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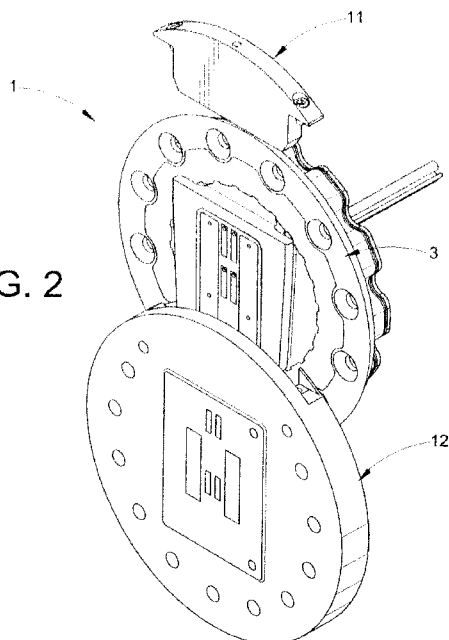
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[Continued on next page]

(54) Title: MODULAR LIMB SEGMENT CONNECTOR

FIG. 2



(57) Abstract: A joint assembly for releasably securing a first and a second segment of an associated modular limb is provided. The joint assembly includes a male connector including a base and a load bearing blade secured to the base of the male connector protruding therefrom. The male connector is adapted to be secured to one of the first and second segments of the associated modular limb. A female connector is provided and includes a base and a load bearing socket secured to the base of the female connector. The socket is configured to selectively receive the blade of the male connector. The female connector is adapted to be secured to the other of the first and second segments of the associated modular limb. A locking member selectively retains the blade of the male connector in the socket of the female connector. The male connector, the female connector, and the locking member cooperate to form a resilient and selectively releasable modular limb joint.



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## MODULAR LIMB SEGMENT CONNECTOR

### BACKGROUND

**[0001]** The present disclosure relates to man-made or artificial limbs for prosthetic or orthotic devices, as well as for robots. More particularly, it relates to a modular limb segment connector, such as an arm segment connector, which can be used in prosthetics, as well as for robotics applications when an artificial limb is required.

**[0002]** In the field of prosthetics, there remains a limited ability to control prosthetic and/or orthotic joints in a suitable manner for practical clinical application. While great strides have been made in prosthetic legs, the development of prosthetic arms has not been as advanced. Typically, limbs such as arms, whether for prosthetics or robotics, are assembled with custom bolted and screwed mechanical connections that are different for each joint. These mechanical connections may or may not include the electrical interconnections between adjacent arm components. Typical solutions can include complex wiring harnesses that require bulky electrical connectors or solder connections. Such solutions are disadvantageous because they only work for a specific joint. In other words, they are not usable for joints between multiple arm modules.

**[0003]** Although prosthetic technology has advanced in recent years, the prior art still has failed to bridge the gap between manmade prosthetics and user demands and needs. Therefore, an extensive opportunity for design advancements and innovation remains where the prior art fails or is deficient. Most myoelectric prosthetic arms move in three ways. They bend at the elbow, rotate at the wrist and a rudimentary hand clamps shut. A need exists to replicate the great many varieties of movements that a human arm is capable of making. It is believed that a human arm has 27 degrees of freedom, including individual finger bending, and the use of an opposable thumb. Robotic arms used as prostheses are not fully articulated to give the user the same degrees of freedom as a natural arm, not to mention the speed and torque of a human arm. Moreover, the human arm can sense pressure, which conventional man-made arms cannot do. It would be advantageous if the prosthetic or robotic arm was sensitive enough to pick up a piece of paper, a wine glass or even a grape without mishap.

**[0004]** While many advances are taking place to allow for better prosthetics and orthotics, as well as more functional robotic limbs, there remains a need to develop better connections for the various segments of a limb so that the segments can be more readily attached and detached in a simple manner, without external wiring, and in a manner that provides a weather tight seal. It would also be advantageous to provide sensors for torque being transmitted between adjacent components of a limb.

#### BRIEF DISCLOSURE OF THE DEVELOPMENT

**[0005]** According to one aspect of the present disclosure, a joint assembly for releasably securing a first and a second segment of an associated modular limb is provided. The joint assembly includes a male connector including a base and a load bearing blade secured to the base of the male connector protruding therefrom. The male connector is adapted to be secured to one of the first and second segments of the associated modular limb. A female connector is provided and includes a base and a load bearing socket secured to the base of the female connector. The socket is configured to selectively receive the blade of the male connector. The female connector is adapted to be secured to the other of the first and second segments of the associated modular limb. A locking member selectively retains the blade of the male connector in the socket of the female connector. The male connector, the female connector, and the locking member cooperate to form a resilient and selectively releasable modular limb joint.

**[0006]** According to another aspect of the present disclosure, another joint assembly for releasably securing a first and a second segment of an associated modular limb is provided. The joint assembly includes a male connector including a base, a load bearing hub secured to the base of the male connector, and at least one first electrical contact secured to the load bearing hub. The base of the male connector is adapted to be secured to one of the first and second segments of the associated modular limb. A female connector is provided including a base, a load bearing socket secured to the base of the female connector, and at least one second electrical contact secured to the load bearing socket. The socket is configured to selectively receive the hub of the male connector and the base of the female connector is adapted to be secured to the other of

the first and second segments of the associated modular limb. The at least one first electrical contact is aligned with the at least one second electrical contact when the hub is received in the socket for establishing electrical communication between the first and second segments of the associated modular limb. The male connector and the female connector cooperate to form a resilient yet releasable modular limb joint.

**[0007]** According to yet another aspect of the present disclosure, a torque sensing quick-release joint assembly is provided for selectively securing a first segment of an associated artificial limb to a second segment thereof and sensing a torque transmitted therebetween. The joint assembly includes a male connector including a base and a load bearing projection secured to the base of the male connector. The base of the male connector is adapted to be secured to one of the first and second segments of the associated artificial limb. A female connector includes a base and a load bearing socket secured to the base of the female connector. The socket is configured to selectively receive the projection of the male connector. The base of the female connector is adapted to be secured to the other of the first and second segments of the associated artificial limb. A load sensor is secured to one of the male and female connectors for measuring a torsional load transmitted through the joint assembly. The male connector and the female connector cooperate to form a resilient yet releasable artificial limb joint.

#### Brief Description of the Drawings

**[0008]** Figs. 1A and 1B show a fully assembled and mated connector according to a first embodiment of the present disclosure.

**[0009]** Fig. 2 shows a partially disassembled connector of Fig. 1A with a locking clip removed and male and female connector sides partially removed from each other.

**[0010]** Figs. 3A and 3B show the connector of Fig. 2 in a fully disassembled condition.

**[0011]** Figs. 4A and 4B show exploded views of the female side of the connector of Fig. 2.

**[0012]** Figs. 5A and 5B show exploded views of the male side of the connector of Fig. 2.

[0013] Figs. 6A and 6B show exploded views of the blade and electrical contact assembly of the male side of the connector of Fig. 2.

[0014] Fig. 7 shows an exploded view of the locking clip assembly of the connector of Fig. 2.

[0015] Fig. 8 shows a fully engaged and clamped connector according to a second embodiment of the present disclosure.

[0016] Fig. 9 shows the connector of Fig. 8 with a locking lever open.

[0017] Fig. 10 shows the connector of Fig. 8 with the locking lever open and male and female sides disengaged.

[0018] Figs. 11 and 12 show exploded views of a connector assembly of Fig. 8.

[0019] Fig. 13 shows an exploded view of the male side of the connector of Fig. 8.

[0020] Figs. 14 and 15 show exploded views of the female side of the connector of Fig. 8.

[0021] Fig. 16 shows an exploded view of a locking lever assembly of the connector of Fig. 8.

[0022] Figs. 17 - 20 show the steps involved in securing a first limb element to a second limb element when employing the male side assembly and female side assembly illustrated in Figs. 1A - 7.

#### Detailed Description of the First Embodiment

[0023] One embodiment of the connector or modular joint assembly **1** for an artificial limb is shown in Figs. **1A** through **7**. As is shown in the drawings and particularly in Fig. **2**, the joint assembly includes a male side connector **3** which slides into a female side connector **12**. A locking member or clip assembly **11** secures the two sides of the connector. The male connector, female connector, and locking member cooperate to form the resilient yet selectively releasable modular limb joint **1**.

[0024] When fully assembled, in the embodiment shown in Figs. **1A** and **1B**, the joint assembly **1** forms a compact assembly that provides robust mechanical attachment, multiple weather-sealed electrical connections, and integral torque sensing. As is shown in particular in Figs. **3A** and **3B**, the mechanical attachment between the female side connector **12** and male side connector **3** is achieved when blade **10** or other load

bearing projection of the male side connector assembly slides into a socket **29** or other receiver in the female connector **12**. In particular, Fig. **3B** shows that a U-shaped socket **29** is defined in the female side assembly **12** for this purpose. In the instant embodiment, blade **10** is received into or under the lip **17** in the socket **29**. Electrical contact or communication through the joint can be achieved via one or more flat contacts **2**, **2A**, **2B**, **2C**, **4**, and **9** in the male connector **3** which engage suitable elements in the female connector **12**. By way of example only, electrical communication is established when the plurality of spring pins **18** (see Fig. 4B) in the female side connector **12** are seated against the contacts in the male connector as would typically occur upon full insertion of the blade **10** into the socket **29**. Also, a pocket **5** (Fig. 3B) is formed above the socket **29** for receiving the locking clip assembly **11** once the male and female connectors are fully joined or engaged.

**[0025]** A unique feature of the instant disclosure is the ability of the modular limb joint assembly to sense torque, load, and/or pressure, etc. about the cylindrical axis of the connector assembly (or the axis of rotation of the joint). This can be measured by means of strain gages **13A** and **13B** and a strain gage signal conditioning circuit board **8** (Figs. 3B, 5A and 5B) mounted to the back of the male blade **10**. One or more electrical connectors **43** can be used for maintaining electrical communication to the conditioning circuit board **8**, strain gages **13A**, **13B**, and/or other electronics through the various components of the limb, joint assembly, or individual male/female connectors. It should be noted that the strain gages **13A**, **13B** could include a full, half, or quarter strain gage bridge.

**[0026]** While the use of strain gages is illustrated in the instant disclosure, other torque or load sensing devices can be used such as load cells, piezoelectric sensors, or pressure/strain sensing semiconductors, etc. In addition, position sensors could be used to measure the relative rotational displacement between the male/female connectors of the joint which can then be used to calculate the associated torque and/or load values.

**[0027]** Such torque or load sensing capability is advantageous for a number of reasons. For one, it allows for a modular limb controller to properly limit the stresses that the joint and limb are subject to thereby preventing damage to the joint and/or limb.

In addition, such load and/or torque information can be used by the controller to more accurately control limb motion, position, and/or to provide bio-feedback control, sensation, etc. for prosthetic limb users. An additional advantage is that torque or load sensing allows precise control of forces being exerted by the prosthetic limb on external objects (or people), thus preventing damage or injury to those objects or people. Furthermore, precise force control further enhances the stability of the system and/or limb as well as the stability of the objects being manipulated. Moreover, torque and/or load sensing is also advantageous for controlling the impedance of each joint for the same reasons that force or torque control is.

**[0028]** As is shown in the exploded views in Figs. **4A** and **4B**, the female side connector/assembly **12** may include a spring pin mounting circuit board **24** having electrical contacts **6**, **6A**, **6B**, **6C**, **6D**, and **6E** (Fig. 3A), electrical spring pins **18** in spring pin blocks **25** (which are in electrical communication with contacts **6** - **6E**), a socket or receiver plate **34**, a connection backing **35**, an o-ring **26**, an electrical contact insulating member **28**, and a connection plain bearing **20**. As illustrated in Figs. **4A** and **4B**, the spring pin circuit board **24** supports the spring pin blocks **25** which are both seated or received in a recess **27** of the connection backing **35**. The insulating member **28** and the o-ring **26** are generally secured to either the spring pin circuit board **24**, the spring blocks **25**, and/or the connection backing **35**. A plurality of screws **32**, **33** can then be used to fasten together the socket or receiver plate **34** and the connection backing **35** (via holes **30**, **22**) to a respective modular limb segment. Once assembled, the socket or female receiver **29** is formed between the lip **17** of the socket plate **34** and the connection backing **35**. Power and ground contacts **4** and **9** of the male joint connector **12** can each be contacted by multiple spring pins **18** to allow high electrical currents to flow across the joint.

