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HYDROPHONE MODULE

[0001] The present application is a divisional non-provisional application which claims the benefit of previously-filed United States Patent Application Serial No. 17/015,144 filed on September 9, 2020 and entitled "Thin Line Towed Array Bootable Bulkhead" by the inventors Eric H. Kirchoff and Michael J. Kroger.

STATEMENT OF GOVERNMENT INTEREST

[0002] The invention described herein may be manufactured and used by or for the Government of the United States of America for any governmental purpose without payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

[0003] The present invention is directed to towed array modules and more particularly, to bootable bulkhead assemblies for joining modular arrays.

(2) Description of the Prior Art

[0004] Arrays of hydrophones are towed for sensing sound below the surface of the ocean. Typically, such arrays are

linear assemblies of modules with each module having sections that have a bulkhead at opposing ends.

[0005] Hydrophones are mounted in the sections. Sound pressure waves in the ocean pass through the wall of various sections where the hydrophones sense the pressure fluctuations and transform the sensed pressures into electrical signals which are transmitted back to a support vessel.

[0006] Submarines can deploy a thin-line towed-array (TLTA) using mechanical handling systems. Each module of the thin-line array includes an outer sheath or hose that contains the hydrophones and supporting electronics. However, TLTAs have historically had poor reliability. One of the reasons for this poor reliability is the mechanical stress on the electrical and optical data paths during booting of the array module.

[0007] Booting is the process of pulling a pre-hose assembly into the hose to create the final module assembly. The pre-hose assembly includes electrical and optical harnesses, telemetry units, internal strength members and other components that constitute functional elements along with strength members to carry tension across each array module.

[0008] To pull the pre-hose assembly into the hose of the TLTA module, the hose is inflated beyond a nominal, non-pressurized inner diameter in order to reduce friction between the pre-hose assembly and the inside wall of the hose.

Typically, bulkheads at the end of each module are too large to fit through the ends of the hose; therefore, each end of the pre-hose assembly is terminated with a coupling. However, one end of the pre-hose assembly may be constructed without the wires and optical fibers terminated into the connector insert and coupling. This end is pulled into the hose first and to the other end of the hose until the terminated end of the pre-hose assembly is seated in the coupling.

[0009] Once the first end of the pre-hose assembly is seated in the coupling; the other end of the pre-hose assembly is terminated in the connector insert and bulkhead. In order to make this happen, an excess length of wire and fiber is needed free from the hose to terminate the second end. As a result, the pre-hose assembly is longer than the hose.

[0010] The hose is then elongated over the pre-hose assembly until the other end of the unseated bulkhead is seated in the coupling. Occasionally, final sections of the pre-hose assembly are reinserted into the hose by hand. In either case, the wires and fibers in the excess pre-hose assembly may wrinkle and fold inside the hose; thereby, subjecting the wires and fibers to stresses that contribute to poor reliability.

SUMMARY OF THE INVENTION

[0011] Devices and methods described herein allow for the booting of a thin line towed array with connector inserts prepopulated inside a bulkhead. Wires and fibers are pre-terminated in the connector insert and bulkhead before the booting process. This pre-termination eliminates the need to pull excess pre-hose material through the hose.

[0012] It is anticipated that the pre-hose can be shortened in relation to the hose such that both bulkheads can be seated at the same time; thereby, reducing wire and fiber stresses introduced through excess lengths and pulling back into the hose. Since some frictional buildup will remain between the pre-hose assembly and the hose walls; excess length may be required to account for hose stretch caused by induced tension from the friction. Furthermore, the TLTA bulkhead enables a booting process that reduces stress on the electrical and optical data paths in the array.

[0013] The TLTA bulkhead disclosed herein is novel in the capability to be booted with the optical and electrical connectors already terminated in the connector inserts and the connector insert installed in the bulkhead. This reduces the amount of pre-hose assembly, or towed array internals, which must be pulled past the booting process. This also reduces the excess pre-hose length requirement and improves towed array

reliability by reducing stresses on the optical and electrical components and wiring.

[0014] According to another aspect of the invention, an assembly has a first coupling having a forward bulkhead device therein. The forward bulkhead device contains a first connector insert having first end connections for wires and optical fibers of an acoustic array. The assembly also includes a second coupling having an aft bulkhead device therein. The aft bulkhead device contains a second connector insert having second end connections for the wires and optical fibers of the acoustic array.

[0015] The forward bulkhead device further includes an alignment assembly. The alignment assembly is matable with the aft bulkhead device to align the first connector insert with the second connector insert. The forward bulkhead device includes a locking ring to connect with the aft bulkhead device.

