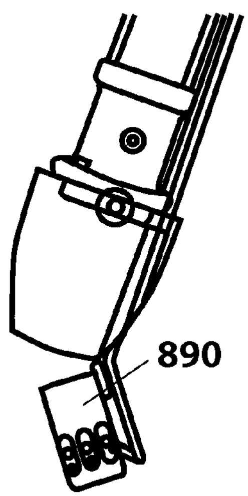

Figure 44C

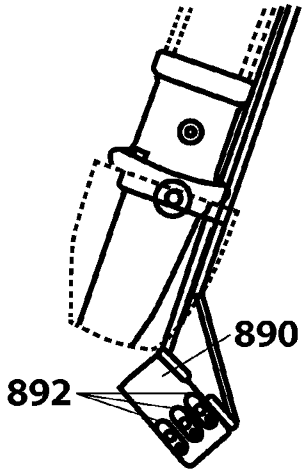

Figure 44D

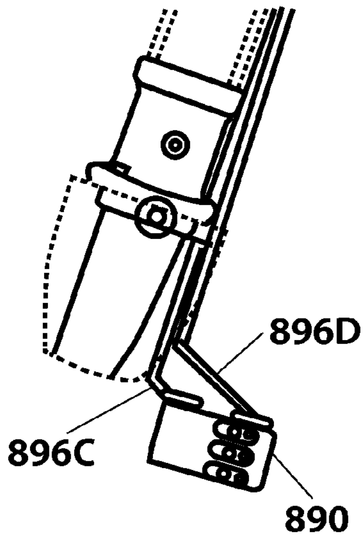

Figure 44E

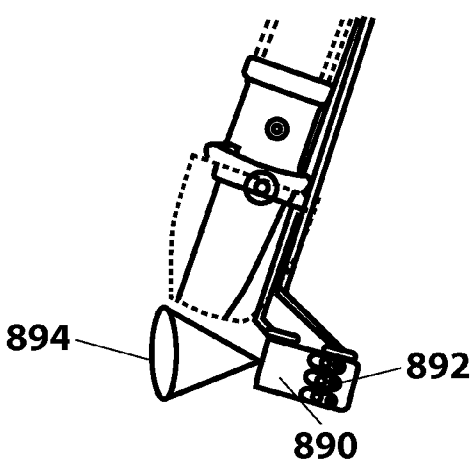

Figure 44F

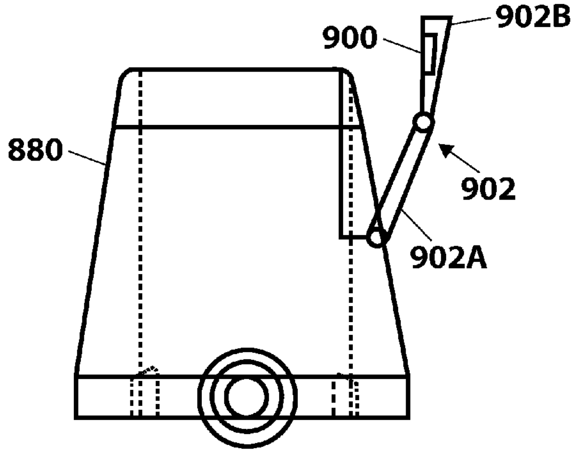

Figure 45A

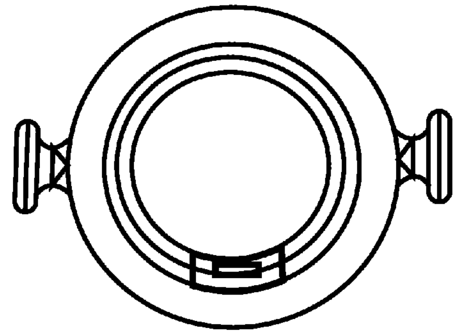

Figure 45B

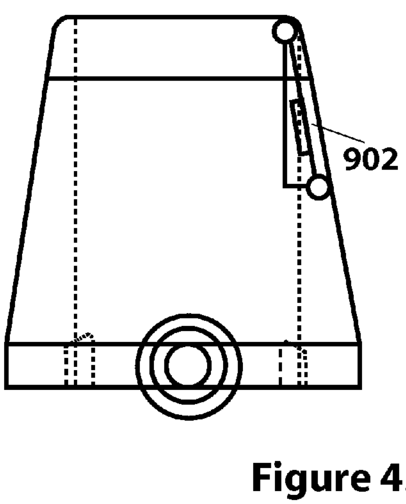

Figure 45C

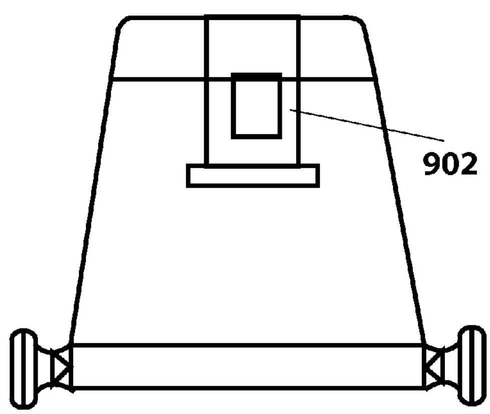

Figure 45D

LOCAL CONTROL ROBOTIC SURGICAL DEVICES AND RELATED METHODS

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is a continuation of U.S. application Ser. No. 13/834,792, filed Mar. 15, 2013, and entitled "Local Control Robotic Surgical Devices and Related Methods," which claims the benefit under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application No. 61/663,194, filed on Jun. 22, 2012, both of which are hereby incorporated herein by reference in their entirety.

GOVERNMENT SUPPORT

This invention was made with government support under Grant No. NNX09AO71A and NNX10AJ26G awarded by the National Aeronautics and Space Administration and Grant No. W81XWH-09-2-0185 awarded by U.S. Army Medical Research and Materiel Command within the Department of Defense. Accordingly, the government has certain rights in this invention.

FIELD OF THE INVENTION

The embodiments disclosed herein relate to various medical devices and related components, 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 support component disposed through an orifice or opening in the body cavity. Further embodiment relate to methods of operating the above devices.

BACKGROUND OF THE INVENTION

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

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, Calif.) 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.

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

BRIEF SUMMARY OF THE INVENTION

Discussed herein are various embodiments relating to robotic surgical devices, including robotic devices configured to be disposed within a cavity of a patient and positioned using a support or positioning component disposed through an orifice or opening in the cavity.

In Example 1, a robotic device comprises a device body, a first arm, and a second arm. The device body has a motor housing and a gear housing. The motor housing comprises a first motor and a second motor. The gear housing has a first gear positioned at a distal end of the gear housing, the first gear operably coupled to the first motor, and a second gear

positioned at a distal end of the gear housing, the second gear operably coupled to the second motor. The first arm is operably coupled to the first gear and positioned substantially within a longitudinal cross-section of the device body when the first arm is extended in a straight configuration. The second arm is operably coupled to the second gear and positioned substantially within the longitudinal cross-section of the device body when the second arm is extended in a straight configuration.

Example 2 relates to the robotic device according to Example 1, wherein the gear housing comprises first, second, and third housing protrusions disposed at the distal end of the gear housing, wherein the first gear is disposed between the first and second housing protrusions and the second gear is disposed between the second and third housing protrusions.

In Example 3, a robotic device comprises a device body, a first arm, and a second arm. The device body has a first gear and a second gear. The first gear is positioned at a distal end of the device body and configured to rotate around a first axis parallel to a length of the device body. The second gear is positioned at the distal end of the device body and configured to rotate around a second axis parallel to the length of the device body. The first arm is operably coupled to the first gear at a first shoulder joint, wherein the first shoulder joint is positioned substantially within a longitudinal cross-section of the device body. The second arm is operably coupled to the second gear at a second shoulder joint, wherein the second shoulder joint is positioned substantially within the longitudinal cross-section of the device body.

In Example 4, a robotic device comprises a device body, a first arm, and a second arm. The device body has a motor housing and a gear housing. The motor housing has a first motor and a second motor. The gear housing has a first gear and a second gear. The first gear is positioned at a distal end of the gear housing, is operably coupled to the first motor, and is positioned to rotate around a first axis parallel to a length of the device body. The second gear is positioned at a distal end of the gear housing, is operably coupled to the second motor, and is positioned to rotate around a second axis parallel to a length of the device body. The first arm is operably coupled to the first gear and has a first upper arm and a first forearm. The first arm is positioned substantially within a longitudinal cross-section of the device body when the first arm is extended in a straight configuration such that the first upper arm and the first forearm are collinear. The second arm is operably coupled to the second gear and has a second upper arm and a second forearm. The second arm is positioned substantially within the longitudinal cross-section of the device body when the second arm is extended in a straight configuration such that the second upper arm and the second forearm are collinear.

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

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a perspective view a robotic medical device, according to one embodiment.

FIG. **1**B is a perspective view of the robotic medical device of FIG. **1**A.

FIG. **1**C is a perspective view of the robotic medical device of FIG. **1**A.

FIG. **2** is a perspective view of the robotic medical device of FIG. **1**A.

FIG. **3**A is a perspective view of a device body of a robotic device, according to one embodiment.

FIG. **3**B is a different perspective view of the device body of FIG. **3**A.

FIG. **4**A is a different perspective view of the device body of FIG. **3**A.

FIG. **4**B is a side view of the device body of FIG. **3**A.

FIG. **5**A is a different perspective view of the device body of FIG. **3**A.

FIG. **5**B is a different perspective view of the device body of FIG. **3**A.

FIG. **6**A is a perspective view of some of the internal components of the device body of FIG. **3**A.

FIG. **6**B is a different perspective view of the internal components of the device body of FIG. **6**A.

FIG. **7** is a cross-section view of the device body of FIG. **3**A.

FIG. **8**A is a perspective view of a gear housing, according to one embodiment.

FIG. **8**B is a different perspective view of the gear housing of FIG. **8**A.

FIG. **9**A is a different perspective view of parts of the gear housing of FIG. **8**A.

FIG. **9**B is a different perspective view of parts of the gear housing of FIG. **8**A.

FIG. **10**A is a perspective view of an upper arm, according to one embodiment.

FIG. **10**B is a different perspective view of the upper arm of FIG. **10**A.

FIG. **11**A is a different perspective and cutaway view of the upper arm of FIG. **10**A.

FIG. **11**B is a side and cutaway view of the upper arm of FIG. **10**A.

FIG. **11**C is a cross-section view of the upper arm of FIG. **10**A.

FIG. **12**A is a side view of a portion of an upper arm, according to one embodiment.

FIG. **12**B is a cross-section view of the portion of the upper arm in FIG. **12**A.