**[0029]** The male side connector/assembly **3**, shown in exploded views in Figs. **5A** and **5B**, can include a torsion member **37**, a backing sheet **38**, a shim **40**, a connector side plain bearing **41**, a drive support **39**, a male joint connector subassembly **42**, strain gages **13A** and **13B** for measurement of torque in the connector/joint, a connection printed circuit board **8**, and internal wiring **15**. A plurality of countersunk clearance



holes **21** may be used to allow the male side assembly to be bolted to an artificial arm assembly or respective segment of the modular limb (see Figs. 17 - 20).

**[0030]** Figs **6A** and **6B** show exploded views of the male joint connector subassembly **42**. In particular, the conductive power and ground contacts **4** and **9**, the conductive communications bus contacts **2**, **2A**, **2B**, and **2C**, an electrically insulating connection plug **44**, and the blade **10** (which may be made from hardened steel) are shown. In addition, knurling **45** can be formed on the housing **49** of the male joint connector subassembly **42** which increases the contact area with the toothed outer periphery of the polymer material of the torsion member **37**. This helps improve the mechanical bond and prevent or retard the torsion member from slipping. It should be noted the torsion member can be a torsional spring manufactured from any material (plastic, rubber, metal, etc.) having the appropriate spring characteristics for the particular parameters (maximum load, stiffness, etc.) which the joint is designed to accommodate.

**[0031]** The locking clip assembly **11**, shown in an exploded view in Fig. **7**, includes a plain bearing **23**, a lock or clip **46**, and socket cap screws **19** and **19A**. The plain bearing **23** (which can be made from a polymer based material) in this embodiment fits into recess **47** in lock **46** and the screws **19** and **19A** fit into the counterbored clearance holes **48** and **48A**.

#### Operation of the First Embodiment

**[0032]** In operation, the male side connector/assembly **3** and female side connector/assembly **12** can be attached to separate artificial arm sections (e.g., see modules **A** and **B** as shown in Figs. 17 - 20). These can be a humeral rotator and an elbow, as illustrated in Figs. **17-20**. However, they can, instead, be other limb segments of an arm or a leg or a robot. As is shown in Fig. **2**, the joint connection process begins by first sliding blade **10** of male side connector **3** into the socket/receiver **29** of female side connector **12**. The joint connection is fully established when blade **10** is fully engaged in a sliding interference fit with edge or lip **17** in receiver/socket **29**. These steps are shown in Figs. **17** and **19**. When full engagement is achieved then power and ground contacts **4** and **9** are in intimate contact with the plurality of conductive spring

pins **18**, and communications contacts **2**, **2A**, **2B**, and **2C** are each in intimate contact with its respective spring pin **18**.

[0033] To ensure that the male side connector **3** and female side connector **12** do not become disengaged during service or operation, the locking clip assembly **11** is inserted into receiver **29** after blade **10** is fully engaged with edge/lip **17**. In the embodiment shown, the screws **19** and **19A** (see Fig. 7) are driven into threaded holes **31** (see Figs. 4A-4B) and tightened. Of course, other ways of securing the locking clip in place, in a manner that the clip can be detached as needed when disassembling the joint, are also contemplated. The modular limb joint assembly **1** is thus configured as shown in Figs. **1A** and **1B**. Similarly, Fig. **20** shows the two arm section modules in a connected fashion. In the embodiment shown, the first arm section can be the humeral rotator **A** and the second arm section can be an elbow **B**. However, other embodiments are also contemplated. In other words, the two limb sections which are joined can be, for example, a wrist connection to a forearm or an upper arm connection to a shoulder.

[0034] When the male and female connectors are fully engaged, blade **10** transfers rotational and linear mechanical loads from the male connector **3** to the socket/receiver **29** in the female connector **12**. Electrical contacts **4**, **9**, **2**, **2A**, **2B**, and **2C** transfer power and electrical signals from the male connector **3** to spring pins **18** in the female connector **12**.

[0035] Torsion member **37** and plain bearing **41** allow rotation of the male joint connector subassembly portion **42** in relation to the base/drive support **39**. The rotation allowed by torsion member **37** reduces the torsional stiffness of the connector about the axis of torsion member **37** so that torsional shock loads transferred across the joint are minimized. The reduced stiffness allowed by torsion member **37** also allows better control of torque passing through the joint. In the embodiment illustrated, joint torque is measured by means of strain gages **13A** and **13B** mounted in male joint inner connector portion **42**. It should be noted that the strain gages or other load, torque, or position sensing devices can be located in either or both of the male and female side connectors.

#### Detailed Description of the Second Embodiment

**[0036]** Another embodiment of the joint assembly **100** is shown in Figs. **8** through **16**. As is shown in the drawings and particularly in Fig. **10**, the joint assembly **100** has a male side connector **50** which slides into a female side connector **65**. In this embodiment, a sliding motion along the aligned axes of the male side connector **50** and the female side connector **65** is contemplated. A locking lever assembly **56** secures together the two associated limb segments attached to the respective male/female side connectors of the joint assembly.

**[0037]** When fully assembled as shown in Fig. **8** the joint assembly **100** forms a compact joint that provides robust mechanical attachment, multiple weather-sealed electrical connections, and integral torque sensing. As is shown in particular in Figs. **9** - **12**, the mechanical attachment between female side connector **65** and male side connector **50** is achieved when a plurality of tabs **52** on a hub portion **74b** of the male side connector slide into a plurality of slots or notches **62** in the socket/receiver of the female connector. Moreover, an indexing tab **51** slides into an indexing slot **63** in the female receiver **64** in order to correctly orient the male side assembly in relation to the female side assembly. Naturally, the tabs, slots, or notches can be arranged in any configuration and on either connector so as to facilitate positive traction or engagement between the male and female connectors of the joint for the purpose of transmitting torsional as well as axial loads. Electrical contact/communication can be achieved through flat contacts **69**, **70**, **71**, and **72** in male side connector **50** when such contacts engage a plurality of spring pins **68** in the female side connector **65**.

**[0038]** The male side connector **50** is shown in an exploded view in Fig. **13**. In general, the male connector **50** may include a cup or base portion **74a**, the load bearing hub or projection **74b**, a connection plug **75**, a plug recess **76**, and electrical contacts **69**, **70**, **71**, and **72**. As with the first embodiment, torque about the cylindrical axis (or axis of rotation) of the joint assembly can be measured by means of strain gauges **49A** and **49B** mounted to the male connector **50** (as illustrated) or to the female connector **65**.

**[0039]** As is shown in the exploded views in Figs. **14** and **15**, the female side connector **65** may include a spring pin mounting circuit board **77**, electrical spring pins **68** in spring pin blocks **78**, a torsional member **67**, a backing sheet **79**, a housing **80**, a

plain bearing **82**, and a female receiver or socket **64**. Power and ground contacts **69** and **70** (Fig. 13) can each be contacted by multiple spring pins **68** to allow high electrical currents to flow across the joint assembly. In addition, knurling **83** can also be formed on the body of the socket **49** of the female joint connector **65** which increases the contact area with the toothed inner periphery of the torsion member **67**. Similarly, as best illustrated in Fig. 14, the housing **80** can be knurled or toothed so as to mesh with a toothed outer periphery of the torsion member **67**. This helps improve the mechanical bond and prevent or retard slipping between the torsion member and the male and/or female joint connectors.

**[0040]** The locking lever assembly **56**, shown in an exploded view in Fig. **16**, can be composed of a locking collar **54**, a locking lever **57**, a pin **86**, a pull rod **88**, and a nut **91**. A head portion **87** of the pull rod **88** is pivotally secured in a lobed end **85** of the lever **57** by the pin **86**. Rotating the lever **57** causes a split **89** in the collar **54** to open or close, depending on the direction of rotation. In this manner, when the lever assembly **56** is placed in a locked state, it cinches the socket/receiver of the female connector about the hub portion of the male connector creating a rigid joint connection. In addition, a locking lever guard **59** (Figs. 11-12) may also be provided and secured to the housing **80** by way of fasteners **58A-58C**. It should be appreciated that other locking lever assembly constructions can also be employed.

#### Operation of the Second Embodiment

**[0041]** In operation, the male side connector **50** and female side connector **65** are attached to separate limb segments or modules (not shown for this embodiment) that are to be joined together using the previously described joint assembly. In one embodiment, these can be a wrist and a forearm, for example. As is shown in Fig. **10**, the joint is established by first sliding the tabs **52** of male connector **50** into slots **62** of the socket/receiver **64** of female connector **65** (with the male and female sides oriented so that indexing tab **51** engages indexing slot **63**). The male and female connectors are fully engaged when tabs **52** and **51** bottom in slots **62** and **63** of the receiver **64**. When full engagement is achieved, power and ground contacts **69** and **70** are in intimate

contact with a plurality of conductive spring pins **68**, and communications contacts **71** and **72** are each in intimate contact with a single spring pin **68**.

**[0042]** To ensure that the male connector **50** and female connector **65** do not become disengaged during operation of the artificial, prosthetic, or robotic limb, locking lever **57** (shown opened in Fig. **9**) is pushed down into the position shown in Fig. **8** to clamp female socket/receiver **64** around hub portion **74b** (Fig. **13**). The joint is thus established as shown in Fig. **8**.

**[0043]** When the joint is fully established, tabs **52** and **51** transfer torque to slots/notches **62** and **63** in socket/receiver **64** in the female side assembly **65**. Electrical contacts **69**, **70**, **71**, and **72** transfer electrical power and electrical signals from the male connector **50** to spring pins **68** in the female connector **65** thus establishing electrical communication between the limb segments of the artificial limb.

**[0044]** Torsion member **67** and plain bearing **82** allow rotation of female receiver/socket **64** with respect to housing/base **80** about the cylindrical axis of housing **80**. The rotation allowed by torsion member **67** reduces the torsional stiffness of the connector about the axis of spring **67** so that torsional shock loads transferred across the joint are minimized. The reduced stiffness allowed by torsion member **67** also facilitates better control of torque passing through the joint. Torque in the joint can be measured by means of strain gages **49A** and **49B** mounted to the male connector **50**. As discussed with respect to the first embodiment, other known means for measuring torque are also contemplated.

**[0045]** The modular limb joint assembly disclosed herein can be used to connect multiple modules or segments of an associated modular limb in series. It provides a high strength mechanical connection capable of bearing high torque and axial loads, as well as an integral electrical connection for power and signals. It also includes integral torque sensing elements. Further, it provides an elastic element, compliance element, or torsion member which enables some resiliency in the joint. It should be noted that the torsion member may also serve as a series elastic element within the joint assembly which is effectively in series between the "input" or driving end of the joint and the "output" or driven end of the joint. Such a series elastic element may act as low pass filter effectively filtering out shock loads while providing enhanced force control and

stability (particularly when coupled with load or torque sensors as described previously). A more detailed discussion of the advantages of using a series elastic element can be found in U.S. Patent No. 5,910,720 to Williamson, et al., the entire disclosure of which is incorporated herein by reference.

**[0046]** Typical artificial limbs, such as prosthetic arms or robot arms, are designed as a single integrated assembly which cannot be simply and quickly disassembled into component modules. Moreover, such arms are not designed with load and/or torque sensing elements which are integral to the connector, since they do not even have a modular connector. Due to the lack of easily connectible limb modules or segments, typical man-made arms do not have a single assembly which combines the mechanical and electrical interface with a load and/or torque sensor, as well as a compliance element, as in the disclosed embodiments.

**[0047]** Disclosed has been a new and improved artificial limb, such as an arm, which comprises modular segments. With the system disclosed herein, the reliability and safety of the electrical connection can be improved. At the same time, an integral torque sensor can be provided along with a compliance or torsion element to allow the joint between two segments of a limb to function better.

**[0048]** According to one embodiment of the present disclosure, there is provided a connecting device which electrically connects first and second components of an artificial limb. The connecting device comprises a first component block including a blade and a second component block including a socket in which the blade is selectively accommodated. A locking clip can selectively secure the first component block to the second component block.

**[0049]** According to another embodiment of the present disclosure, a joint is provided for an artificial limb. The joint comprises a first connector including a blade and a first electrical contact surface and a second connector including a socket in which the blade is selectively accommodated, the socket including a second electrical contact surface. A locking clip is provided for securing the first connector to the second connector. Electrical communication is achieved between the first and second connectors when the first and second electrical contact surfaces are in contact with each other.