[0016] According to an exemplary hydrophone assembly herein, a housing tube comprises an elongated sleeve having a first end and a second end. A pre-tube assembly is located inside the housing tube. The pre-tube assembly includes a plurality of hydrophones, and a harness connected to the hydrophones.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] Other objects, features and advantages of the present invention will become apparent upon reference to the following description of the preferred embodiments and to the drawings, wherein corresponding reference characters indicate corresponding parts throughout the several views of the drawings and wherein:

[0018] **FIG. 1** is a sectional view of a towed array system of the present invention;

[0019] **FIG. 2** is a cross section view of an aft bulkhead assembly of the present invention;

[0020] **FIG. 3** is a cross section view of a forward bulkhead assembly of the present invention;

[0021] **FIG. 4** is a cross section view of a bootable bulkhead of the present invention;

[0022] **FIG. 5** is a perspective view of an alignment assembly of the present invention;

[0023] **FIGS. 6A** and **FIG. 6B** are end views of an alignment assembly and forward bulkhead device of the present invention;

[0024] **FIG. 7** shows an end view of the alignment piece on the aft bulkhead device of the present invention;

[0025] **FIG. 8** is an end view of an aft bulkhead device of the present invention;

[0026] **FIG. 9** is a cross section view of a female clevis of the present invention;

[0027] **FIG. 10** illustrates the tensile load path across the bootable bulkhead; and

[0028] **FIG. 11** is a flow chart illustrating methods herein.

DETAILED DESCRIPTION OF THE INVENTION

[0029] Referring to the drawings, **FIG. 1** shows a towed array **100**. The towed array **100** contains a linear series of modules **102** in which the modules couple together. The array **100** is towed from a vessel **104**, such as a surface ship or a submarine, using a cable **106**.

[0030] Each of the modules **102** has a housing formed by a flexible hose **108**. The flexible hose **108** may be made from an elastomer or plastic and may be reinforced, such as with Kevlar™ fibers or other suitable fibers. For a thin-line towed array, the hose section for each module **102** will typically be one and one-half inch or less in diameter and have a length of 30 to 250 feet. The relative dimensions of the modules **102** are distorted in **FIG. 1** for illustration purposes.

[0031] Hydrophones **110** are disposed in each of the modules **102**. A plurality of modules **102** may be coupled together to form the array **100**. The hydrophones **110** communicate via a harness

112 inside the flexible hose **108,** which is connected to a transmission line **114** inside the cable **106.**

[0032] Sound pressure waves in the ocean pass through the wall of various modules **102** where the hydrophones **110** sense the pressure fluctuations and transform the sensed pressures into signals that are transmitted via the cable **106** back to the vessel **104.** The transmission line **114** may be an electric and/or optical conduit for relaying signals from the array **100** via the harness **112** to the vessel **104.** The signals are then processed to provide a representation of the underwater sound.

[0033] The flexible hose **108** for each module has a first end **116** and a second end **118,** referred to herein as the forward end (corresponding to **116**) and the aft end (corresponding to **118**). Typically, the ends of the modules **102** are sealed at each of opposing ends by a connector **120.** The connector **120** is constructed of two halves, which will be described in detail below.

[0034] The connector **120,** referred to herein as the Bootable Bulkhead includes forward and aft couplings and forward and aft bulkheads. The harness **112** can be attached to the bulkheads. The connectors **120** permit mating of adjacent modules **102** and allow the signals from the hydrophones **110** to pass therethrough as if the harness **112** were continuous.

[0035] As mentioned above, each module **102** for a towed array **100** is formed by pulling a pre-hose assembly into the flexible hose **108** to create a final assembly. The pre-hose assembly comprises the hydrophones, electrical and/or optical harnesses, telemetry units and other components that constitute the functional elements of each module **102**. To pull the pre-hose assembly into the flexible hose **108**; the flexible hose is inflated beyond a non-pressurized inner diameter. Typically, bulkheads at the end of each module **102** are too large to fit through the ends of the flexible hose **108**; therefore, each end of the pre-hose assembly is terminated with a coupling.

[0036] However, one end of the pre-hose assembly may be constructed without the wires and optical fibers terminated into the connector insert and coupling. This end is pulled into the flexible hose **108** first and through to the other end of the flexible hose until the terminated end of the pre-hose assembly is seated in the coupling.

[0037] Once the first end of the pre-hose assembly is seated in the coupling; the other end of the pre-hose assembly is terminated in the connector insert and bulkhead. In order to make this happen, some excess length of wire and fiber is needed free from the flexible hose **108** to terminate the second end. The flexible hose **108** is then elongated over the pre-hose

assembly until the other end of the unseated bulkhead is seated in the coupling.

[0038] As mentioned above, the connector **120** is constructed of two halves, the aft bulkhead assembly and the forward bulkhead assembly, which reside on the aft and forward ends of each array module **102**, respectively. **FIG. 2** shows a section view of an aft bulkhead assembly **202**. The aft bulkhead assembly **202** includes an aft coupling **204**, an aft bulkhead device **206**, an aft connector insert **208**, and a female clevis **210**.