FIG. **13**A is a side view of a portion of an upper arm, according to one embodiment.

FIG. **13**B is a perspective view of the portion of the upper arm in FIG. **13**A.

FIG. **13**C is a cross-section view of the portion of the upper arm in FIG. **13**A.

FIG. **13**D is a cross-section view of the portion of the upper arm in FIG. **13**A.

FIG. **13**E is a different perspective view of the portion of the upper arm in FIG. **13**A.

FIG. **14**A is a perspective view of a portion of an upper arm, according to one embodiment.

FIG. **14**B is a side view of the portion of the upper arm in FIG. **14**A.

FIG. **15**A is a side view of a portion of an upper arm, according to one embodiment.

FIG. **15**B is a perspective view of the portion of the upper arm in FIG. **15**A.

FIG. **16**A is a side view of a portion of an upper arm, according to one embodiment.

FIG. **16**B is a perspective view of the portion of the upper arm in FIG. **16**A.

FIG. **17**A is a side view of a portion of an upper arm, according to one embodiment.

FIG. **17**B is another side view of the portion of the upper arm in FIG. **17**A.

FIG. **17**C is another side view of the portion of the upper arm in FIG. **17**A.

FIG. **18**A is a perspective view of a forearm, according to one embodiment.

FIG. **18**B is a different perspective view of the forearm in FIG. **18**A.

FIG. **19**A is a perspective view of a portion of a forearm, according to one embodiment.

FIG. **19**B is a different perspective view of the forearm in FIG. **19**A.

FIG. **20**A is a perspective view of a portion of a forearm, according to one embodiment.

FIG. **20**B is a cross-section view of the forearm in FIG. **20**A.

FIG. **21**A is a perspective view of a portion of a forearm, according to one embodiment.

FIG. **21**B is a different perspective view of the forearm in FIG. **21**A.

FIG. **21**C is a different perspective view of the forearm in FIG. **21**A.

FIG. **22**A is a perspective view of a forearm, according to one embodiment.

FIG. **22**B is a different perspective view of the forearm in FIG. **22**A.

FIG. **23**A is a cross-section view of a forearm, according to one embodiment.

FIG. **23**B is an expanded cross-section view of the forearm in FIG. **23**A.

FIG. **24**A is a perspective view of a portion of a forearm, according to one embodiment.

FIG. **24**B is a different perspective view of the portion of the forearm in FIG. **24**A.

FIG. **24**C is a different perspective view of the portion of the forearm in FIG. **24**A.

FIG. **25** is an exploded view of a forearm, according to one embodiment.

FIG. **26**A is a cross-section view of a forearm, according to one embodiment.

FIG. **26**B is an expanded cross-section view of the forearm in FIG. **26**A.

FIG. **27**A is a perspective view of a forearm, according to one embodiment.

FIG. **27**B is a different perspective view of the forearm in FIG. **27**A.

FIG. **27**C is a different perspective view of the forearm in FIG. **27**A.

FIG. **28**A is a perspective view of a portion of a forearm, according to one embodiment.

FIG. **28**B is a different perspective view of the portion of the forearm in FIG. **28**A.

FIG. **28**C is a different perspective view of the portion of the forearm in FIG. **28**A.

FIG. **28**D is a different perspective view of the portion of the forearm in FIG. **28**A.

FIG. **29**A is a side view of a portion of a forearm, according to one embodiment.

FIG. **29**B is a perspective view of the portion of the forearm in FIG. **29**A.

FIG. **30** is a perspective view a robotic medical device, according to one embodiment.

FIG. **31**A is a top view of the medical device of FIG. **30**.

FIG. **31**B is an expanded top view of a portion of the device in FIG. **31**A.

FIG. 31C is a side view of the portion of the device in FIG. 31B.

FIG. 31D is a side view of a portion of a medical device, according to another embodiment.

FIG. 32A is a perspective view of a joint of a medical device, according to one embodiment.

FIG. 32B is a perspective view of a gear from the joint of FIG. 32A.

FIG. 33 is a perspective view of the medical device of FIG. 30.

FIG. 34 is an exploded view of a forearm, according to one embodiment.

FIG. 35 is an exploded view of a forearm, according to one embodiment.

FIG. 36 is an exploded view of a forearm, according to one embodiment.

FIG. 37 is an exploded view of a forearm, according to one embodiment.

FIG. 38A is an expanded perspective view of a portion of the forearm of FIG. 37.

FIG. 38B is an expanded perspective view of a portion of the forearm of FIG. 37.

FIG. 39A is an expanded perspective view of a portion of the forearm of FIG. 37.

FIG. 39B is an expanded perspective view of a portion of the forearm of FIG. 37.

FIG. 40A is a perspective view of an access and insertion device, according to one embodiment.

FIG. 40B-1 is a perspective view of an access and insertion device in use, according to one embodiment.

FIG. 40B-2 is a perspective view of the access and insertion device of FIG. 40B-1 in use.

FIG. 40B-3 is a perspective view of the access and insertion device of FIG. 40B-1 in use.

FIG. 40B-4 is a perspective view of the access and insertion device of FIG. 40B-1 in use.

FIG. 41A is a side view of an access and insertion device, according to one embodiment.

FIG. 41B is a perspective view of the access and insertion device of FIG. 41A.

FIG. 42A is a exploded view of a portion of an access and insertion device, according to one embodiment.

FIG. 42B is a perspective view of the portion of the access and insertion device of FIG. 42A.

FIG. 43 is a side view of a portion of the access and insertion device of FIG. 42A.

FIG. 44A is a perspective view of an access and insertion device in use, according to one embodiment.

FIG. 44B is a perspective view of the access and insertion device of FIG. 44A in use.

FIG. 44C is a perspective view of the access and insertion device of FIG. 44A in use.

FIG. 44D is a perspective view of the access and insertion device of FIG. 44A in use.

FIG. 44E is a perspective view of the access and insertion device of FIG. 44A in use.

FIG. 44F is a perspective view of the access and insertion device of FIG. 44A in use.

FIG. 45A is a side view of a portion of an access and insertion device, according to one embodiment.

FIG. 45B is a cross-section view of the portion of the access and insertion device of FIG. 45A.

FIG. 45C is a side view of the portion of the access and insertion device of FIG. 45A.

FIG. 45D is a side view of the portion of the access and insertion device of FIG. 45A.

DETAILED DESCRIPTION

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.

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 copending U.S. application Ser. No. 11/766,683 (filed on Jun. 21, 2007 and entitled "Magnetically Coupleable Robotic Devices and Related Methods"), Ser. No. 11/766,720 (filed on Jun. 21, 2007 and entitled "Magnetically Coupleable Surgical Robotic Devices and Related Methods"), Ser. No. 11/966,741 (filed on Dec. 28, 2007 and entitled "Methods, Systems, and Devices for Surgical Visualization and Device Manipulation"), 61/030,588 (filed on Feb. 22, 2008), Ser. No. 12/171,413 (filed on Jul. 11, 2008 and entitled "Methods and Systems of Actuation in Robotic Devices"), Ser. No. 12/192,663 (filed Aug. 15, 2008 and entitled Medical Inflation, Attachment, and Delivery Devices and Related Methods"), Ser. No. 12/192,779 (filed on Aug. 15, 2008 and entitled "Modular and Cooperative Medical Devices and Related Systems and Methods"), Ser. No. 12/324,364 (filed Nov. 26, 2008 and entitled "Multifunctional Operational Component for Robotic Devices"), 61/640,879 (filed on May 1, 2012), Ser. No. 13/493,725 (filed Jun. 11, 2012 and entitled "Methods, Systems, and Devices Relating to Surgical End Effectors"), Ser. No. 13/546,831 (filed Jul. 11, 2012 and entitled "Robotic Surgical Devices, Systems, and Related Methods"), 61/680,809 (filed Aug. 8, 2012), Ser. No. 13/573,849 (filed Oct. 9, 2012 and entitled "Robotic Surgical Devices, Systems, and Related Methods"), and Ser. No. 13/738,706 (filed Jan. 10, 2013 and entitled "Methods, Systems, and Devices for Surgical Access and Insertion"), and U.S. Pat. No. 7,492,116 (filed on Oct. 31, 2007 and entitled "Robot for Surgical Applications"), U.S. Pat. No. 7,772,796 (filed on Apr. 3, 2007 and entitled "Robot for Surgical Applications"), and U.S. Pat. No. 8,179,073 (issued 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.

Certain device and system implementations disclosed in the applications listed above can be positioned within a body cavity of a patient 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.

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. 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.

Certain embodiments herein relate to robotic devices (also referred to herein as "platforms") configured to be inserted into a patient cavity—such as an insufflated abdominal cavity—and related systems and methods. In some embodiments, the systems include direct visualization of the device during the procedure. Other embodiments relate to various access or insertion devices that can be used to position the above robotic devices in the patient's cavity.

One embodiment of a robotic device **8** is depicted in FIGS. **1**A-**1**C and **2**. This embodiment has a device body **10**, a left arm **20**, and a right arm **30**, as shown in FIGS. **1**A and **2**. Both the left and right arms **20**, **30** are each comprised of 2 segments: an upper arm (or "first link") and a forearm (or "second link"). Thus, as best shown in FIG. **1**B, the left arm **20** has an upper arm **20**A and a forearm **20**B and the right arm **30** has an upper arm **30**A and a forearm **30**B. As also shown in FIGS. **1**B and **2**, the device main body **10** can, in some embodiments, be coupled to an insertion rod **40**.

As best shown in FIG. **1**C, the various joints in the right arm **30** provide for various degrees of freedom. More specifically, the right shoulder (the joint at which the upper arm **30**A is coupled to the device body **10**) provides two degrees of freedom: shoulder pitch θ**1** and shoulder yaw θ**2**. The elbow joint (the joint at which the forearm **30**B is coupled to the upper arm **30**A) provides elbow yaw θ**3**, and the end effector on the distal end of the forearm **30**B provides end effector roll θ**4**.

As shown in FIGS. **1**A-**1**C and **2**, the device **8** is configured to have a reduced profile and/or cross-section. That is, the shoulder joints (where the upper arms **20**A, **30**A couple with the body **10**), are positioned within the longitudinal cross-section of the body **10** such that shoulder joints and the proximal ends of the upper arms **20**A, **30**A do not extend beyond or exceed that cross-section. Further, when the arms **20**, **30** are positioned in a straight configuration such that the upper arms **20**A, **30**A and forearms **20**B, **30**B extend along the same axis (the elbows are not bent), no part of the arms **20**, **30** extend beyond the longitudinal cross-section of the body **10**. This minimal cross-section greatly simplifies insertion of the device **8** into an incision. For purposes of this application, the "longitudinal cross-section" is the cross-section of the body **10** as viewed when looking at the distal end or the proximal end of the body **10** such that one is looking along the longitudinal axis of the body **10**.