**[0050]** The disclosure has been described with reference to several embodiments. Obviously, alterations and modifications will occur to others upon a reading and understanding of this specification. It is intended to include all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

What is claimed is:

1. A joint assembly for releasably securing a first and a second segment of an associated modular limb, the joint assembly comprising:

a male connector including a base and a load bearing blade secured to the base of the male connector and protruding therefrom, the male connector being adapted to be secured to one of the first and second segments of the associated modular limb;

a female connector including a base and a load bearing socket secured to the base of the female connector, the socket being configured to selectively receive the blade of the male connector, the female connector being adapted to be secured to the other of the first and second segments of the associated modular limb;

a locking member selectively retaining the blade of the male connector in the socket of the female connector; and

wherein the male connector, the female connector, and the locking member cooperate to form a resilient and selectively releasable modular limb joint.

2. The joint assembly of claim 1, wherein the male connector further includes a first electrical contact mounted to the blade of the male connector and wherein the female connector further includes a second electrical contact mounted to the socket of the female connector, the first electrical contact being aligned with the second electrical contact when the blade is received in the socket for establishing electrical communication between the first and second segments of the associated modular limb.

3. The joint assembly of claim 1, wherein one of the male connector or the female connector includes a torsion member.

4. The joint assembly of claim 3, wherein the torsion member is ring shaped and disposed between the blade and the base of the male connector.

5. The joint assembly of claim 1, wherein one of the male connector and the



female connector includes a load sensor for measuring a torsional load across the joint.

6. The joint assembly of claim 5, wherein the load sensor comprises one of a full, half, or quarter strain gage bridge.

7. The joint assembly of claim 6, wherein the strain gage bridge includes a first half and a second half, the first half of the bridge being disposed adjacent the blade at a first location spaced from an axis of rotation of the joint and the second half of the bridge being disposed adjacent the blade at a second location spaced from the axis of rotation of the joint.

8. The joint assembly of claim 1, further including a watertight seal disposed between the male connector and the female connector.

9. The joint assembly of claim 1, wherein the locking member comprises one a clip and a collar.

10. A joint assembly for releasably securing a first and a second segment of an associated modular limb, the joint assembly comprising:

a male connector including a base, a load bearing hub secured to the base of the male connector, and at least one first electrical contact secured to the load bearing hub, the base of the male connector being adapted to be secured to one of the first and second segments of the associated modular limb;

a female connector including a base, a load bearing socket secured to the base of the female connector, and at least one second electrical contact secured to the load bearing socket, the socket being configured to selectively receive the hub of the male connector and the base of the female connector being adapted to be secured to the other of the first and second segments of the associated modular limb;

wherein the at least one first electrical contact is aligned with the at least one second electrical contact when the hub is received in the socket for establishing electrical communication between the first and second segments of the associated

modular limb; and

wherein the male connector and the female connector cooperate to form a resilient yet releasable modular limb joint.

11. The joint assembly of claim 10, further comprising a locking member for selectively securing the male connector to the female connector.
12. The joint assembly of claim 10, wherein the hub includes one of a plurality of tabs or notches and the socket includes the other of the plurality of tabs or notches, the plurality of tabs and the plurality of notches being aligned when the hub is received into the socket for transmitting a torsional load across the first and second segments of the associated modular limb.
13. The joint assembly of claim 10, wherein one of the male connector and the female connector includes a torsion member.
14. The joint assembly of claim 13, wherein the torsion member is ring shaped and disposed between the socket and the base of the female connector, the socket being rotatably mounted to the base of the female connector.
15. The joint assembly of claim 10, wherein one of the male connector and the female connector includes a load sensor for measuring a torsional load across the joint.
16. The joint assembly of claim 15, wherein the load sensor comprises one of a full, half, or quarter strain gage bridge.
17. The joint assembly of claim 16, wherein the strain gage bridge includes a first half and a second half, the first half of the bridge being disposed adjacent the hub at a first location spaced from an axis of rotation of the joint and the second half of the bridge being disposed adjacent the hub at a second location spaced from the axis of rotation of the joint.
18. The joint assembly of claim 10, further including a watertight seal located between the male connector and the female connector.

19. A torque sensing quick-release joint assembly for selectively securing a first second segment of an associated artificial limb to a second segment thereof, and sensing a torque transmitted therebetween, the joint assembly comprising:

a male connector including a base and a load bearing projection secured to the base of the male connector, the base of the male connector being adapted to be secured to one of the first and second segments of the associated artificial limb;

a female connector including a base and a load bearing socket secured to the base of the female connector, the socket being configured to selectively receive the projection of the male connector and the base of the female connector adapted to be secured to the other of the first and second segments of the associated artificial limb;

a load sensor secured to one of the male and female connectors for measuring a torsional load transmitted through the joint assembly; and

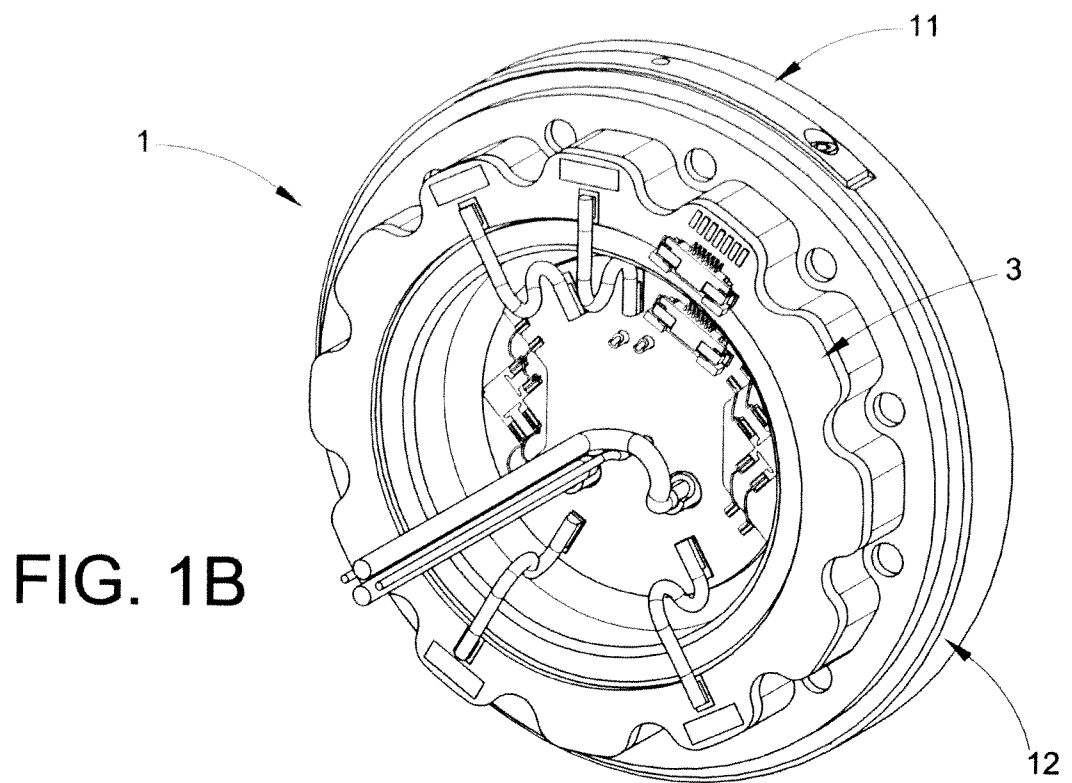
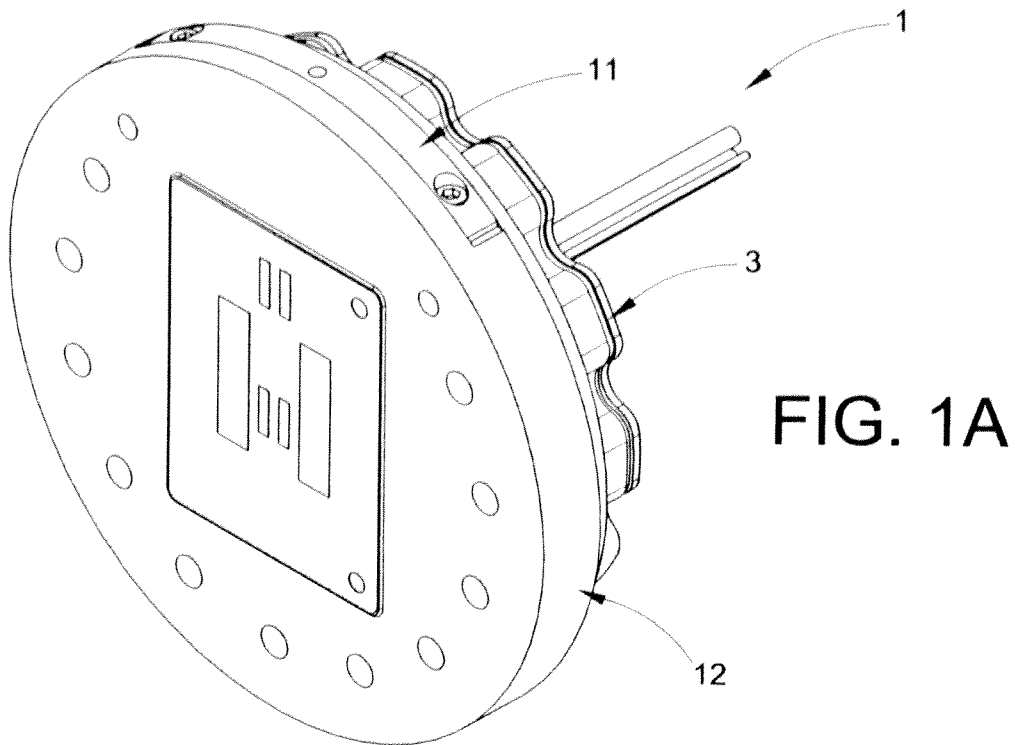
wherein the male connector and the female connector cooperate to form a resilient yet releasable artificial limb joint.

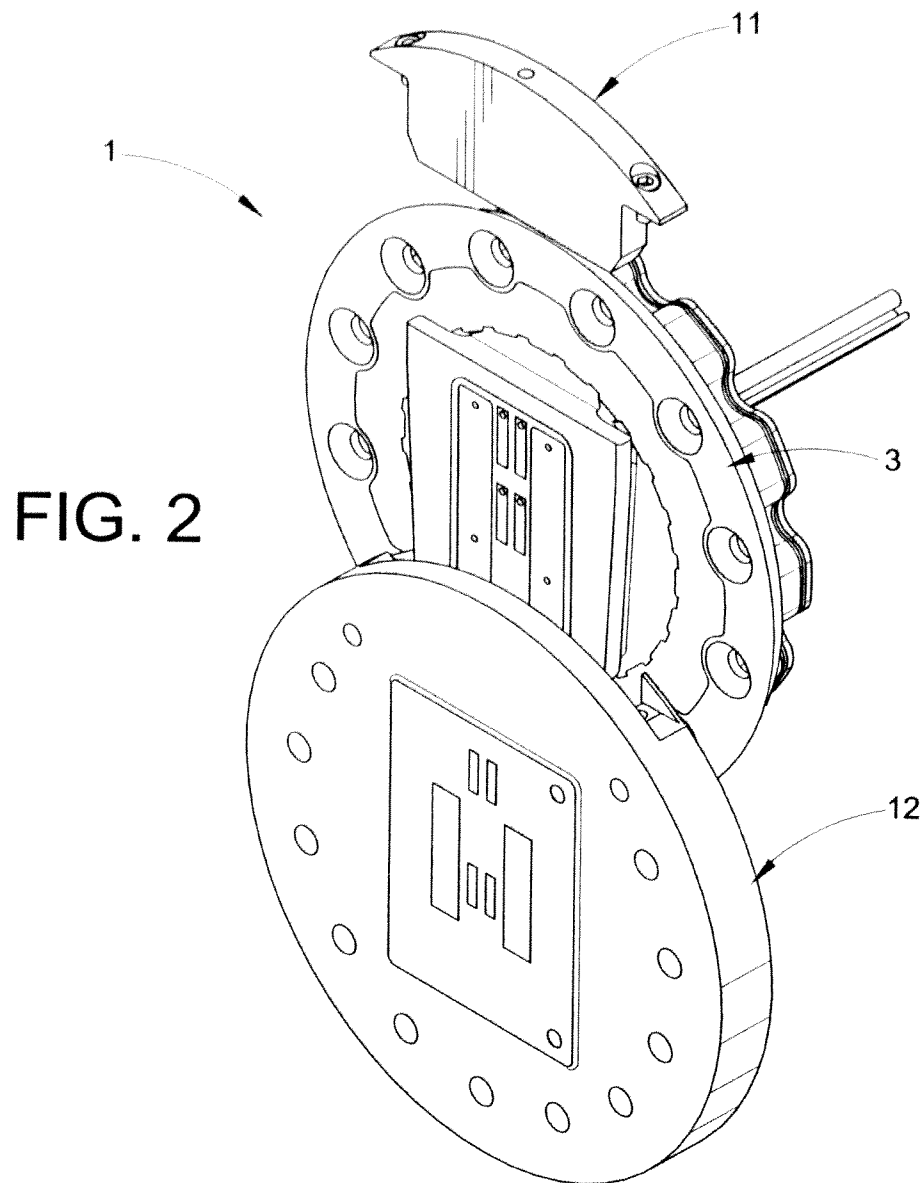
20. The joint assembly of claim 19, further including a locking member for selectively retaining the projection of the male connector in relative fixed relationship with the socket of the female connector, the locking member being selectively secured to the joint assembly.