[0039] The aft connector insert **208** is housed within the aft bulkhead device **206**. By design, the aft bulkhead assembly **202** is not bootable, and therefore cannot be pulled through the aft coupling **204** or the flexible hose **108**. The aft bulkhead assembly **202** is assembled prior to booting of the module **102**.

[0040] While the aft bulkhead assembly **202** comprises three main components, various hardware components, such as O-ring grooves **212** in the aft bulkhead device **206**, along with the one or more O-rings **214** may be provided to seal the aft bulkhead device against a mating surface **216** on the aft coupling **204**. The aft end of the wires and optical fibers (not shown) of the harness **112** terminate in the aft connector insert **208**. The aft end of the internal strength members (not shown) for the module **102** terminate to the female clevis **210**. Once seated in the aft

coupling **204,** the aft bulkhead assembly **202** is held in place using radial screws (not shown) or other fasteners.

[0041] **FIG. 3** shows a section view of a forward bulkhead assembly **302.** The forward bulkhead assembly **302** includes a forward coupling **304,** a female clevis **306,** a forward connector insert **308,** and a forward bulkhead device **310.** The forward connector insert **308** is housed within the forward bulkhead device **310.** In a mirror view to the aft bulkhead assembly **202,** the forward end of the wires and optical fibers (not shown) of the harness **112** terminate in the forward connector insert **308** and the forward end of the internal strength members (not shown) for the module **102** terminate to the female clevis **306.**

[0042] The outer diameter of the forward bulkhead device **310** is smaller than the inner diameter of the forward coupling **304.** Given that the outer diameter of the forward bulkhead device **310** is smaller than the inner diameter of the forward coupling **304;** the forward bulkhead device **310** can be booted through the forward coupling **304** and the flexible hose **108** when the flexible hose is inflated.

[0043] The forward bulkhead assembly **302** can be pulled clear of the flexible hose **108.** Since the wires and optical fibers have been terminated in the forward connector insert **308** and the forward connector insert is contained in the forward bulkhead

device **310**; the pre-hose assembly does not need to be pulled far out of the flexible hose **108**.

[0044] The forward bulkhead assembly **302** also includes a sealing sleeve **312** that can be pushed over the outside of the forward bulkhead device **310** after the sleeve has been pulled through the flexible hose **108**. A locking ring **314** is slid over the sealing sleeve **312** and screwed onto the forward bulkhead device **310**. The locking ring **314** has standard threads to mate with the aft bulkhead assembly **202**.

[0045] The sealing sleeve **312** is inserted around the forward bulkhead device **310** to seal the bulkhead to environmental conditions. The sealing sleeve **312** also acts as a centering ring to allow the forward bulkhead device **310** to remain centered in the forward bulkhead assembly **302**.

[0046] The forward bulkhead assembly **302** may also include hardware components, such as O-ring grooves **316** in the forward bulkhead device **310**, along with the one or more O-rings **318** provided to seal the forward bulkhead device **310** against a mating surface **320** on the sealing sleeve **312**. In addition, other O-ring grooves **322** in the sealing sleeve **312**, along with the one or more O-rings **324** may be provided to seal the sealing sleeve **312** against a mating surface **326** on the forward coupling **304**.

[0047] Each module **102** includes a forward bulkhead assembly **302** on the first end **116** and an aft bulkhead assembly **202** on the second end **118.** The array **100** is constructed by attaching the first end **116** of a module **102** to the second end of another module **102.**

[0048] **FIG. 4** shows the connector **120** (Bootable Bulkhead) with the aft bulkhead assembly **202** of a first module mated to the forward bulkhead assembly **302** of a second module. As shown in the figure, a portion **402** of the aft bulkhead device **206** fits within the locking ring **314** and a portion **404** of the aft connector insert **208** fits within the forward bulkhead device **310,** such that a distal end **406** of the aft connector insert **208** abuts a distal end **408** of the forward connector insert **308** to form a mating junction.