Various embodiments of the device body **10** are depicted in FIGS. **3**A-**9**B. As shown in FIGS. **3**A and **3**B, the device body **10** has a motor housing **50** that is configured to contain at least one motor (described below) and a master control board (not shown) or other processor configured to control various components and/or actions of the device. The device body **10** also has a gear housing **62** coupled to the motor housing **50**. In addition, as best shown in FIGS. **3**A and **5**A, the housing **50** has a housing cover **52** that is configured to be coupleable to the housing **50** and to provide access to the at least one motor positioned within an internal portion of the housing **50**.

In one embodiment as shown in FIGS. **3**A and **3**B, the housing cover **52** has an opening **53** defined in the portion of the housing cover **52** that covers the proximal end of the housing **50**. The opening **53** is configured to receive an insertion rod **54** (also referred to as a "positioning rod" or "positioning component"). In accordance with one implementation, screws **56** or other fastening components are used to couple the rod **54** to the cover **52** as shown. According to one implementation, the insertion rod **54** is used to advance the device **8** during insertion. In other implementations, it can also be used to position the device **8** within the patient's cavity during the procedure. In accordance with certain embodiments, the rod **54** will have communication and power wires (also referred to herein as "cables" or "connection components") disposed in one or more lumens defined in the rod **54** that will operably couple the device **8** to an external controller (not shown). For example, the external controller can be a personal computer, a joystick-like controller, or any other known controller that allows a user to operate the device **8**. In further embodiments in which the device **8** has at least one camera, the connection components can also include one or more camera and/or lighting wires.

As best shown in FIGS. **4**A and **4**B, the motor housing **50** is coupled to the gear housing **62** such that a portion of each of the motor assemblies **60**A, **60**B is positioned in the motor housing **50** and a portion is positioned in the gear housing **62**. In one embodiment, the motor housing **50** is coupled to the gear housing **62** with screws **44**, **46** that are positioned through holes in the motor housing **50** and threadably coupled within holes in the gear housing **62**.

As best shown in FIGS. **5**A and **5**B, in one embodiment the housing cover **52** is removably coupled to the motor housing **50** with screws **48**. The screws **48** are positioned through holes defined in the housing **50** and threadably coupled within holes in the housing cover **52**. Alternatively, any known coupling mechanisms, such as bolts or snap or friction fit mechanisms, can be used to removably couple the cover **52** to the housing **50**.

As discussed above and depicted in FIGS. **4**A, **4**B, **5**A, and **5**B, the device body **10** contains the two motor assemblies **60**A, **60**B. The two motor assemblies **60**A, **60**B actuate the movement of the left and right arms **20**, **30**, as will be described in further detail below. In addition, the body **10** can also contain a master control board (not shown) and a stereoscopic camera (not shown). In one embodiment, the master control board controls the motors **60**A, **60**B.

In accordance with one embodiment, each of the two motor assemblies **60**A, **60**B is the actuator for a drive train with a three stage gear head. That is, the left motor assembly **60**A is the actuator for a drive train coupled to the left arm **20**, while the right motor assembly **60**B is the actuator for a drive train coupled to the right arm **30**. While the following description will focus on the right motor **60**B and its drive train, it is understood that the left motor assembly **60**A and its drive train will have similar components and operate in a similar fashion.

In one implementation, as best shown in FIGS. **6**A, **6**B, **8**A, **8**B, **9**A, and **9**B, the first stage of the three stage gear head is the gear head **60**B-**2** attached to the motor **60**B-**1** of the motor assembly **60**B. The second stage is the spur gear set, which is made up of the motor gear **68** and the driven gear **96** as best shown in FIG. **9**A. The motor gear **68** and the driven gear **96** are rotationally coupled to each other in the gear housing **62**. In one embodiment, the motor gear **68** and driven gear **96** are spur gears. Alternatively, they can be any known gears. The motor gear **68** is also known as a "first gear," "drive gear," or "driving gear." The driven gear **96** is also known as a "second gear" or "coupling gear." The third stage is the bevel gear set, which is made up of the housing bevel gear **92** and the link bevel gear **102**. The housing bevel gear **92** and the link bevel gear **102** are rotationally coupled to each other as best shown in FIG. **9**A. These components and gear sets will be discussed in detail below. The housing bevel gear **92** is also known as the "third gear," "housing gear," "second drive gear," or "first shoulder gear." The link bevel gear **102** is also know as the "fourth gear," "link gear," or "second shoulder gear."

As best shown in FIGS. **6**A, **6**B, and **7**, both the right and left motor assemblies **60**A, **60**B are positioned at their distal ends into the gear housing **62**. The right motor assembly **60**B has a motor **60**B-**1** and a gearhead **60**B-**2**. In this embodiment, the gearhead **60**B-**2** is the first stage gear head and is operably coupled to the motor **60**B-**1**. The motor assembly **60**B has a motor shaft **67** operably coupled at the distal end of the assembly **60**B. In one embodiment, the motor shaft **67** has a flat surface **67**A that creates a "D" configuration that geometrically couples the shaft **67** to the spur gear **68**. The right motor assembly **60**B is positioned in the right motor gear opening **69** of the gear housing **62**, as best shown in FIG. **6**B. In one embodiment, the motor assembly **60**B has a configuration or structure that allows for the assembly **60**B to be geometrically coupled within the right motor gear opening **69**. Further, as best shown in FIG. **7**, the gear housing **62** has a clamp **70** that can be used to retain the motor assembly **60**B within the motor gear opening **69**. That is, a threaded screw **66** or other coupling mechanism is positioned in the clamp **70** and threaded into the clamp **70**, thereby urging the clamp **70** against the assembly **60**B, thereby retaining it in place. Alternatively, the assemblies **60**A, **60**B can be secured to the housing **62** via adhesive or any other known coupling or securement mechanisms or methods.

As best shown in FIGS. **8**A and **8**B, the gear housing **62** is coupled to a bearing housing **64**. In one embodiment, the bearing housing **64** is comprised of three housing projections **64**A, **64**B, **64**C. As best shown in FIG. **8**B in combination with FIGS. **9**A and **9**B, the right driven spur gear assembly **96** is rotationally coupled to the bearing housing **64**. More specifically, the right driven spur gear assembly **96** is rotationally retained in the bearing housing by the bearings **94**, **98** as shown in FIG. **9**A. The bearings **94**, **98** are positioned in and supported by the bearing housing **64** and the gear housing **62**.

As best shown in FIGS. **8**A and **8**B in combination with FIGS. **9**A and **9**B, the spur gear assembly **96** is operably coupled to the housing bevel gear **92** such that the spur gear **96** drives the bevel gear **92**. More specifically, the spur gear **96** is positioned over the proximal portion of the bevel gear **92**, with the proximal portion having a flat portion or other configuration that rotationally couples the spur gear **96** to the bevel gear **92** such that the spur gear **96** and bevel gear **92** are not rotatable in relation to each other. Further, the bevel gear **92** is positioned between the first and second housing projections **64**A and **64**B and supported by bearings **94**, **98**. As best shown in FIG. **9**A, the bearings **94**, **98** and the spur gear **96** are secured to the gear **92** by screw **100**, which is threadably coupled to the bevel gear **92**. Further, the bevel gear **92** is rotationally coupled to the first and second projections **64**A, **64**B. The spur gear **96** and bevel gear **92** are rotationally coupled to housing **62** and housing **64** by screws **80**, **82** (as best shown in FIG. **8**A), which are threadably coupled to the housings **62**, **64** such that the housings **62**, **64** are coupled to each other.

As mentioned above, the bevel gear **92** is rotationally coupled to the link **102**, which is operably coupled to the right arm **30** of the device **8** as described in further detail below. Thus, the link **102** couples the device body **10** to the right arm **30** such that actuation of the motor **60**B results in actuation of some portion or component of the right arm **30**. The link **102** is supported by bearings **90**A, **90**B, which are coupled to the housing **64** as best shown in FIGS. **9**A and **9**B.

In one implementation, the right upper arm **30**A is coupled to the device body **10**. And in certain embodiments, the right upper arm **30**A is more specifically coupled to the link **102** discussed above. As best shown in FIGS. **10**A and **10**B, the upper arm **30**A is coupled to the device body **10** at the link **102**. The upper arm **30**A has a motor housing **128** configured to hold at least one motor and a housing cover **124** coupled to the housing **128**. The housing cover **124** is coupled to the motor housing **128** by screws **126**, which are threadably coupled to the motor housing **128** as shown. Alternatively, any mechanical coupling mechanisms can be used. The motor housing **128** is operably coupled to a spur gear housing **120** at each end of the motor housing **128** such that there are two spur gear housings **120** coupled to the motor housing **128**.

As best shown in FIGS. **11**A, **11**B, and **11**C, the housing **128** contains two motor and gear head assemblies **142**, **143** and a local control board **132**, which will be described in further detail below. The two assemblies **142**, **143** are secured to the housing **128** with screws **130**, which are threadably coupled to motor housing **128** as best shown in FIG. **10**B.

As best shown in FIG. **11**A, the local control board **132** is operably coupled to the motor housing **128** and housing cover **124** and controls the two motor assemblies **142**, **143** in the housing **128**. The board **132** is also operably connected to both of the motor assemblies **142**, **143** within the housing **128** via flexible electrical ribbon cable (either FFC or FPC) **134**, **136**. The board **132** receives communications (such as commands and requests, for example) from the master control board (not shown) located in the device body **10** via the flexible electrical ribbon cable **134**. Further, the board **132** also transmits, passes, or relays communications (such as commands and requests) from the master board to the next device component, which—in this embodiment—is the right forearm **30**B via the flexible electrical ribbon cable **136**.

According to one implementation, each of the local boards disclosed herein is "daisy chained" or wired together in a sequence in the device **8**. In this context, "daisy chain" is intended to have its standard definition as understood in the art. The local boards are daisy chained together using flexible ribbon cable such as the cable **134**, **136** such that the cable can transmit power, analog signals, and digital data. The use of a daisy chain configuration can create an electrical bus and reduce the number of wires required.