21. The joint assembly of claim 19, wherein the projection of the male connector includes one of a blade, a hub, or a protrusion.

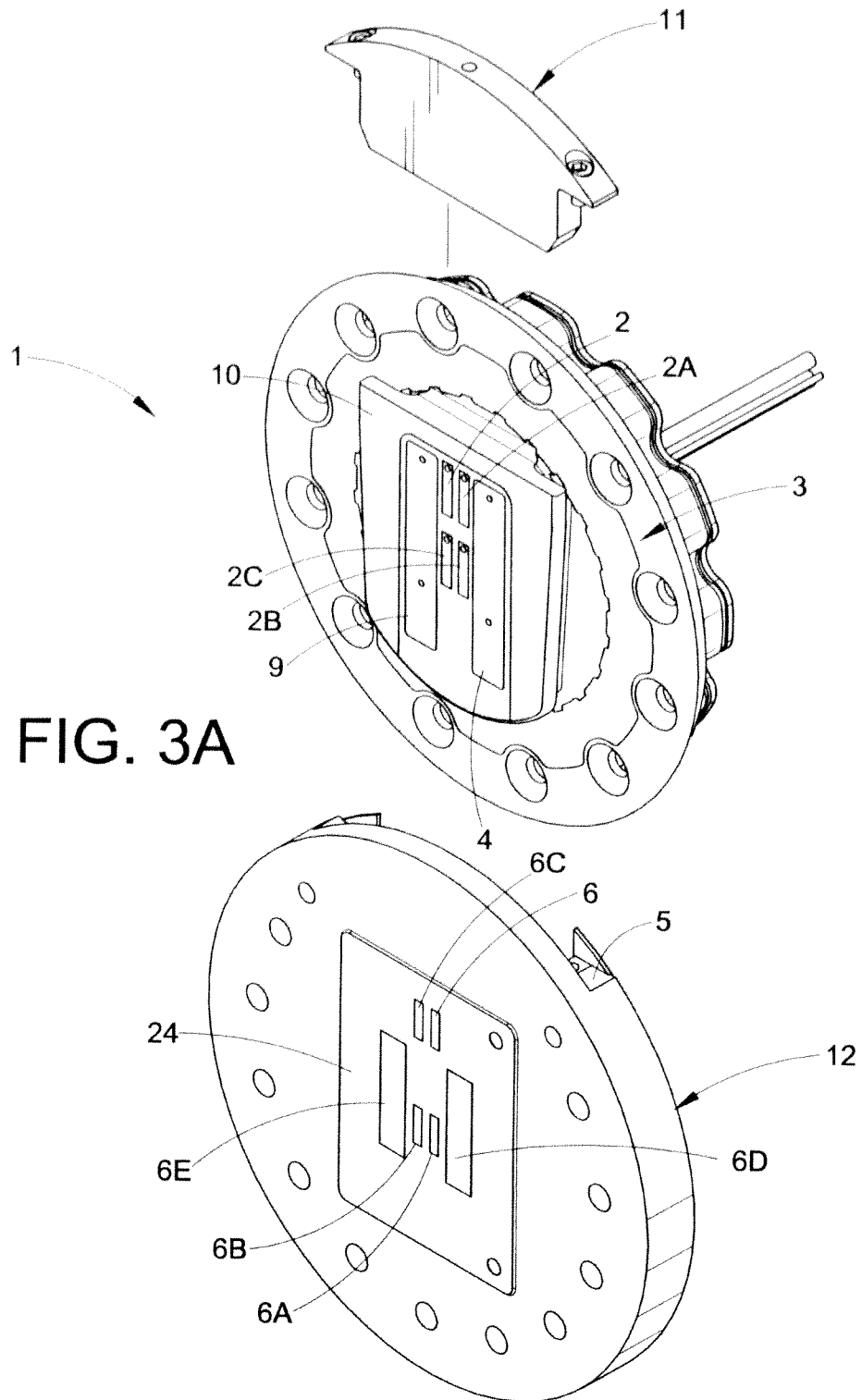
22. The joint assembly of claim 19, wherein the male connector includes at least one first electrical contact disposed adjacent the projection and wherein the female connector includes at least one second electrical contact disposed adjacent the socket, the at least one first electrical contact being aligned with the at least one second electrical contact when the projection is received in the socket for establishing electrical communication between the first and second segments of the associated artificial limb.
23. The joint assembly of claim 19, wherein one of the male connector or the female connector includes a torsion member.
24. The joint assembly of claim 19, wherein the load sensor comprises one of a full, half, or quarter strain gage bridge.
25. The joint assembly of claim 24, wherein the strain gage bridge includes a first half and a second half, each of the first half and the second half being spaced approximately equidistant from an axis of rotation of the artificial limb joint.
26. The joint assembly of claim 19, further including a watertight seal disposed between the male connector and the female connector.

1/15





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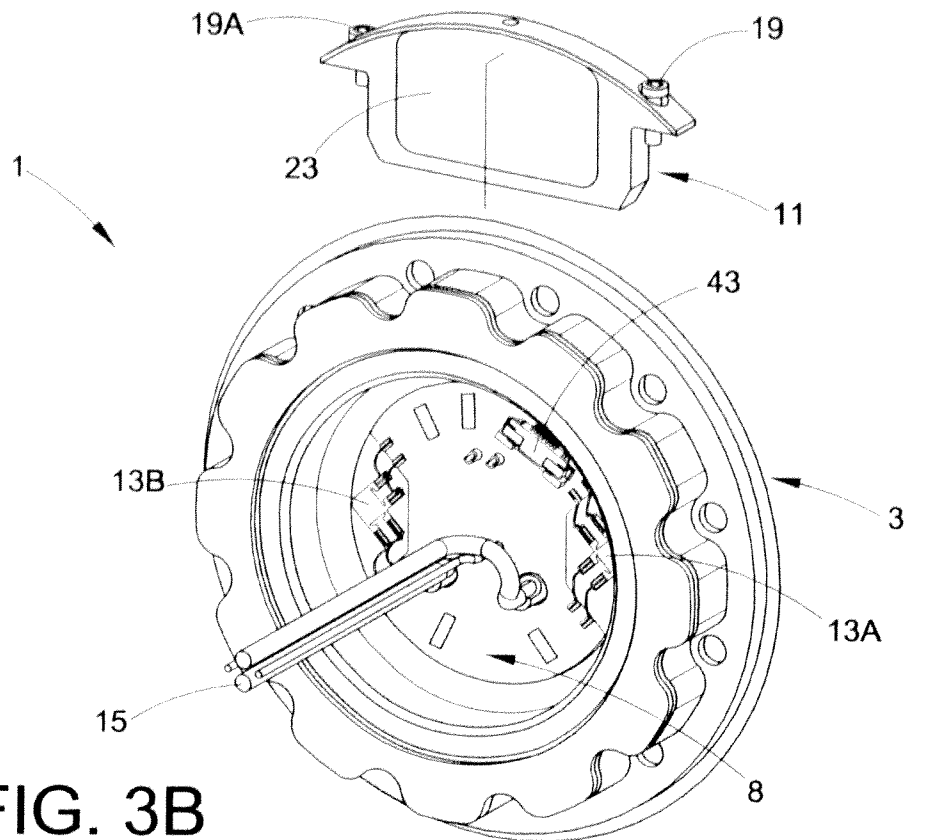
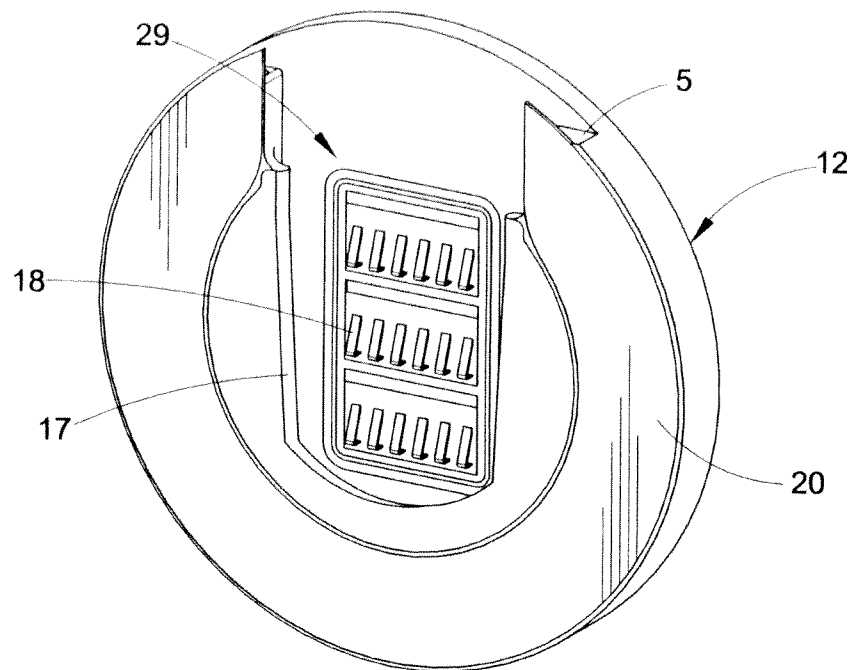