In one embodiment, the two motor assemblies **142**, **143** are responsible for the right arm **30** shoulder yaw and elbow pitch as best shown in FIG. **1**C. Like the description of the motor assemblies in the device body **10** as discussed above, the two motor assemblies **142**, **143** in the upper arm **30**A as best shown in FIGS. **11**B and **11**C are substantially similar, so the right motor assembly **142** will be discussed in detail herein. As best shown in FIGS. **12**A and **12**B, the motor drive train has a three stage gear head. The first stage is the gear head **142**B attached to the motor **142**A in the motor assembly **142** (as best shown in FIG. **11**C), the second stage is a spur gear set made up of the motor spur gear **138** and the driven spur gear **156**, and the third stage is a bevel gear set made up of the bevel gear **152** and the driven bevel gear **170**. All of these components will be described in further detail below.

As best shown in FIG. **13**A, the motor assembly **142** has a drive shaft **144** that is operably coupled to the spur gear **138**. In one embodiment, the drive shaft **144** has a flat portion **144**A that results in a D-shaped shaft, which helps to rotationally couple the spur gear **138** to the shaft **144**. In a further implementation, the spur gear **138** can be further coupled to the shaft **144** using a bonding material such as, for example, JB-Weld. Alternatively, the spur gear **138** can be coupled to the shaft **144** in any known fashion using any known mechanism.

As best shown in FIGS. **13**A, **13**B, **13**C, **13**D, and **13**E, the motor assembly **142** is positioned within a lumen **145** defined in the spur gear housing **120**. According to one embodiment, the assembly **142** can be coupled or otherwise retained within the lumen **145** using a clamping assembly **146** (as best shown in FIGS. **13**C and **13**D). That is, once the motor assembly **142** is positioned within the lumen **145**, the screw **140** can be urged into the hole, thereby urging the clamping assembly **146** against the motor assembly **142**, thereby frictionally retaining the assembly **142** in the lumen **145**. Alternatively, the assembly **142** can be secured to the housing **120** via adhesive or any other known coupling or securement mechanisms or methods.

As best shown in FIGS. **12**A, **12**B, **14**A, and **14**B, the second stage spur gear set is made up of the motor spur gear **138** and the driven spur gear **156**. The two gears **138**, **156** are rotationally coupled to each other within the spur gear housing **120** as shown. Further, the driving bevel gear **152** is operably coupled with the driven spur gear **156**, with bearings **154**, **158** positioned on either side of the spur gear **156**, thereby creating the spur/bevel assembly **150**. The spur gear **156** is rotationally coupled to the bevel gear **152** such that neither the spur gear **156** nor the bevel gear **152** can rotate in relation to each other. In one embodiment, the two gears **156**, **152** are rotationally coupled using a D-shaped geometric feature. The spur gear **156** is translationally constrained by the supporting bearings **154**, **158**, which are preloaded through screw **160**. The fully assembled assembly **150** can be positioned in the lumen **151** in motor housing **120**.

As shown in FIGS. **15**A, **15**B, **16**A, **16**B, **17**A, **17**B, and **17**C, the third stage bevel gear set is made up of a drive bevel gear **152** and a link bevel gear **170**. As discussed above, the drive bevel gear **152** is part of the spur/bevel assembly **150** and thus is operably coupled to and driven by the spur gear **156**.

Setting aside for a moment the focus on the motor assembly **142** and related components coupled thereto (and the fact that the description relating to the assembly **142** and related components applies equally to the motor assembly **143**), it is understood that there are two link bevel gears **170**A, **170**B positioned at opposite ends of the upper arm **30**A, as best shown in FIGS. **11**A, **11**B, and **11**C. The link bevel gear **170**A operably couples the upper arm **30**A to the device body **10**, while the link bevel gear **170**B operably couples the upper arm **30**A to the forearm **30**B.

Returning to FIGS. **15**A-**17**C, the bearings **172**, **174** support the link bevel gear **170**. As best shown in FIGS. **16**A and **16**B, the bearings **172**, **174** are supported by the bearing housing **176**, which is made up of two housing projections **176**A, **176**B. The bearing housing **176** can apply a preload force to the bearings **172**, **174**. As best shown in FIGS. **17**A-**17**C, the housing projections **176**A, **176**B are secured to the motor housing **120** by screws **180**, **182**, which are threadably coupled through the motor housing **120** and into the housing projections **176**A, **176**B.

As discussed above, it is understood that the above description relating to the upper arm **30**A also applies to upper arm **20**A as well. That is, in certain embodiments, the upper arm **30**A and upper arm **20**A are substantially the same.

FIGS. **18**A-**21**C depict one implementation of a grasper forearm component **200** (which could, of course, be the forearm **30**B discussed and depicted above) that can be coupled to the upper arm **30**A. More specifically, the forearm **30**B has an opening **218** defined at a proximal end of the arm **200** that is configured to be coupled to the link bevel gear **170**B as discussed above. This forearm **200** has a grasper end effector (also referred to herein as a "manipulation end effector") **256** discussed in further detail below.

As best shown in FIGS. **18**A and **18**B, in this embodiment, the grasper forearm **200** has a motor housing **202** coupled to a gear housing **212**. The two housings **202**, **212** contain two motor assemblies **206**, **208**, which actuate rotation of the grasper end effector **256** and opening/closing of the grasper **256**, as described in further detail below. The motor housing **202** also contains the local control board **210** and has a housing cover (also referred to as a "cap") **204** configured to removably cover the opening **205** that provides access to the interior of the motor housing **202**. The cover **204** can be coupled to the housing **202** with screw **216**. In addition, the screw **216** is threadably positioned into the opening **218** and thus can be threadably coupled to the link bevel gear **170** as discussed above, thereby rotationally coupling the forearm **200** to the upper arm **30**A. The motor housing **202** and cover **204** are coupled to the gear housing **212** with screws **214**, which are threadably coupled through openings in the housing **202** and cover **204** and into the gear housing **212**. In one implementation, the local control board **210** can be the same or similar to the local control board **132** in the upper arm as described above. The board **210** is coupled to the local control board **132** via the flexible electrical ribbon cable **136** in the upper arm **30**A as described above.

As best shown in FIGS. **19**A-**20**B, the two motor assemblies **206**, **208** are coupled to the gear housing **212** via clamps **222**, **230**. More specifically, the motor assembly **206** is coupled to the housing **212** with the clamp **222** as best shown in FIGS. **19**A and **19**B, while the motor assembly **208** is coupled to the housing with the clamp **230** as best shown in FIGS. **20**A and **20**B. Alternatively, the assemblies **206**, **208** can be secured to the housing **212** via adhesive or any other known coupling or securement mechanisms or methods.

As best shown in FIGS. **19**A and **19**B, the clamp **222** is coupled to the gear housing **212** with screws **224**, which are threadably positioned through holes in the clamp **222** and into the gear housing **212**. According to one embodiment, the clamp **222** secures the motor assembly **206** by frictional force applied by urging the clamp **222** against the housing **212** with the screws **224**. As best shown in FIG. **19**B, the motor assembly **206** contains two parts: a motor **206**B and gear head **206**A. In accordance with one implementation, the gear head **206**A is operably coupled to the motor **206**B. A drive gear (which is also a "spur gear") **220** is operably coupled to the shaft **207** extending from the motor assembly **206**. In one embodiment, the shaft **207** has a flat portion resulting in a "D shaped" geometry, and the gear **220** has a hole that mates that geometry, thereby ensuring that the shaft **207** and gear **220** are not rotatable in relation to each other when they are coupled. In a further alternative, the gear **220** is also adhesively coupled to the shaft **207** with JB Weld or any known adhesive material. Alternatively, the gear **220** and shaft **207** can be coupled in any known fashion using any known coupling mechanism or configuration.

As best shown in FIGS. **20**A and **20**B, the clamp **230** is urged toward the housing **212** with screw **232**, thereby creating frictional retention of the motor assembly **208**. As such, the clamp **230** can retain the assembly **208** in the housing **212**.

As best shown in FIG. **21**C, the motor assembly **208** has two parts: a motor **208**A and a gear head **208**B coupled to the motor **208**A. A drive gear (which is also a "spur gear") **264** is operably coupled to the shaft **209** extending from the motor assembly **208**. In one embodiment, the shaft **209** has a flat portion resulting in a "d shaped" geometry, and the gear **264** has a hole that mates that geometry, thereby ensuring that the shaft **209** and gear **264** are not rotatable in relation to each other when they are coupled. In a further alternative, the gear **264** is also adhesively coupled to the shaft **209** with JB Weld or any known adhesive material. Alternatively, the gear **264** and shaft **209** can be coupled in any known fashion using any known coupling mechanism or configuration.

As best shown in FIG. **21**A, drive spur gear **264** is coupled in the gear housing **212** with driven spur gear **250**, and actuation of the drive spur gear **264** (and thus the driven spur gear **250**) causes the grasper end effector **256** to rotate. Further, as best shown in FIGS. **19**B and **21**B, the drive spur gear **220** is coupled in the gear housing **212** with driven spur gear **248**, and actuation of the drive spur gear **220** (and thus the drive spur gear **248**) causes the grasper end effector **256** to move between its open and closed positions.

Continuing with FIG. **21**A, the gear housing **212** has a bearing cover (also referred to as a "cap") **240**, which is attached to the gear housing **212** by screws **242** which are threadably coupled through holes in the cover **240** and into the gear housing **212**. The screws **242** can also be configured to apply a preload force to bearings **244**, **246**, **260**, **252**. As shown in FIG. **21**B, the bearings **244**, **246**, **260**, **252** are supported within the gear housing **212**. Bearings **244**, **246** support the driven spur gear **248** of the end effector actuation spur gear set **220**, **248**.

Continuing with FIG. **21**B, the spur gear **248** has a lumen with internal threads formed in the lumen and thus can be threadably coupled to the grasper drive pin **254**, which can be positioned at its proximal end in the lumen of the spur gear **248**. As the spur gear **248** rotates, the threads in the lumen of the spur gear **248** coupled to the threads on the drive pin **254** cause the drive pin **254** to translate, thereby causing the grasper links **256** to move between open and closed positions. In this particular embodiment, translation of the drive pin **254** is transferred through a four bar linkage made up of links **262**A, **262**B and grasper links **256**A, **256**B. Alternatively, this actuation of the grasper **256** can be accomplished through any other known mechanisms such as a pin and slot or worm gear drive train. A pin **266** secures the four bar linkage **262**A, **262**B, **256**A, **256**B to the spur gear **250**. The pin **266** is threadably coupled to spur gear **250**.

The bearings **260**, **252** support the driven spur gear **250**. The driven spur gear **250** is coupled to the grasper **256** such that when spur gear **250** is rotated, the grasper **256** is rotated. To rotate the grasper **256** without also actuating the grasper to move between its open and closed positions, the spur gear **248** must rotate in the same direction and at the same speed as the spur gear **250**. That is, as described above, the drive pin **254** is rotationally coupled to spur gear **250** (otherwise translation of the pin **254** is not possible) such that when spur gear **250** is rotated (to cause the end effector to rotate), the drive pin **254** is also rotated. Hence, if spur gear **248** is not also rotated in the same direction at the same speed as the spur gear **250**, the drive pin **254** will translate, thereby causing the grasper **256** to open or close. As a result, to rotate the grasper **256** without opening or closing it, the spur gears **250** and **248** must rotate together. The spacer **258** can provide spacing between the bearings **246**, **260** and can also transfer the preload force through each bearing within the assembly.

FIGS. **22**A-**24**C depict an alternative embodiment relating to a cautery forearm component **300** (which could, of course, be the forearm **30**B discussed and depicted above) that can be coupled to the upper arm **30**A. More specifically, as best shown in FIG. **22**A, the forearm **300** has an opening **306** defined at a proximal end of the arm **300** that is configured to be coupled to the link bevel gear **170**B as discussed above. In one implementation, a screw **308** secures or threadably couples the link bevel gear **170**B to motor housing **302**A. This forearm **300** has a cautery end effector **332** that can be a monopolar electrocautery device as discussed in further detail below.

As shown in FIGS. **22**A and **22**B, the forearm **300** is made up a motor housing **302** that is coupled to a gear housing **304**. A motor assembly **320** is positioned within the motor housing **302** and gear housing **304**. The motor housing **302** is actually made up of two housing components—a first motor housing component **302**A and a second motor housing component **302**B—that are coupled to each other to make up the housing **302**. The first component **302**A and second component **302**B are secured to each other at least in part by the screw **310**, which is inserted through holes in both components **302**A, **302**B and threadably coupled to both. The motor housing **302** is secured to the gear housing **304** via screws **312**, which are positioned through holes in the motor housing **302** and into the gear housing **304**.

As best shown in FIGS. **23**A-**24**C, the motor assembly **320** is comprised of two parts: a motor **320**B and a gear head **320**A, which is operably coupled to the motor **320**B. A drive gear (which is also a "spur gear") **324** is operably coupled to the shaft **322** extending from the motor assembly **320**. In one embodiment, the shaft **322** has a flat portion resulting in a "d shaped" geometry, and the gear **324** has a hole that mates that geometry, thereby ensuring that the shaft **322** and gear **324** are not rotatable in relation to each other when they are coupled. In a further alternative, the gear **324** is also adhesively coupled to the shaft **322** with JB Weld or any known adhesive material. Alternatively, the gear **324** and shaft **322** can be coupled in any known fashion using any known coupling mechanism or configuration.

As best shown in FIG. **24**B, the gear housing **304** has a housing cover (also referred to as a "housing cap") **326** that is coupled to the distal portion of the gear housing **304** with screws **328** that are threadably coupled through holes in the cover **326** and into the gear housing **304**. The housing cover **326** and screws **328** can, in some embodiments, apply a preload force to bearings **340**, **342** positioned inside the housing **304** (as best shown in FIG. **24**C). As best shown in FIGS. **23**A and **23**B, the drive spur gear **324** is operably coupled in the gear housing **304** to the driven spur gear **336**. As shown in FIG. **24**C, the driven spur gear **336** is operably coupled to the cautery end effector **332** and is supported by bearings **340**, **342**. The bearings **340**, **342** are translationally fixed to the driven spur gear **336** by a nut **338** that is threadably coupled to the spur gear **336**. The nut **338** does not apply a preload to the bearings **340**, **342**. In one embodiment, a spacer **344** is included to provide bearing spacing. The monopolar electrocautery end effector **332** is threadably coupled at a proximal end of the end effector **332** to the spur gear **336**.

In use, electricity is transferred from the proximal tip **334** of the end effector **332** to the distal portion of the end effector **332** through a slip ring (not pictured) that is secured to the motor housing **302**. In one embodiment, the slip ring is secured to a configuration **314** formed in the motor housing **302** as shown in FIG. **22**B. The distal end of the end effector **332** is used to cauterize tissue.

In the embodiment described herein, the cautery forearm **300** has only one motor assembly **320** that has a two-stage gearhead. The first stage is the gear head **320**A coupled to the motor **320**B, and the second stage is the spur gear set made up of the drive spur gear **324** and the driven spur gear **336**.

In accordance with one implementation, the cautery forearm component **300** does not contain a local control board. Instead, the component **300** can have a flexible electrical ribbon cable (not shown) operably coupled to the motor that connects to the local control in the upper arm (such as the local control board **132** in FIG. **11**A). In one embodiment, the local control board in the upper arm (such as board **132**, for example) can have one or more extra components to facilitate an additional motor. The single motor (not shown) in the cautery forearm component **300** can actuate rotation of the end effector **332**.

FIGS. **25**-**29**B depict yet another alternative embodiment of a cautery forearm component **400** (which could, of course, be the forearm **30**B discussed and depicted above) that can be coupled to the upper arm **30**A. This forearm **400** has a cautery end effector **402** that has an "inline" configuration that minimizes the overall cross-section of the forearm **400** and ultimately the robotic device to which it is coupled, thereby aiding in both surgical visualization and insertion. As described in further detail below, according to one embodiment, the inline configuration has a direct-drive configuration that enables the size of the forearm **400** to be reduced by almost half.

As best shown in FIGS. **25**, **26**A, **26**B, and **28**A, according to one implementation, the cautery end effector **402** is a removable cautery tip **402**. The end effector **402** is removably coupled to the arm **400** at the drive rod **404**. More specifically, in this embodiment, the end effector **402** has a lumen at its proximal end with threads formed on the inside of the lumen such that the threads **404**A on the distal portion of the drive rod **404** can be threaded into the lumen in the end effector **402**. The coupling of the end effector **402** and the drive rod **404** results in an electrical connection between the end effector **402** and the drive rod **404**.

As best shown in FIG. **26**B, a first slip ring **426** electrically couples the monopolar cautery generator (the power source for the end effector **402**, which is not shown) to the motor coupler **410**. More specifically, the first slip ring **426** is coupled to a wire **429** that is coupled to the generator (not shown), thereby electrically coupling the ring **426** to the generator. Further, the slip ring **426** is secured to the body portions **430**A, **430**B (as best shown in FIG. **25** and discussed in further detail below) such that the ring **426** does not rotate in relation to the body **430**. In contrast, the slip ring **426** is rotatably coupled to the motor coupler **410** such that the ring **426** and coupler **410** are electrically coupled and can rotate in relation to each other. The motor coupler **410** is threadably and electrically coupled to the drive rod **404**. The cautery end effector **402** is coupled to the electrical cautery interface (also referred to herein as a "pin") **412**. This pin **412** is coupled to the drive rod **404** via a second slip ring, which is positioned generally in the area identified as **428** in FIG. **26**B, thereby ultimately resulting in an electrical connection between the end effector **402** and the first slip ring **426**. In one embodiment, the second slip ring **428** is secured to the drive rod **404** or is a part of the drive rod **404**. Alternatively, the slip ring **428** can be a separate component. This electrical connection of the first slip ring **426** to the end effector **402** through the motor coupler **410** enables transfer of the electrical energy to the end effector **402** that is necessary for cauterization. This is explained further below. According to one embodiment, the coupling of the end effector **402** and the drive rod **404** is maintained by the friction of the threadable coupling of the two components, along with the deformability of the end effector **402**, which reduces the amount of force applied to that coupling. In accordance with one implementation, the end effector **402** has an o-ring at its distal end that helps to create a seal at the coupling to the drive rod **404** that inhibits inflow of biological material.

Alternatively, the end effector **402** can be non-removable. Instead, the end effector **402** can be integrated into the drive rod such that the need for the removable threaded connection would be eliminated. In such an embodiment, the second slip ring **428** could be replaced with a rigid electrical connection.

As best shown in FIGS. **25**, **28**A, **28**B, **28**C, and **28**D, two bearings **408**A, **408**B are positioned over a proximal portion of the drive rod **404** and help to provide support to the end effector **402**. The shoulder **406** on the drive rod **404** help to maintain the position of the bearings **408**A, **408**B in relation to the drive rod **404**. In addition, the motor coupler **410** is threadably coupled to threads **404**B on the proximal end of the drive rod **404** and thus also helps to retain the bearings **408**A, **408**B in place on the drive rod **404**. The electrical connection discussed above extends through all three components: the motor coupler **410**, the drive rod **404**, and the end effector **402**. According to one embodiment, as noted above, the pin **412** extending from the proximal portion of the end effector **402** (as best shown in FIGS. **25** and **26**A) makes the electrical connection of the three components possible. This configuration of the three components allows for easy removal of one end effector **402** and replacement with another end effector **402** that is positioned such that the electrical connection is re-established by the simple threaded coupling of the new end effector **402** to the drive rod **404**.

Alternatively, the bearings **408**A, **408**B can be replaced with other support components. One example would be bushings.

Continuing with FIGS. **25**, **28**C, and **28**D, the motor coupler **410** couples the motor assembly **414** to the end effector **402** through the drive rod **404**. More specifically, the motor coupler **410** is coupled with the motor shaft **416** such that the coupler **410** is positioned over the shaft **416**. In one embodiment, the motor shaft **416** has a flat portion **416**A on the shaft that creates a "D-shaped" configuration and the motor coupler **410** has a corresponding "D-shaped" configuration that mates with the shaft **416** such that the shaft **416** and coupled **410** are not rotatable in relation to each other when they are coupled.

In accordance with one embodiment as best shown in FIGS. **28**C and **28**D, the motor coupler **410** has two portions with different diameters: a large portion **410**A and a small portion **410**B. The small portion **410**B is sized to receive the first slip ring **426** discussed above that creates the necessary electrical connection. That is, as discussed above, when positioned over the small portion **410**B of the motor coupler **410**, the slip ring **426** can provide a constant clamping force on the motor coupler **410** that maintains the electrical connection between the motor coupler **410** and the motor shaft **416** during rotation. This type of connection (the slip ring) allows for infinite rotation without twisting of any wires. With respect to the coupling of the motor coupler **410** with the drive rod **404**, the coupling in some implementations is reinforced or further secured with an adhesive. For example, the adhesive could be a Loctite® adhesive or any other known adhesive for use in medical device components.

As best shown in FIGS. **29**A and **29**B, the proximal end of the forearm **400** has a coupling component **420** that allows for coupling the forearm **400** to the rest of the surgical system with which the forearm is incorporated. For example, in the device **10** depicted and discussed above, the coupling component **420** would be coupled to the upper arm **30**A. The coupling component **420** is coupled to the proximal portion of the forearm **400** with two screws **424** that are positioned through holes in the forearm **400** and into a portion of the coupling component **420** as shown.