FIG. 3B





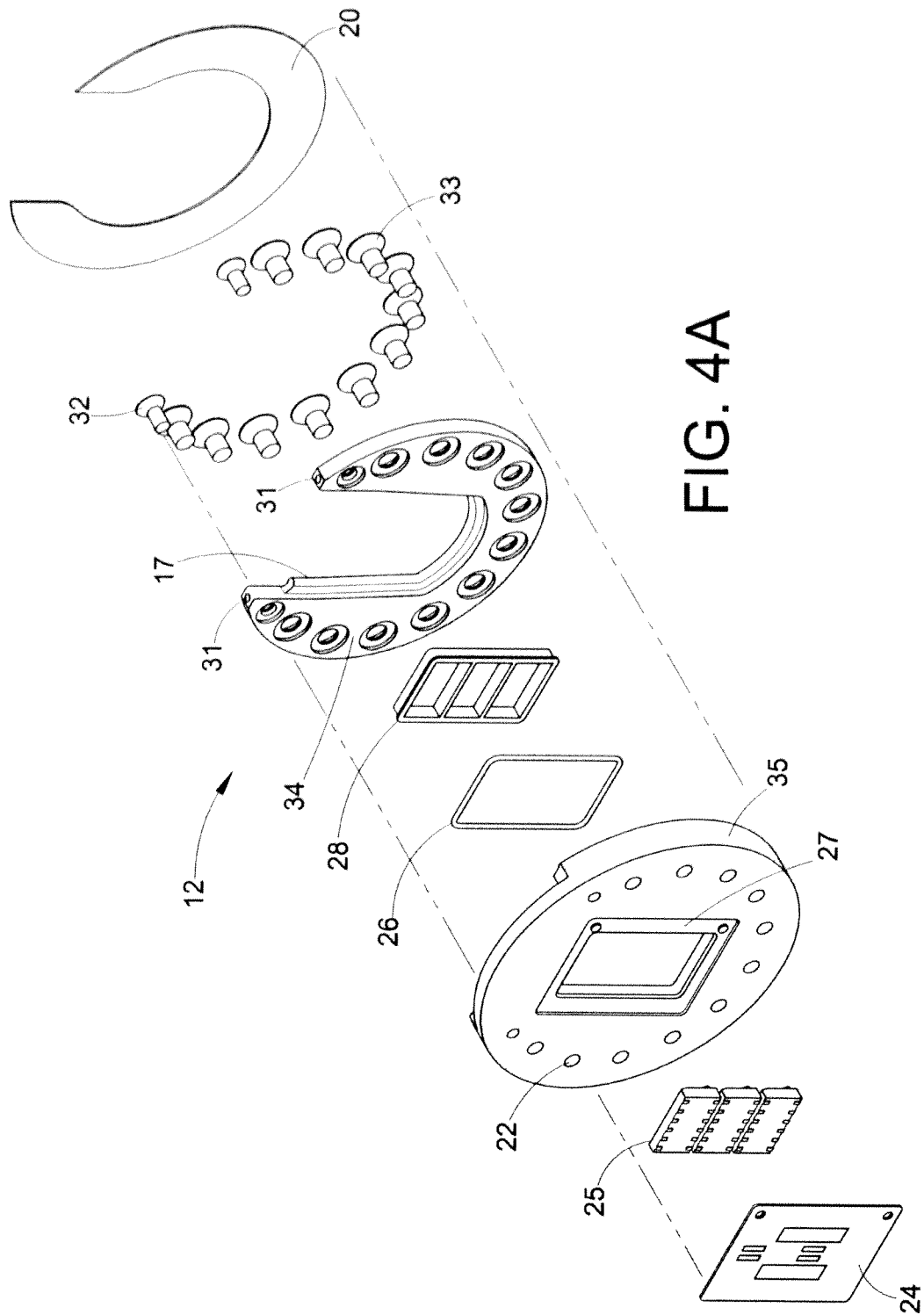


FIG. 4A

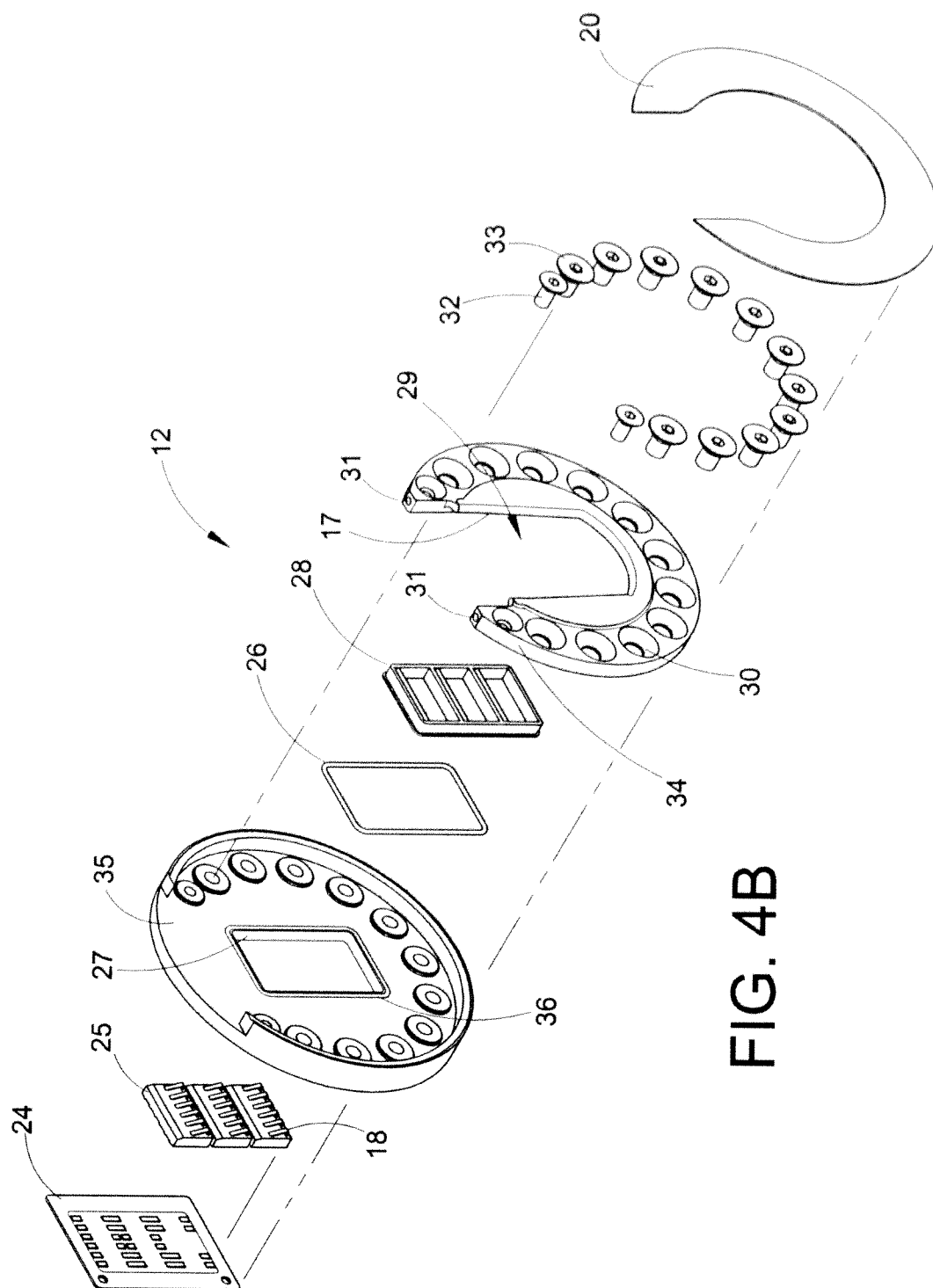


FIG. 4B

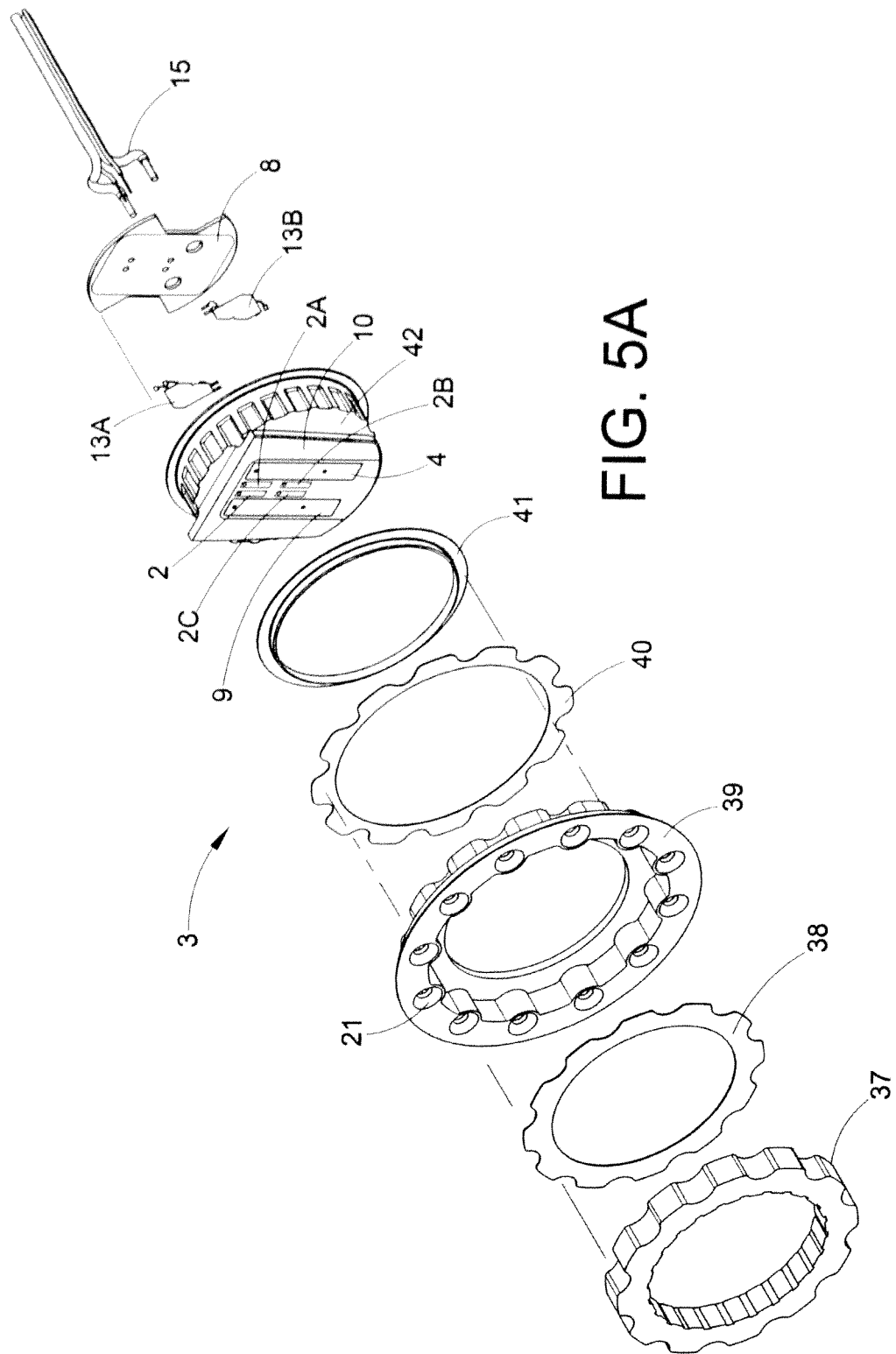


FIG. 5A

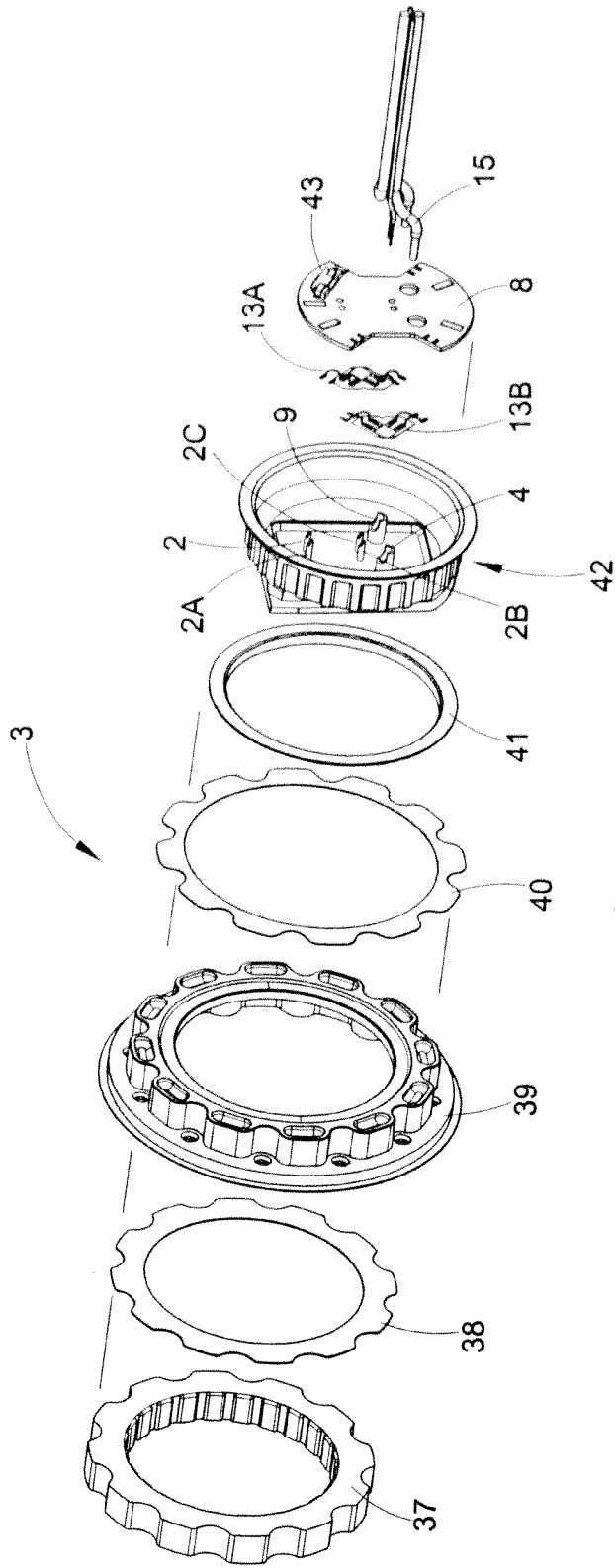