The coupling component **420** has an opening **422** defined in the component **420** (as best shown in FIG. **29**B) that couples to the appropriate component of the surgical system. In this embodiment, the opening **422** is a rectangular-shaped opening **422**, but it is understood that it could be any configuration of any type of coupling component or mechanism, depending on the system to which the forearm **400** is being coupled.

Alternatively, the coupling component **420** can be eliminated in those embodiments in which the forearm **400** is an integral part of the upper arm of a device or in any embodiment in which there is no forearm.

Returning to FIGS. **25** and **26**A, the body **430** of the forearm **400** is made up of two body portions (also referred to as "shells") **430**A, **430**B. The two portions **430**A, **430**B are coupled together with the screws **432** and the aforementioned screws **424**. According to one embodiment, each of the two body portions **430**A, **430**B have internal features as best shown in FIG. **26**A that help to retain the motor assembly **414**, bearings **408**A, **408**B, and other internal components in position with respect to each other inside the body **430**. In one implementation, there is space provided within the body **430** to allow for inclusion of any excess wires. It is understood that additional components or mechanisms can be included on an outer portion of the portions **430**A, **430**B to aid in fluidically sealing the body **430**. For example, in one embodiment, the interface of the portions **430**A, **430**B may have mating lip and groove configurations to provide a fluidic seal at the coupling of the two portions **430**A, **430**B.

Another embodiment of a robotic device **500** is depicted in FIGS. **30**-**39**B. This embodiment has a device body **510**, a left arm **520**, and a right arm **530**, as shown in FIG. **30**. Both the left and right arms **520**, **530** are each comprised of 2 segments: an upper arm (or "first link") and a forearm (or "second link"). Thus, the left arm **520** has an upper arm **520**A and a forearm **520**B and the right arm **530** has an upper arm **530**A and a forearm **530**B.

In this embodiment, the robotic device **500** is similar in some respects to the device embodiment described above and depicted in FIGS. **1**A-**2**. However, the current device **500** is unique because of its "clutch-like" joint configuration as described in detail below. To insert a device or platform in a NOTES procedure through a natural orifice, the device **500** needs to be very flexible to navigate the natural curvature of the natural orifice. The clutch-like joint configuration at each joint in this device **500** provides the device **500** with the necessary flexibility. According to one embodiment, this device **500** will be locally controlled by a control system similar to the system described above with respect to the previous embodiments.

The clutch-like configuration, according to one embodiment, is best shown in FIGS. **32**A and **32**B. As can be seen in these figures, the overall joint design is fairly similar to the joint design of the embodiments described above. However, in this embodiment, the drive bevel gear **560** has a portion **562** of the gear **560** that has no teeth. The tooth-free portion **562** creates the clutch-like configuration. That is, when the drive bevel gear **560** is positioned such that the tooth-free portion **562** is in contact with or adjacent to the driven gear **564** such that no teeth are engaged, the overall joint **566** is free to move and thus has flexibility that can be helpful during insertion.

As best shown in FIGS. **31**A, **31**B, and **31**C, this embodiment can also have one or more rubber band-like components (also referred to herein as "elastomers" or "elastic bands") **550** that can be used to keep each joint stabilized and thus each arm positioned to keep the robotic device **520** as compact as possible during insertion. In a further embodiment, the band(s) **550** can also keep the arms in the correct position for engagement of the bevel gears. More specifically, the device body **510** and the two upper arms **520**A, **530**A have a channel **552** formed on a top portion of each component as shown in FIG. **31**B that is configured to receive the elastic band(s) **550**. In certain embodiments, there are also bolts **554** positioned at strategic locations—such as, for example, the locations shown in FIG. **31**B—to which the elastic band(s) **550** can be attached. In one implementation, the elastic band (or bands) **550** applies forces to the arms **520**A, **530**A that urge the arms **520**A, **530**A together as shown by the arrows in FIG. **31**B while also urging both arms upward as shown by the arrow in FIG. **31**C.

In one alternative embodiment, this clutch-like configuration could also be used for homing if the positioning of the arms **520**, **530** is lost (that is, the joint positions are unknown). In that scenario, each of the drive bevel gears could be positioned so that they are not engaged, whereby the joint positions of the device **500** are known once again. In this embodiment, no additional redundant position sensors would be needed.

It is understood that other types of stabilization devices or mechanisms could also be used in place of the elastic bands **550**. For example, in one alternative embodiment, two torsion springs could be used that are positioned opposite of each other, resulting in equal and opposite rotational forces. Alternatively, other known clutch-like devices or mechanisms could be used, including, for example, any commercially available or custom made clutch. In further alternatives, flexible links could be used in combination with solid bevel gears (no teeth missing). In such embodiments, the flexibility of the flexible links could be activated thermally (thermo plastic), electrically (shape memory alloy), or mechanically (friction based). FIG. **31**D depicts one exemplary embodiment of a mechanically-activated link **556**. The link **556** becomes flexible when a small force F is applied to the cable **558**, thereby reducing the friction between the balls **557** and sockets **559** in the link **556** and thus creating flexibility in the link **556**. In contrast, when a large force F is applied to the cable **558**, friction is increased between the balls **557** and sockets **559** and the link **556** becomes more rigid.

FIG. **33** depicts the various degrees of freedom of the various joints of the two arms **520**, **530**. In this embodiment, the left arm **520** has four degrees of freedom, while the right arm **530** has five degrees of freedom. More specifically, moving from the proximal end of the right arm **530** to the distal end, the right arm **530** has shoulder pitch (θ**1**), shoulder yaw (θ**2**), elbow roll (θ**3**), elbow yaw (θ**4**), and end effector roll (θ**5**). In contrast, the left arm **520** has shoulder pitch, shoulder yaw, elbow yaw, and end effector roll, but no elbow roll. Alternatively, any other known kinematic configuration could also be used. The multiple degrees of freedom for each arm results in more dexterous arms for more precision operations.

FIG. **34** depicts the key components that make up the joint (also referred to as an "elbow joint") between the upper arm **530**A and the forearm **530**B of the right arm **530**. The upper arm **530**A has a motor assembly **600** that includes a motor, an encoder, and a gearhead. The distal end of the motor assembly **600** is positioned in and coupled to the gear housing **602**. In one embodiment, the motor assembly **600** has a flat portion along an exterior portion of the assembly **600** that creates a "D-shaped" configuration that matches a D-shaped configuration of a lumen in the gear housing **602** such that the assembly **600** and housing **602** cannot rotate in relation to each other when the assembly **600** is positioned in the lumen. In a further implementation, an adhesive can also be used to further secure the assembly **600** and housing **602**.

The motor assembly **600** has a motor shaft **600**A extending from the distal end of the assembly **600**. The shaft **600**A can be coupled to the motor spur gear **604** such that the spur gear **604** is positioned over the shaft **600**A. In one embodiment, the shaft **600**A has a flat portion that results in a "D-shaped configuration that matches a "D-shaped" configuration of the lumen in the spur gear **604** such that when the spur gear **604** is positioned over the shaft **600**A, neither component can rotate in relation to the other. The motor spur gear **604** couples or mates with the driven spur gear **606** when the two gears are properly positioned in the gear housing **602** such that rotation of the motor spur gear **604** rotates the driven spur gear **606**.

The driven spur gear **606** is coupled to the output link **608** such that actuation of the motor assembly **600** causes the output link **608** to rotate. More specifically, the driven gear **606** is positioned over the proximal end of the output link **608**. In one embodiment, a portion of the proximal end of the output link **608** has a flat portion that results in a "D-shaped" configuration as described with respect to other components above, thereby resulting in the output link **608** and spur gear **606** being coupled such that they are not rotatable in relation to each other. A screw **610** is threadably coupled to the output link **608** and secures the spur gear **606** on the output link **608**, along with the bearings **612**, **614**, while also translationally securing the output link **608**. The bearings **612**, **614** can constrain and support the output link **608** and are supported within the gear housing **602**. The components are retained in the gear housing **602** with the help of the housing cover **616**, which is secured to the housing **602** with the help of screws **618**, which also apply a preload force through the gear housing cover **616**. According to one embodiment, the screw **620** helps to secure an elastic band between the upper arm **530**A and forearm **530**B, as described above.

FIG. **35** depicts the forearm **530**B and end effector **630** of the right arm **530**. In this embodiment, the end effector **630** is another implementation of a monopolar electrocautery device **630**. The forearm **530**B has a motor housing **632** that is configured to hold the motor assembly (not shown) and also contains the slip ring **638**, which is secured in the housing **632**. It is understood that the motor assembly and associated drive train are substantially similar to the same components in the upper arm as described above.

The motor spur gear **634** is operably coupled to the driven spur gear **636** in the motor housing **632**. The driven gear **636** is supported and constrained by bearing **640** and bushing **642**, which prevents translation of the driven gear **636**. The driven gear **636** is threadably coupled to the removable end effector **630** via the threads on the distal portion of the gear **636**. The end effector **630** is electrically coupled to the slip ring **638**.

In addition, according to one embodiment, the forearm **530**B is fluidically sealed such that external fluids (such as body fluids, for example) are prevented from entering the internal portions of the forearm **530**B. One component that helps to fluidically seal the forearm **530**B is a gasket **644**, which is positioned between the housing **632** and the housing cover **646** such that the screws **648** that secure the housing cover **646** to the housing **632** also secures the gasket **644** to the bushing **642**. In one embodiment, the gasket **644** is made of soft urethane or silicon. Alternatively, the gasket **644** is made of any material that can help to fluidically seal the housing **632**.

FIGS. **36**-**39**B depict the forearm **520**B and end effector **650** of the left arm **520**. In this embodiment, the end effector **650** is another implementation of a grasper component (also referred to herein as a "tissue manipulation component" or "tissue manipulator") **650**. As best shown in FIGS. **36** and **37**, the forearm **520**B has two motor assemblies: the rotation motor assembly **652** and the grasper motor assembly **654**. As best shown in FIG. **36**, the rotation motor assembly **652** can cause the forearm **520**B to rotate. As best shown in FIG. **37**, the grasper motor assembly **654** can cause the grasper **650** to move between its open and closed positions.

Returning to FIG. **36**, in one embodiment, the rotation motor assembly **652** has a motor, an encoder, and an integrated gear head. Further, the assembly **652** has a motor shaft **656** that couples to the motor spur gear **658**. According to one implementation, the shaft **656** has a flat portion **656**A that results in the shaft **656** having a "D-shaped" configuration that mates with a "D-shaped" lumen defined in the spur gear **658**. As such, the shaft **656** and gear **658** are coupled such that neither component can rotate in relation to the other. A portion of the motor assembly **652** and the motor spur gear **658** are positioned in the proximal gear housing **660**, which also houses the driven spur gear **662** such that the motor spur gear **658** and driven spur gear **662** are rotatably coupled to each other when positioned in the housing **660**. In one embodiment, the motor assembly **652** is coupled to the housing **660**, and in certain implementations, the assembly **652** is geometrically and/or adhesively secured to the housing **660**. Actuation of the motor assembly **652** causes rotation of the motor spur gear **658**, which causes rotation of the driven spur gear **662**.

The driven spur gear **662** is operably coupled to the output link **664**, which is coupled to the upper arm **520**A and thus is part of the joint between the upper arm **520**A and forearm **520**B. As shown in FIG. **36**, the driven spur gear **662** and two bearings **666**, **668** are positioned on the output link **664** such that the bearings **666**, **668** are supported within the proximal gear housing **660** and provide some support and constraint to the output link **664**. A screw **670** is coupled to the output link **664** and helps to secure the gear **662** and bearings **666**, **668** to the link **664** while also translationally constraining the link **664**. In one embodiment, the output link **664** has a flat portion **664**A that creates a "D-shaped" configuration that mates with a D-shaped lumen defined in the driven spur gear **662** such that the gear **662** and link **664** cannot rotate in relation to each other when the gear **662** is positioned on the link **664**.

The housing **660** also has a housing cover **672** that is positioned over the opening in the housing **660** that contains the gears **658**, **662**. The cover **672** is secured in place by screws **674** and thereby applies a preload force to the bearings **666**, **668**. The housing also has an additional screw **676** that can be used to secure or otherwise constrain an elastic band that is coupled to both the upper arm **520**A and the forearm **520**B to stabilize the arms as described above.

In one implementation, the housing **660** is configured to be fluidically sealed such that no liquid can gain access to any interior portions of the housing **660**.

Returning to FIG. **37**, in one embodiment, the grasper motor assembly **654** has a motor, an encoder, and an integrated gear head. Further, the assembly **654** has a motor shaft **680** that couples to the motor spur gear **682**. According to one implementation, the shaft **680** has a flat portion **680**A that results in the shaft **680** having a "D-shaped" configuration that mates with a "D-shaped" lumen defined in the spur gear **682**. As such, the shaft **680** and gear **682** are coupled such that neither component can rotate in relation to the other. A portion of the motor assembly **654** and the motor spur gear **682** are positioned in the distal gear housing **684**, which also houses the driven spur gear **686** such that the motor spur gear **682** and driven spur gear **686** are rotatably coupled to each other when positioned in the housing **684**. In one embodiment, the motor assembly **654** is coupled to the housing **684**, and in certain implementations, the assembly **654** is geometrically and/or adhesively secured to the housing **684**. Actuation of the motor assembly **654** causes the grasper **650** to move between its open and closed positions, as described in detail below.

The driven spur gear **686** is operably coupled to a push/pull mate **688**, which is coupled to the grasper **650**. More specifically, the driven spur gear **686** and two bearings **690**, **692** are positioned on a threaded rod **694** extending from the push/pull mate **688** such that the bearings **690**, **692** are supported within the distal gear housing **684** and provide some support and constraint to the driven gear **686**. The gear **686** is threadably coupled to the rod **694**. A housing cover **702** is configured to cover the opening in the gear housing **684** and thereby applies a preloading force to bearings **690**, **692** via screws **704**, **708** that are threadably coupled through the cover **702** and into the housing **684**. The housing **684** also has a gasket or seal **710** that fluidically seals against the push/pull mate **688**, thereby preventing any fluids from entering the interior of the housing **684**. In one embodiment, the seal **710** is made of soft urethane or silicon or any other known material for use in creating a fluidic seal.

When the driven spur gear **686** rotates, the push/pull mate **688** translates, because the push/pull mate **688** is rotationally constrained to the grasper housing **696**. More specifically, as best shown in FIGS. **38**A and **38**B, the push/pull mate **688** has a projection **689** that extends away from the push/pull mate **688** at 90 degrees in relation to the longitudinal axis of the forearm **520**B. As such, the projection **689** is positioned in the housing **696** such that the push/pull mate **688** cannot rotate in relation to the housing **696**.

In one embodiment, as best shown in FIGS. **37**, **38**A, and **39**A, the grasper **650** is removably coupled to the push/pull mate **688** via a ball and socket coupling, with the ball **698** positioned at a proximal end of the replaceable grasper **650**. Through this coupling, the translational motion of the push/pull mate **688** is transferred to the grasper **650** jaws such that the jaws move between open and closed positions. The grasper **650** is geometrically and adhesively constrained to the grasper mate **700**, which is geometrically constrained to the grasper housing **696**.

As best shown in FIGS. **38**A, **39**A, and **39**B, the grasper **650** and the grasper mate **700** are configured to be removably mateable to the distal end of the grasper housing **696** and the push/pull mate **688** as described above. As such, the grasper **650** can be easily coupled for use and just as easily removed and replaced with another end effector. According to one implementation, the grasper end effector **650** could be replaced with other known manipulation devices such as, but not limited to, other toothed graspers, bipolar electrocautery devices, clip appliers, shears, ultrasonic sealers, and the like. When the grasper **650** (or other end effector) has been coupled to the grasper housing **696** and the push/pull mate **688** such that the ball **698** is positioned in the socket of the push/pull mate **688**, the end effector **650** can be secured to the housing **696** with an elastic band **712** as shown in FIG. **39**B. Alternatively, any other type of band or retention device or mechanism can be used.

The various in vivo robotic devices disclosed herein and other such devices are intended to be inserted into and positioned inside a cavity inside a patient, such as, for example, the peritoneal cavity. Various methods and devices can be used to achieve the insertion of the device into the cavity. FIGS. **40**A-**45** depict various embodiments of such insertion devices.

FIGS. **40**A, **41**A, and **41**B depict an insertion device **800** having an insertion tube **802** defining an insertion chamber **804**, an insertion port **806**, and a proximal tube cover **808**. As shown in FIG. **40**A, in use, a robotic device **810** (such as, for example, any of the device embodiments discussed above), can be positioned inside the insertion chamber **804** and coupled to an insertion rod **812** that is positioned through the proximal tube cover **808**. The device **800** can be positioned against an incision in a patient that accesses the target cavity such that the insertion port **806** is positioned against or in the incision. Once the device **800** is correctly positioned, a user can use the insertion rod **812** to urge the device **810** out of the chamber **804** through the port **806** and into the patient's cavity.

Alternatively, as best shown in FIG. **40**B (including FIGS. **40**B-**1**, **40**B-**2**, **40**B-**3**, and **40**B-**4**), the robotic device **810** can be positioned inside the insertion tube **802** and magnetically coupled to a handle **824** positioned along an external portion of the tube **802** (as shown in FIG. **40**B-**1**). According to some implementations, the handle **824** can be used to introduce the robotic device **810** into the abdominal cavity and secure the device **810** to the abdominal wall through a magnetic coupling. More specifically, once an opening is established between the chamber **804** and the patient's cavity, the handle **824** can be urged distally along the outer surface of the tube **802**, thereby urging the device **810** via magnetic forces in a distal direction as well such that the device **810** is urged out of the distal end of the tube **802** as best shown in FIG. **40**B-**2**. The handle **824** can then be urged to the end of the tube **802** such that the arms of the device **810** fully exit the chamber **804** as best shown in FIG. **40**B-**3** and further such that the entire device **810** exits the chamber **804** and is positioned in the cavity using the handle **824** (wherein the handle **824** is positioned outside the patient's body) as best shown in FIG. **40**B-**4**. This insertion method can allow the orifice or insertion tube **802** to remain open for the duration of the surgical procedure. The orifice or insertion tube **802** can be used by other surgical devices as well, such as for specimen removal, for example. Furthermore, the magnetic coupling can allow the robotic device **810** to access a larger area of the abdominal cavity with different platform orientations. According to one embodiment, a channel could be created within the orifice or insertion tube **802** that can pass the communication and power tether to the robotic device **810**.

According to one embodiment, the insertion tube **802** is comprised of a single rigid and/or flexible tubular structure. Alternatively, the tube **802** is not limited to a tubular configuration and could have any known shape that could contain a robotic device for insertion into a patient's cavity. For example, in one embodiment, the cross-section of the tube **802** could have a rectangular or oval shape.

In a further alternative, the insertion tube **802** can be flexible. In such an embodiment, once the insertion port **806** is secured to or otherwise coupled with the incision site, the flexible tube **802** (with the robotic device housed within) could be coupled to the port **806**. At that point, the abdominal cavity is insufflated and the flexible tube **802** becomes semi-rigid as a result of the insufflation, like a balloon full of air. The robotic device is then inserted and, in one embodiment, the flexible tube **802** collapses at a point parallel to the coupling of the insertion rod to the device, reducing the external size of the tube **802**. A pressure release valve would be needed to account for the change in volume.

FIGS. **42**A and **42**B depict one embodiment of the proximal tube cover **808**. In this embodiment, the cover **808** has a tube mate **850** coupled to the insertion tube **802**. In one embodiment, the tube mate **850** is geometrically and/or adhesively secured to the tube **802**. The tube mate **850** is coupled at its opposite end to a housing **852**. In this embodiment, the tube mate **850** and housing **852** are coupled with screws **854**. Alternatively, any known coupling mechanisms or methods can be used. In one implementation, a gasket **856** is positioned between the tube mate **850** and housing **852**. A bushing **864** is positioned in and secured to the housing **852**. In accordance with one implementation, the bushing **864** can be mated with the insertion rod **812** described above such that the rod **812** can move longitudinally with smooth linear motion. The housing **852** is coupled to a seal cap **858** via screws **860**, and a gasket **862** and a seal **866** are positioned between the housing **852** and cap **858**. In one embodiment, the seal **866** creates a dynamic seal between the insertion rod **812** and the seal **866** to prevent the loss of insufflation of the abdominal cavity as the rod **812** is moved back and forth during a procedure.

FIG. **43** depicts one implementation of the insertion port **806**. As shown, the port **806** includes a insertion cone **880** and a tube mate **882**. The tube mate **882** is coupled to the insertion tube **802**. The tube mate **882** can be geometrically and/or adhesively coupled to the tube **802**. On the opposite end, the tube mate **882** is coupled to the insertion cone **880** with screws **884**. In addition, a gasket **886** is positioned between the tube mate **882** and the insertion cone **880**.

It is understood that the insertion cone **880** is not limited to conical geometry. That is, the insertion cone **880** could also have a tubular configuration or any other known configuration so long as the component could still operate as a port.