FIG. 5B

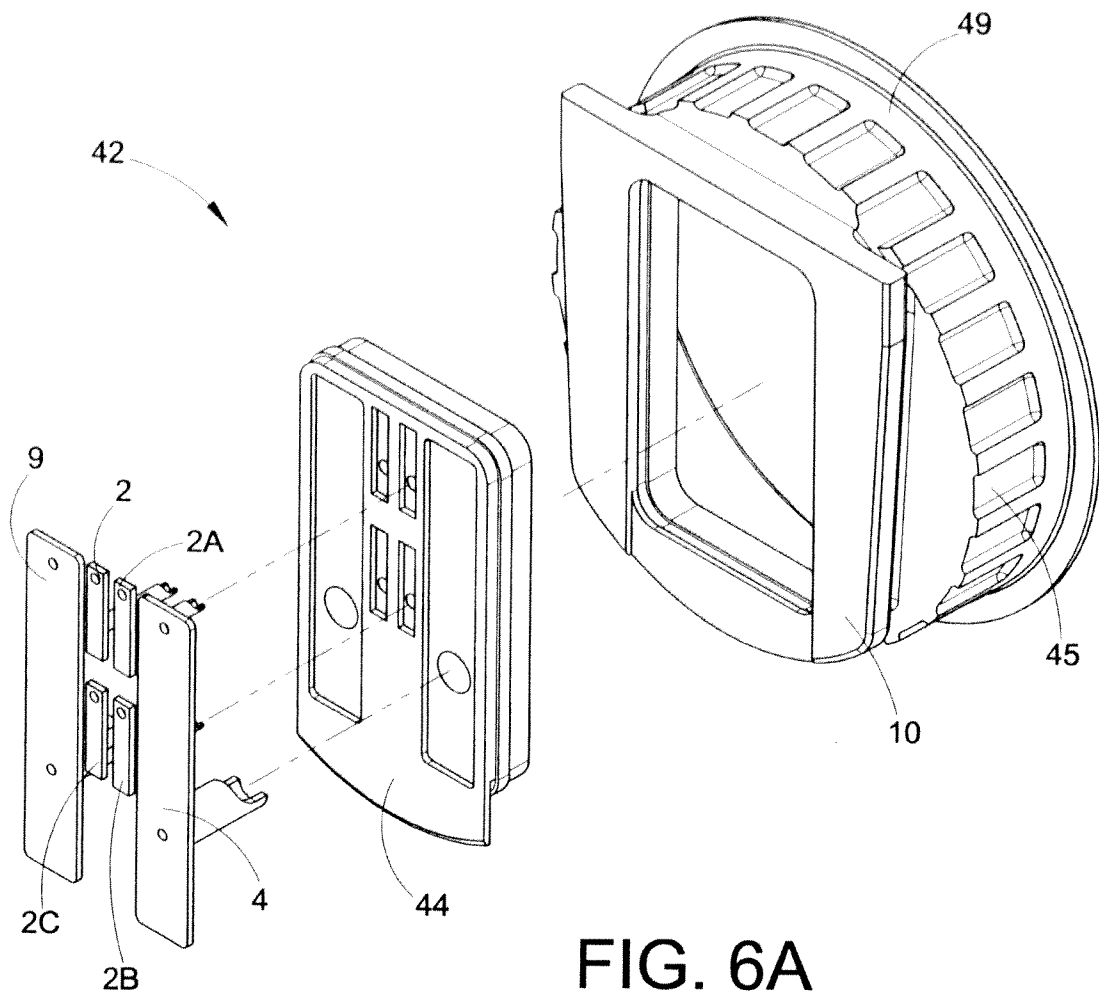


FIG. 6A

10/15

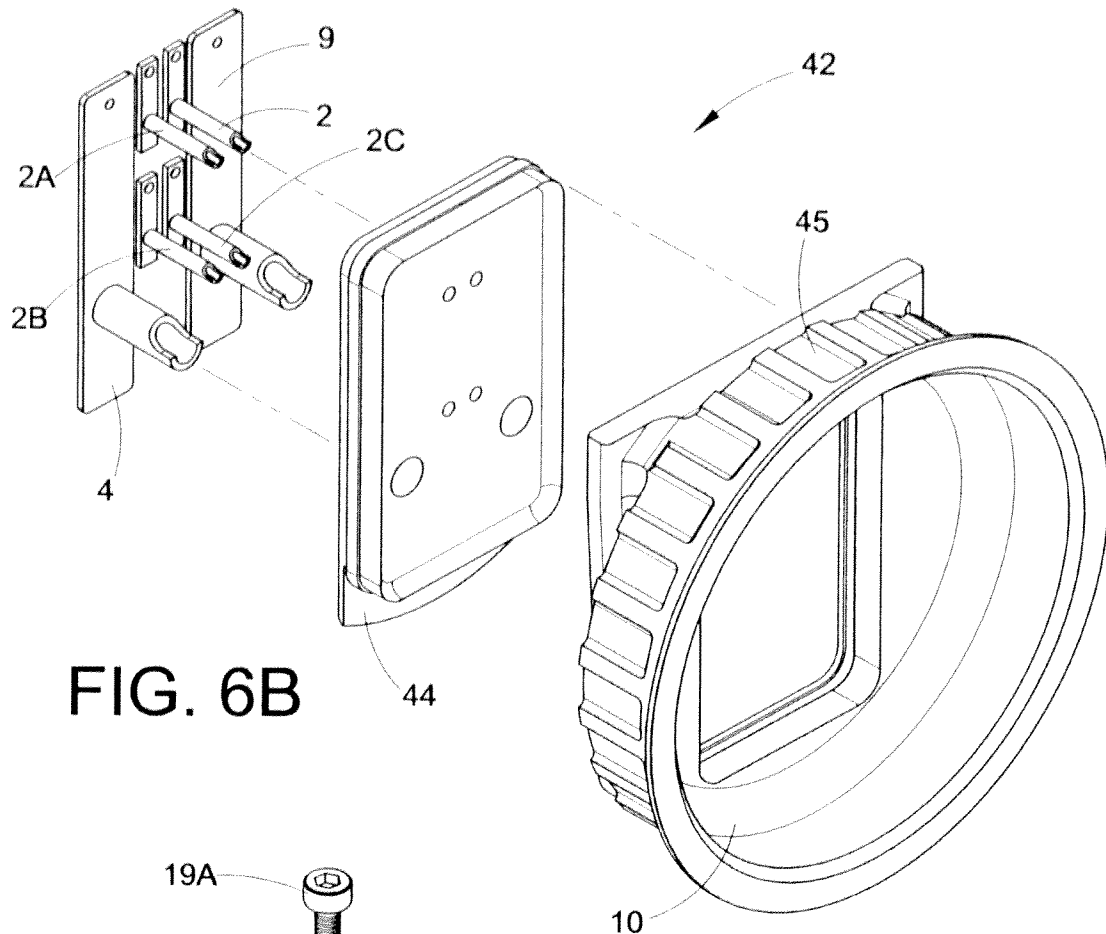


FIG. 6B

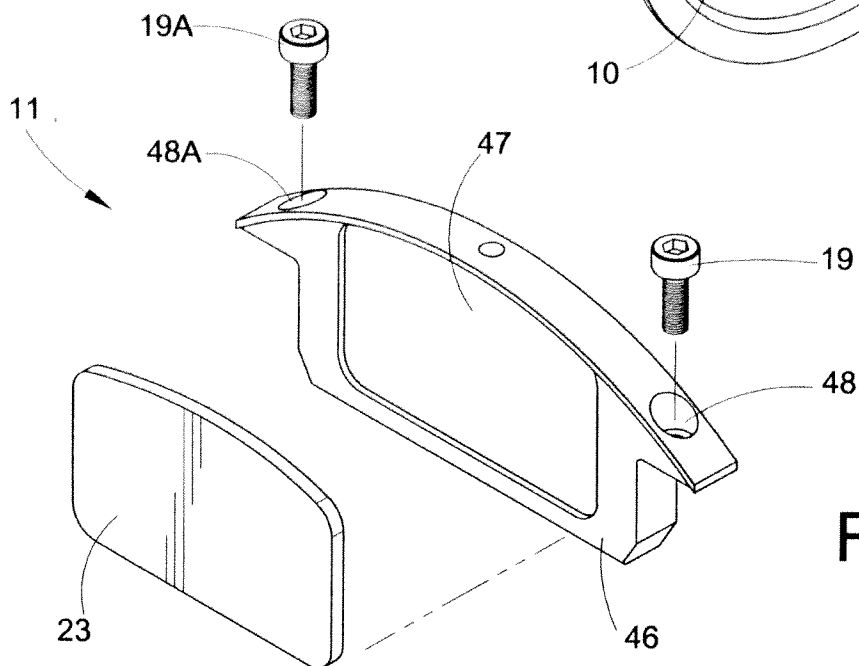


FIG. 7

11/15