In certain alternative embodiments, any of the robotic devices disclosed or contemplated herein (including, for example, the robotic devices **8**, **810**) can be manually inserted into the abdominal cavity through the advancement of an insertion rod (such as, for example, the insertion rods **40**, **812** described above) or a magnet. Alternatively, any such robotic device (such as robotic device **8**, **810**) can be robotically inserted into the abdominal cavity through the use of a robotic arm. In such an embodiment, the insertion procedure could be performed by the surgeon or autonomously. It is understood that the robotic devices such as devices **8**, **810** have a "sweet spot" or robotic workspace volume with high dexterity and manipulability. The use of a robotic arm can expand this workspace volume such that the volume includes the entire abdominal cavity. According to another implementation, a "soft boundary" can be created between the workspace boundary, or limits, and the "sweet spot" of the workspace. That is, if the device crosses the soft boundary, the system has a sensor or other mechanism that is triggered such that the system actuates the external robotic arm to automatically and/or autonomously grossly position the robotic device back to the "sweet spot" of the workspace. Such repositioning operation can also be done manually or robotically under surgeon supervision. Autonomous gross positioning could eliminate the bed side assistant and human errors that commonly occur between the surgeon and assistant relating to positioning of the robotic device.

Various embodiments of the insertion device **800** can have cameras (also referred to herein as "visualization devices"). The camera embodiments disclosed herein allow the user to view the device during insertion into and use in the patient's cavity.

Returning to FIG. **40**A, in one embodiment, a camera **814** is housed within the insertion port **806**. According to one embodiment, the camera **814** is a 3 MM CMOS camera **814**. The vision cone **820** (the area captured by the camera **814** such that a user can see that area on the display) achieved by the camera **814** is shown. In one embodiment, the camera **814** is coupled to a connection component **816** that couples the camera **814** to a monitor **818** or other type of display. Light, in this embodiment, is provided by LED lights **822** positioned on the distal end of the insertion port **806**. Alternatively, any known lights that can be used with a medical device to illuminate a surgical space for viewing with a camera can be used.

FIGS. **44**A-**44**F depict another embodiment of a camera **890** for use with certain embodiments of the insertion device **800**. The camera **890** has lights **892** coupled to the camera **890**. In this embodiment, the camera **890** is coupled to the device **800** with a four-bar linkage **896** made up of four bars (or "links") **896**A, **896**B, **896**C, **896**D. That is, the four bars **896**A, **896**B, **896**C, **896**D can be manipulated by a user to move the camera **890** out of the cone **880** and position it to view the robotic device during insertion and use as shown in the figures. The vision cone **894** provides a schematic depiction of the area captured by the camera **890** in one embodiment. This configuration allows for a larger camera (such as, for example, a high definition camera) to be housed in the insertion cone **880** prior to insertion of the device (when the device is not positioned in or through the cone **880**) and then moved out of the cone **880** during use. That is, once the port **806** is attached to the incision site and the cavity is insufflated, the camera **890** can be deployed via the four-bar linkage **896**. This positioning of the camera in the cone **880** and then moving it out of the cone allows for the robotic device to always be under visualization during insertion.

In a further alternative, any other known actuation device or mechanism could be used to deploy the camera. One such further example is a preformed shape memory alloy or the like.

In one embodiment, the camera **890** is a USB webcam.

FIGS. **45**A-**45**D depict yet another camera implementation. In this embodiment, the camera **900** is coupled to a linkage **902** that is coupled to an exterior portion of the insertion cone **880**. More specifically, the linkage **902** is made up of two links **902**A, **902**B, and the camera **900** is coupled to the link **902**B. The link **902**A is pivotally coupled to the insertion cone **880**, and the link **902**B is pivotally coupled to the link **902**A. In an undeployed configuration as shown in FIGS. **45**B, **45**C, and **45**D, the links **902**A, **902**B are configured such that the camera **900** and links **902**A, **902**B form a portion of the cone **880**. In the deployed configuration as shown in FIG. **45**A, the links **902**A, **902**B are extended so that the camera **900** is in a position to capture images of the surgical area. The lights (not shown) can be coupled to the link **902**B or link **902**A (or both) to illuminate the viewing area.

It is understood that any of the camera embodiments disclosed above can also have a zoom lens package or mechanical translation parallel to the axis of the vision cone via a linear actuator.

Although the present invention has 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 of the invention.

What is claimed is:

1. A robotic device, comprising:

(a) an elongate device body configured to be positioned at least partially within a body cavity of a patient through an incision, the device body comprising:
  (i) a motor housing comprising a first motor and a second motor;
  (ii) a gear housing disposed at a distal end of the device body, the gear housing comprising:
    (A) a first gear positioned at a distal end of the gear housing, the first gear operably coupled to the first motor; and
    (B) a second gear positioned at a distal end of the gear housing, the second gear operably coupled to the second motor; and
  (iii) a coupling mechanism disposed at a proximal end of the device body, the coupling mechanism constructed and arranged to be coupleable with an external positioning component;
(b) a first arm operably coupled to the first gear, wherein the first arm is positioned substantially within a longitudinal cross-section of the device body when the first arm is extended in a straight configuration, the first arm comprising:
  (i) a first upper arm segment comprising a first arm motor;
  (ii) a first forearm segment; and
  (iii) a first end effector; and
(c) a second arm operably coupled to the second gear, wherein the second arm is positioned substantially within the longitudinal cross-section of the device body when the second arm is extended in a straight configuration, the second arm comprising:
  (i) a second upper arm segment comprising a second arm motor;
  (ii) a second forearm segment; and
  (iii) a second end effector.

2. The robotic device of claim **1**, wherein the gear housing comprises first, second, and third housing protrusions disposed at the distal end of the gear housing, wherein the first gear is disposed between the first and second housing protrusions and the second gear is disposed between the second and third housing protrusions.

3. The robotic device of claim **1**, wherein the first arm is operably coupled to the first gear at a first shoulder joint, wherein the first shoulder joint is positioned substantially within the longitudinal cross-section of the device body.

4. The robotic device of claim **3**, wherein the second arm is operably coupled to the second gear at a second shoulder joint, wherein the second shoulder joint is positioned substantially within the longitudinal cross-section of the device body.

5. The robotic device of claim **1**, wherein the first gear is configured to rotate around a first axis parallel to a length of the device body.

6. The robotic device of claim **5**, wherein the second gear is configured to rotate around a second axis parallel to the length of the device body.

7. The robotic device of claim **1**, wherein the first upper arm segment and the first forearm segment are collinear when the first arm is extended in the straight configuration.

8. The robotic device of claim **7**, wherein the second upper arm segment and the second forearm segment are collinear when the second arm is extended in the straight configuration.

9. The robotic device of claim **1**, wherein the external positioning component is a support rod.

10. The robotic device of claim **1**, wherein the first arm motor is operably coupled to a first local control board and the second arm motor is operably coupled to a second local control board.

11. The robotic device of claim **1**, wherein the first gear comprises a tooth-free portion and the second gear comprises a tooth-free portion.

12. A robotic device, comprising:

(a) an elongate device body configured to be positioned at least partially within a body cavity of a patient through an incision, the device body comprising:
  (i) a first gear positioned at a distal end of the device body, the first gear configured to rotate around a first axis parallel to a length of the device body;
  (ii) a second gear positioned at the distal end of the device body, the second gear configured to rotate around a second axis parallel to the length of the device body; and
  (iii) a coupling mechanism disposed at a proximal end of the device body, the coupling mechanism constructed and arranged to be coupleable with an external positioning component;
(b) a first arm operably coupled to the first gear at a first shoulder joint, wherein the first shoulder joint is positioned substantially within a longitudinal cross-section of the device body, the first arm comprising:
  (i) a first upper arm segment comprising a first arm motor;
  (ii) a first forearm segment; and
  (iii) a first end effector; and
(c) a second arm operably coupled to the second gear at a second shoulder joint, wherein the second shoulder

joint is positioned substantially within the longitudinal cross-section of the device body, the second arm comprising:

(i) a second upper arm segment comprising a second arm motor;

(ii) a second forearm segment; and

(iii) a second end effector.

13. The robotic device of claim **12**, wherein the first arm is positioned substantially within the longitudinal cross-section of the device body when the first arm is extended in a straight configuration.

14. The robotic device of claim **12**, wherein the second arm is positioned substantially within the longitudinal cross-section of the device body when the second arm is extended in a straight configuration.

15. The robotic device of claim **12**, wherein the first upper arm segment and the first forearm segment are collinear when the first arm is extended in a straight configuration.

16. The robotic device of claim **12**, wherein the second upper arm segment and the second forearm segment are collinear when the second arm is extended in a straight configuration.

17. The robotic device of claim **12**, wherein the first gear comprises a tooth-free portion and the second gear comprises a tooth-free portion.

18. A robotic device, comprising:

(a) an elongate device body configured to be positioned at least partially within a body cavity of a patient through an incision, the device body comprising:

(i) a motor housing comprising a first motor and a second motor;

(ii) a gear housing disposed at a distal end of the device body, the gear housing comprising:

(A) a first gear positioned at a distal end of the gear housing, the first gear operably coupled to the first motor, wherein the first gear is positioned to rotate around a first axis parallel to a length of the device body, wherein the first gear comprises a first tooth-free portion; and

(B) a second gear positioned at a distal end of the gear housing, the second gear operably coupled to the second motor, wherein the second gear is positioned to rotate around a second axis parallel to the length of the device body, wherein the second gear comprises a second tooth-free portion; and

(iii) an external positioning structure coupling mechanism disposed at a proximal end of the device body;

(b) a first arm operably coupled to the first gear, the first arm comprising a first upper arm, a first forearm, and a first end effector, wherein the first arm is positioned substantially within a longitudinal cross-section of the device body when the first arm is extended in a straight configuration such that the first upper arm and the first forearm are collinear, the first upper arm comprising a first arm motor; and

(c) a second arm operably coupled to the second gear, the second arm comprising a second upper arm, a second forearm, and a second end effector, wherein the second arm is positioned substantially within the longitudinal cross-section of the device body when the second arm is extended in a straight configuration such that the second upper arm and the second forearm are collinear, the second upper arm comprising a second arm motor.

19. The robotic device of claim **18**, wherein the first arm is operably coupled to the first gear at a first shoulder joint, wherein the first shoulder joint is positioned substantially within the longitudinal cross-section of the device body.

20. The robotic device of claim **19**, wherein the second arm is operably coupled to the second gear at a second shoulder joint, wherein the second shoulder joint is positioned substantially within the longitudinal cross-section of the device body.

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