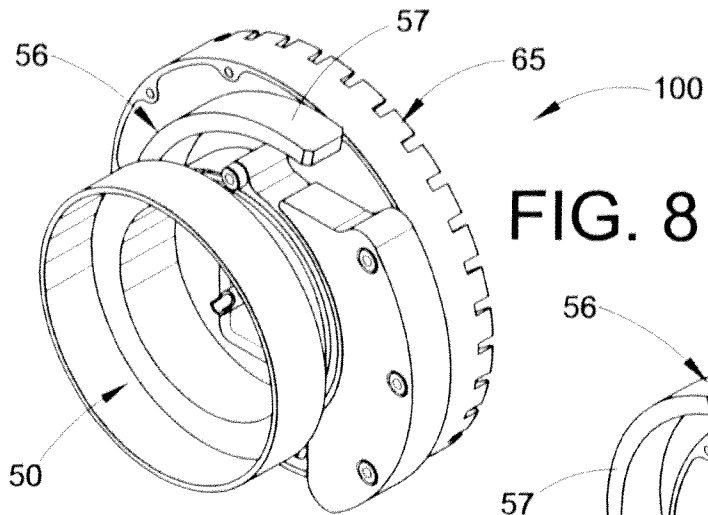


FIG. 8

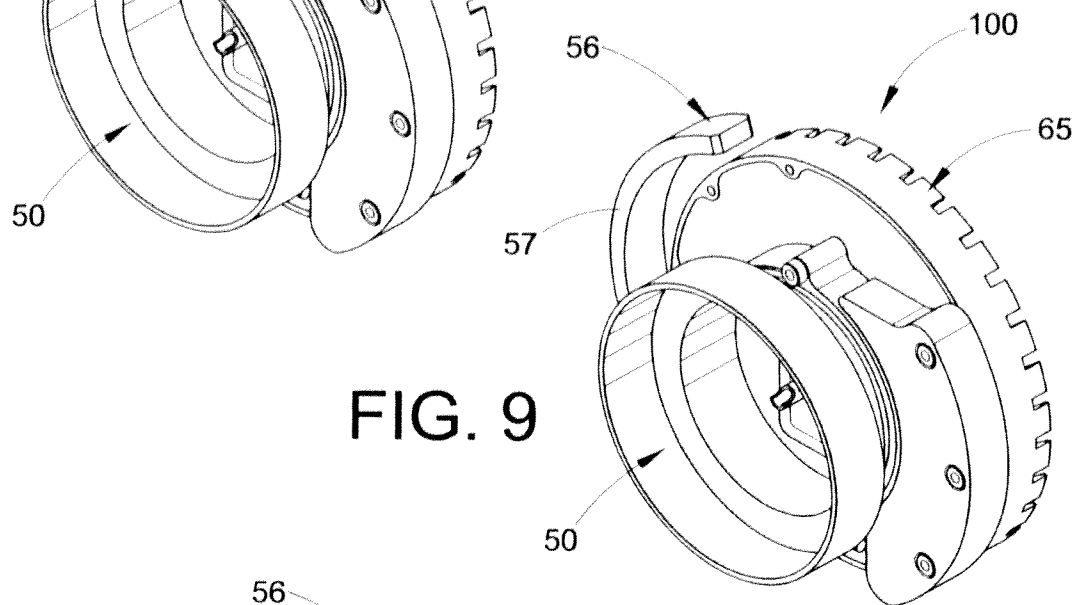


FIG. 9

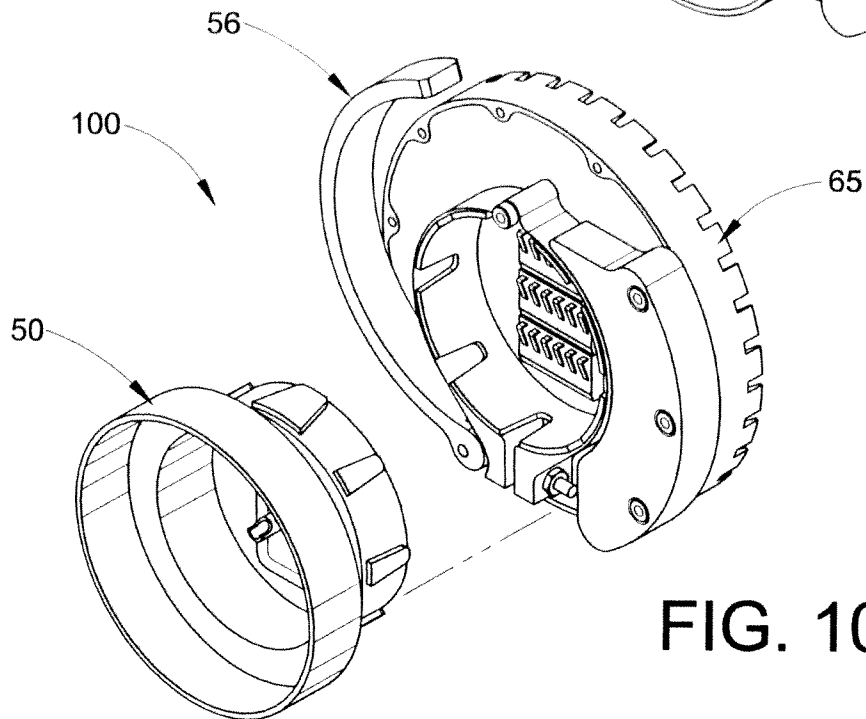
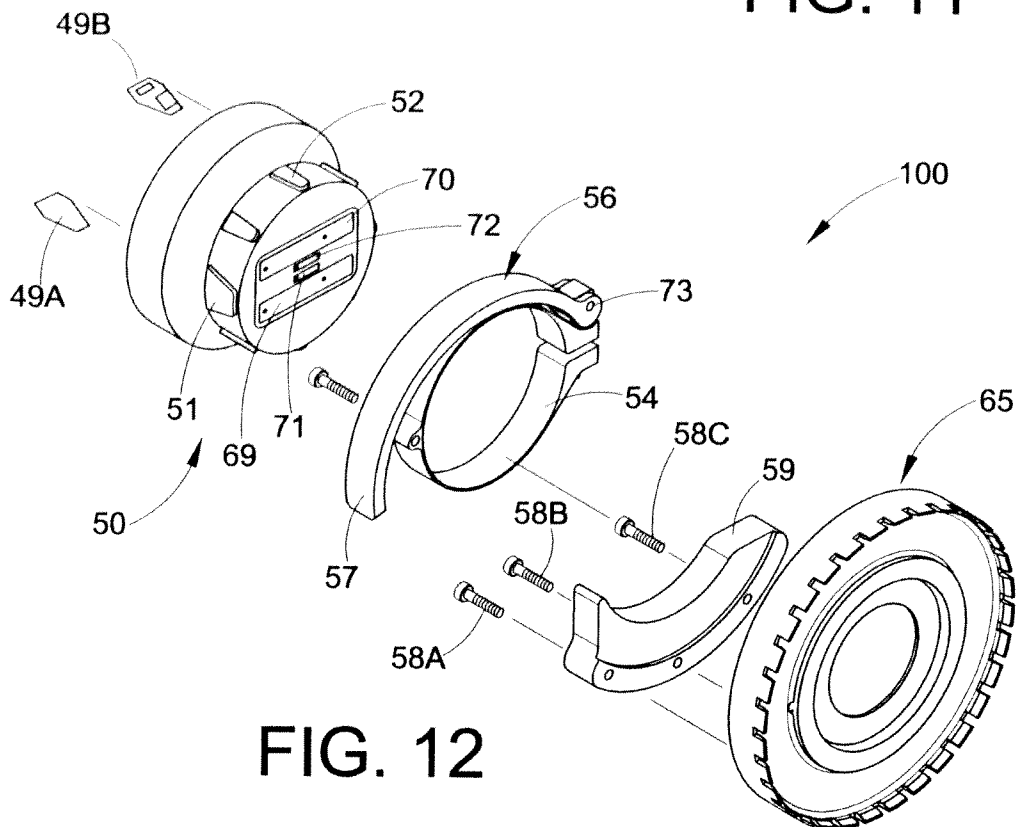
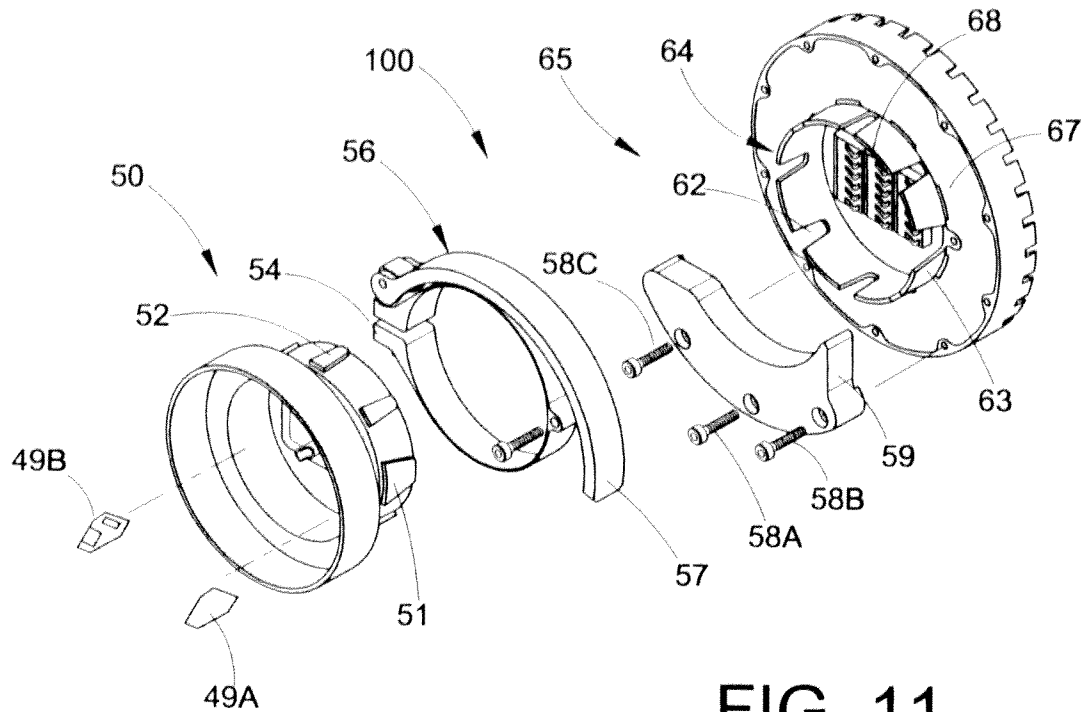


FIG. 10

12/15





13/15

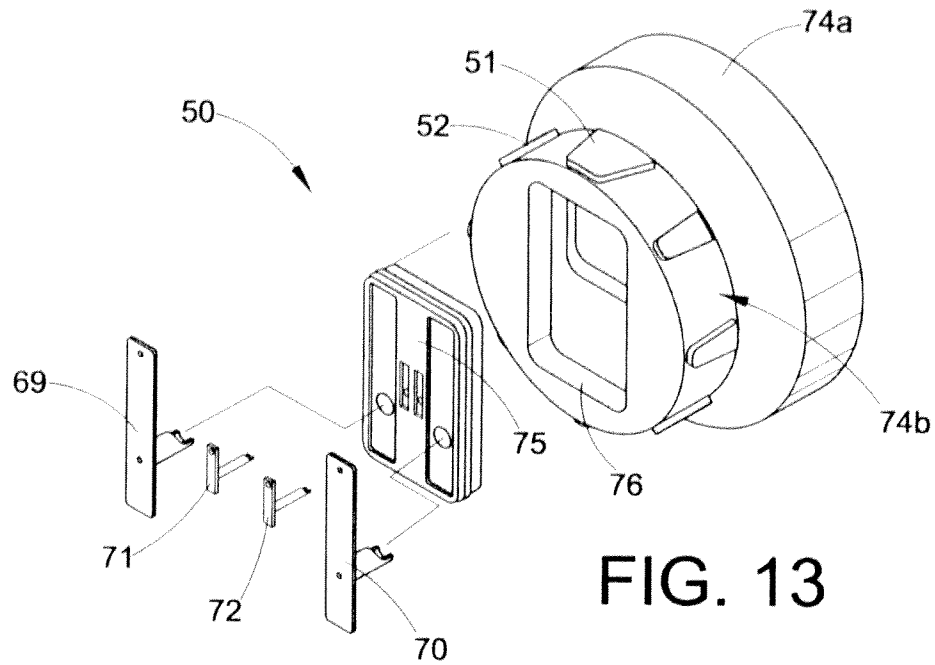


FIG. 13

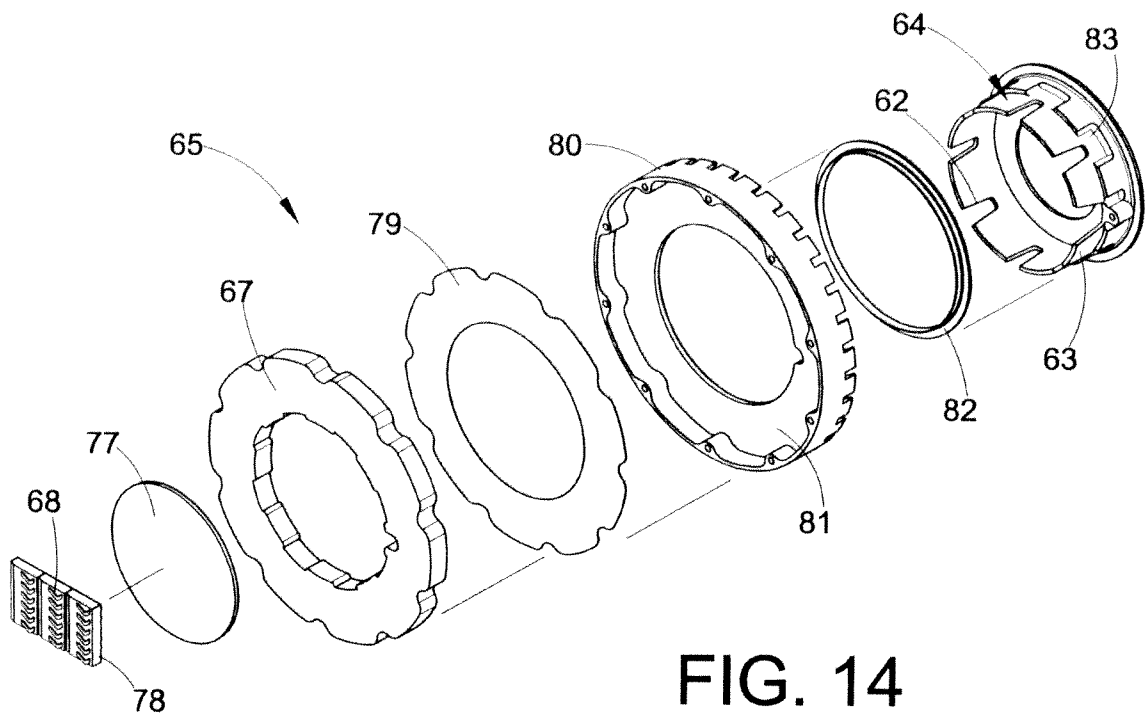


FIG. 14

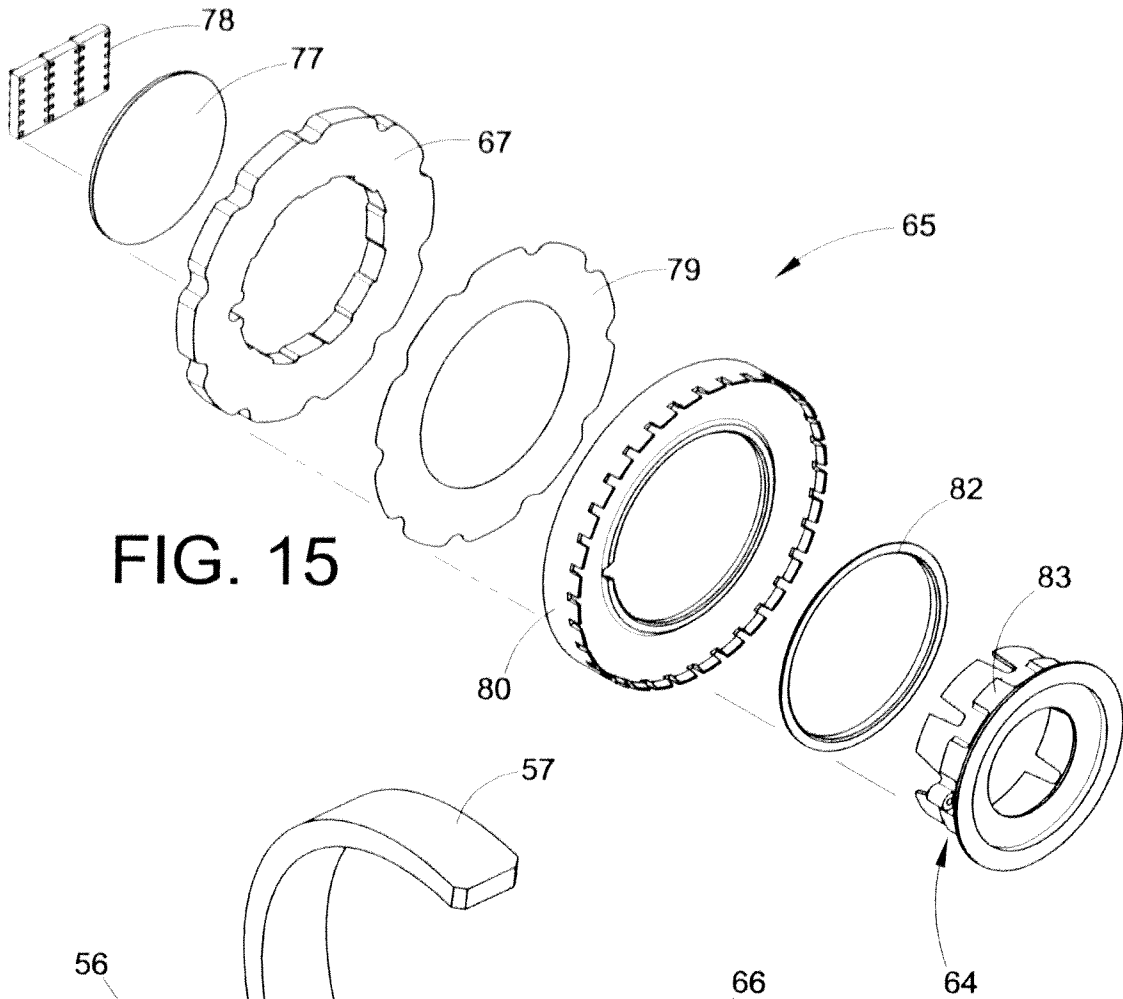


FIG. 15

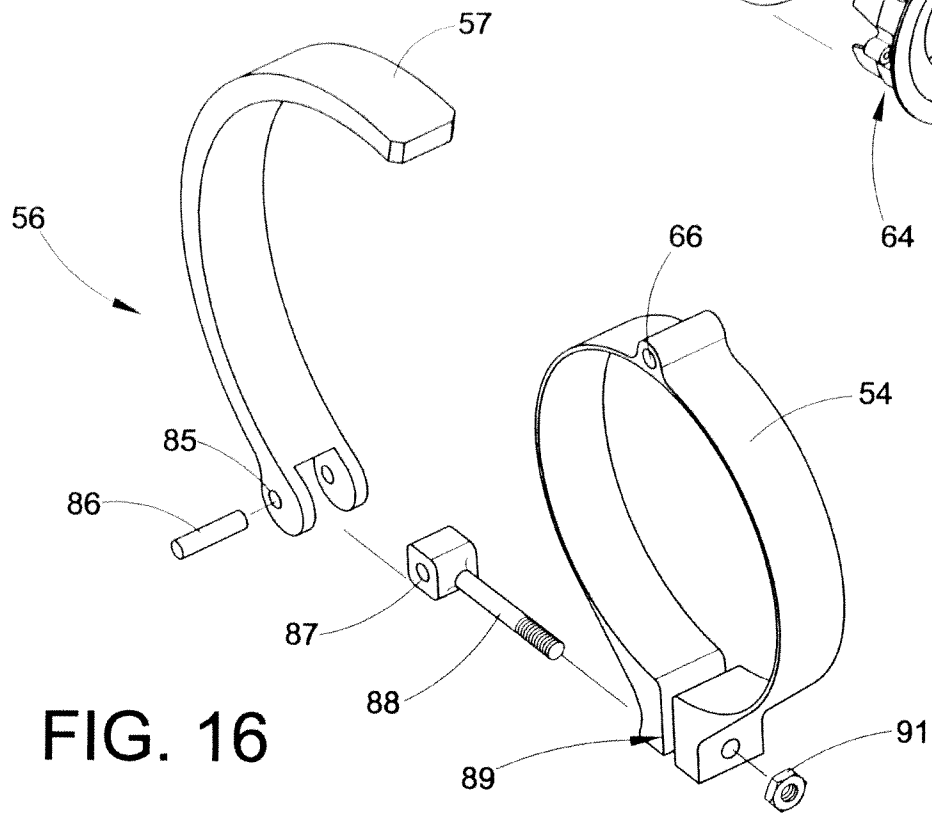


FIG. 16

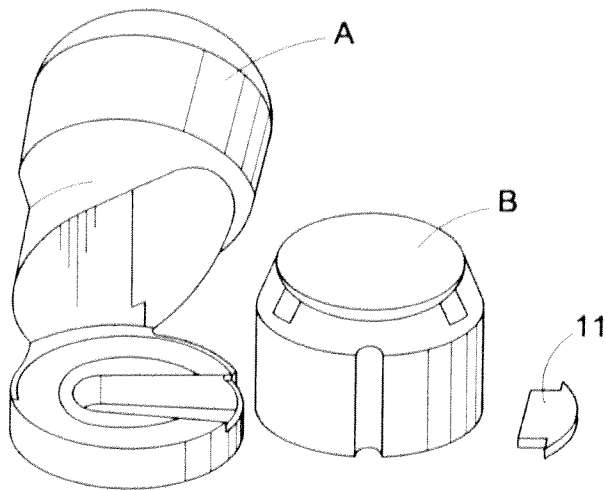


FIG. 17

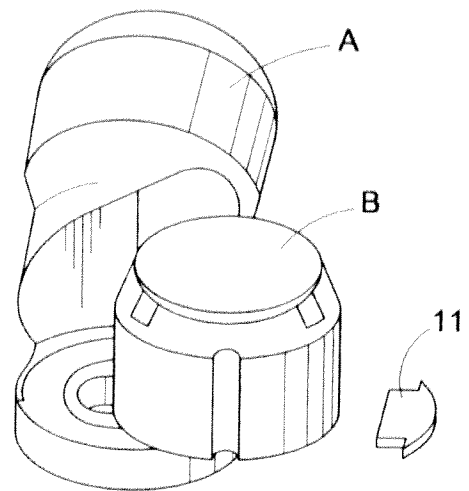


FIG. 18

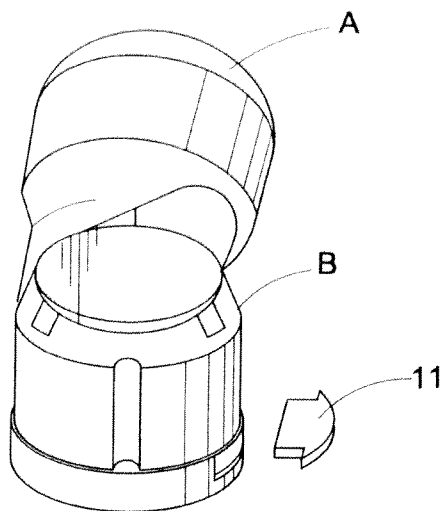


FIG. 19

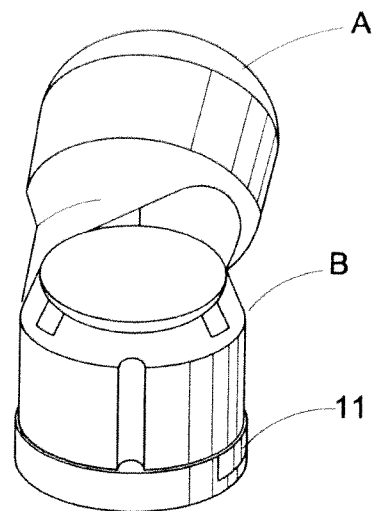


FIG. 20

## INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2010/059229

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> INV. A61F2/76 B25J13/08 B25J15/04 B25J19/00 ADD. A61F2/50 A61F2/68 A61F2/70																							
According to International Patent Classification (IPC) or to both national classification and IPC																							
<b>B. FIELDS SEARCHED</b> Minimum documentation searched (classification system followed by classification symbols) A61F B25J Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EPO-Internal, WPI Data																							
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b> <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>X</td> <td>US 4 512 709 A (HENNEKES DANIEL M [US] ET AL) 23 April 1985 (1985-04-23)</td> <td>1,2,8,9</td> </tr> <tr> <td>Y</td> <td>column 2, line 33 - column 3, line 44; figure 4 column 4, lines 41-42; figure 10 -----</td> <td>3-7</td> </tr> <tr> <td>X</td> <td>DE 103 26 239 A1 (ASS MASCHB GMBH [DE]) 13 January 2005 (2005-01-13)</td> <td>1,2,8,9</td> </tr> <tr> <td>Y</td> <td>paragraphs [0001], [0004] - [0005], [0012], [0020] - [0030]; figure 1 -----</td> <td>3-7</td> </tr> <tr> <td>X</td> <td>US 5 800 563 A (ARBOGAST ROBERT E [US] ET AL) 1 September 1998 (1998-09-01)</td> <td>1,3,4,9</td> </tr> <tr> <td>Y</td> <td>abstract; figures 2,8 column 1, line 54 - column 6, line 44 ----- -/--</td> <td>3-7</td> </tr> </tbody> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X	US 4 512 709 A (HENNEKES DANIEL M [US] ET AL) 23 April 1985 (1985-04-23)	1,2,8,9	Y	column 2, line 33 - column 3, line 44; figure 4 column 4, lines 41-42; figure 10 -----	3-7	X	DE 103 26 239 A1 (ASS MASCHB GMBH [DE]) 13 January 2005 (2005-01-13)	1,2,8,9	Y	paragraphs [0001], [0004] - [0005], [0012], [0020] - [0030]; figure 1 -----	3-7	X	US 5 800 563 A (ARBOGAST ROBERT E [US] ET AL) 1 September 1998 (1998-09-01)	1,3,4,9	Y	abstract; figures 2,8 column 1, line 54 - column 6, line 44 ----- -/--	3-7
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X	US 4 512 709 A (HENNEKES DANIEL M [US] ET AL) 23 April 1985 (1985-04-23)	1,2,8,9																					
Y	column 2, line 33 - column 3, line 44; figure 4 column 4, lines 41-42; figure 10 -----	3-7																					
X	DE 103 26 239 A1 (ASS MASCHB GMBH [DE]) 13 January 2005 (2005-01-13)	1,2,8,9																					
Y	paragraphs [0001], [0004] - [0005], [0012], [0020] - [0030]; figure 1 -----	3-7																					
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Y	abstract; figures 2,8 column 1, line 54 - column 6, line 44 ----- -/--	3-7																					
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.																							
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family																							
Date of the actual completion of the international search		Date of mailing of the international search report																					
11 March 2011		26/05/2011																					
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer  Dennler, Samuel																					

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US2010/059229

### Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

### Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-9

#### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

**FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210**

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-9

A joint assembly for releasably securing a first and a second segment of an associated modular limb, the joint assembly comprising a male connector and a female connector, each connector being adapted to be secured to one of the first and second segments, the female connector comprising a load bearing socket adapted to selectively receive a load bearing projection of the male connector, both connectors cooperating to form a resilient and selectively releasable modular limb joint, wherein the joint assembly further comprises a locking member selectively retaining the projection of the male connector in the socket of the female connector, allowing for a quick coupling and uncoupling of the first and second segments.

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2. claims: 10-18

A joint assembly for releasably securing a first and a second segment of an associated modular limb, the joint assembly comprising a male connector and a female connector, each connector being adapted to be secured to one of the first and second segments, the female connector comprising a load bearing socket adapted to selectively receive a load bearing projection of the male connector, both connectors cooperating to form a resilient and selectively releasable modular limb joint, wherein each of the connectors further comprises an electrical contact, said electrical contacts being aligned with each other when the projection is received in the socket for establishing electrical communication between the first and second segments.

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3. claims: 19-21

A joint assembly for releasably securing a first and a second segment of an associated modular limb, the joint assembly comprising a male connector and a female connector, each connector being adapted to be secured to one of the first and second segments, the female connector comprising a load bearing socket adapted to selectively receive a load bearing projection of the male connector, both connectors cooperating to form a resilient and selectively releasable modular limb joint, wherein the joint assembly further comprises a load sensor secured to one of the male and female connectors for measuring a torsional load transmitted through the joint assembly.

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# INTERNATIONAL SEARCH REPORT

International application No

PCT/US2010/059229

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/267600 A1 (HABERMAN LOUIS J [US] ET AL) 1 December 2005 (2005-12-01)	1,3
Y	paragraphs [0005], [0024]; figures 1-5 -----	3,5-7
Y	US 2008/276725 A1 (PUSCH MARTIN [DE]) 13 November 2008 (2008-11-13) abstract; figures 1-6 -----	5-7

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2010/059229

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