[0049] Referring again to **FIG. 3,** in order to ensure proper alignment of the forward bulkhead assembly **302** with the aft bulkhead assembly **202;** the forward bulkhead assembly includes a retained shoulder **328** that is threaded onto the forward bulkhead device **310.** The retained shoulder **328** provides a bearing surface for the locking ring **314** and an alignment assembly **502,** such as shown in **FIG. 5.**

[0050] The alignment assembly **502** includes an alignment ring **504** with alignment pins **506** extending perpendicular to the alignment ring **504** and a notched key **508.** The alignment

assembly **502** preserves radial alignment between the modules **102.** It is important to preserve radial alignment between the modules **102** in order to align fiber and electrical pins within the aft connector insert **208** and the forward connector insert **308.**

[0051] A plurality of set screws **330** are used in the alignment assembly **502.** The set screws **330** are installed through the locking ring **314** and apertures **510** in the alignment ring **504** to prevent the alignment assembly **502** from falling off during mating of the forward bulkhead assembly **302** with the aft bulkhead assembly **202.** The set screws **330** also prevent the retained shoulder **328** from vibrating off and breaking the inter-module connection. Similarly, a locking tab **332** may be used to prevent the locking ring **314** from vibrating loose. The locking tab **332** overlaps a portion of the locking ring **314** and may be held in place by a fastener **334.**

[0052] **FIGS. 6A** and **FIG. 6B** show end views of the alignment assembly **502** and the forward bulkhead device **310,** respectively. The alignment ring **504** has a central opening **602** through which the forward bulkhead device **310** is located. This provides an opening so that the forward connector insert **308** can match up with the aft connector insert **208.** The alignment assembly **502** is aligned to the forward bulkhead device **310** using the notched key **508** on the alignment assembly **502** and a keyway **604** on the forward bulkhead device **310.** See **FIG. 7.**

[0053] **FIG. 8** shows an end view of the aft bulkhead device **206**. The aft bulkhead device **206** has a plurality of alignment holes **802** that correspond to the alignment pins **506** on the alignment assembly **502**. The alignment assembly **502** then aligns the aft bulkhead assembly **202** and the forward bulkhead assembly **302** through the alignment pins **506** that are in the alignment ring **504**.

[0054] Referring again to **FIG. 4**, the aft bulkhead assembly **202** and the forward bulkhead assembly **302** mate together to form a completed connector **120** (Bootable Bulkhead). Through the mating of the aft bulkhead assembly **202** and the forward bulkhead assembly **302**; the connector **120** preserves radial alignment between modules; passes tensile loads between modules; passes optical and electrical signals between modules; and provides an environmental seal at the mating junction. Because the aft bulkhead assembly **202** is not bootable, the forward bulkhead assembly **302** is pulled into the flexible hose **108** first.

[0055] An additional feature of the present disclosure is the female clevis **210** and the female clevis **306** at the ends of the aft bulkhead assembly **202** and the forward bulkhead assembly **302**, respectively. **FIG. 9** shows an exemplary female clevis **902** having a load end **904** and a seating end **906**. Female threads **908** may be located within the seating end **906**. The female threads **908** are preferably standard Unified Series Threads (UST). The

female threads **908** pass tensile loads while maintaining the geometry for booting the forward bulkhead assembly **302**.

[0056] **FIG. 10** shows the tensile load path across the connector **120** (Bootable Bulkhead). Load is distributed radially, around the entire assembly. The tensile load path starts from the female clevis **210** on the aft bulkhead assembly **202**. Referring to the depicted figures in totality, the female clevis **210** passes loads to the aft bulkhead device **206** through the female threads **908**. The aft bulkhead device **206** subsequently passes the load to the locking ring **314** which bears on the retained shoulder **328**. The retained shoulder **328** passes the load onto the forward bulkhead device **310**.

[0057] Finally, the female clevis **306** on the forward end of the forward bulkhead assembly **302** takes the load. Both female clevises **210**, **306** are connected to internal strength members in the flexible hose **108** to carry loads in the module **102** along with load sharing across the flexible hose **108**.

[0058] **FIG. 11** is a flow chart illustrating an exemplary method of assembling a towed hydrophone array module. At step **1102**, an elongated sleeve having a first end and a second end is provided. The elongated sleeve may be a flexible tube made from an elastomer or plastic and may be reinforced, such as with Kevlar™ fibers or other suitable fibers. At step **1104**, a pre-tube assembly is provided. The pre-tube assembly includes a

plurality of hydrophones and a harness connected to the hydrophones. The harness has a first connector insert connected to a first end of the harness and a second connector insert connected to a second end of the harness.

[0059] At step **1106**, the first connector insert is inserted into a forward bulkhead device. The forward bulkhead device is part of a forward bulkhead assembly, which also includes a first coupling. At step **1108**, the first coupling is connected to the first end of the elongated sleeve. At step **1110**, the elongated sleeve is inflated and the forward bulkhead device is passed through the elongated sleeve from the second end toward the first end, at step **1112**. Responsive to the forward bulkhead device reaching the first end of the sleeve; the forward bulkhead device is sealed onto the first coupling, at step **1114**. At step **1116**, second coupling is connected to the second end of the elongated sleeve. The second coupling includes an aft bulkhead assembly. At step **1118**, a linear array is formed by connecting the forward bulkhead assembly of one module to the aft bulkhead assembly of an adjacent module.

[0060] It will be understood that many additional changes in the details, materials, steps and arrangement of parts, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the

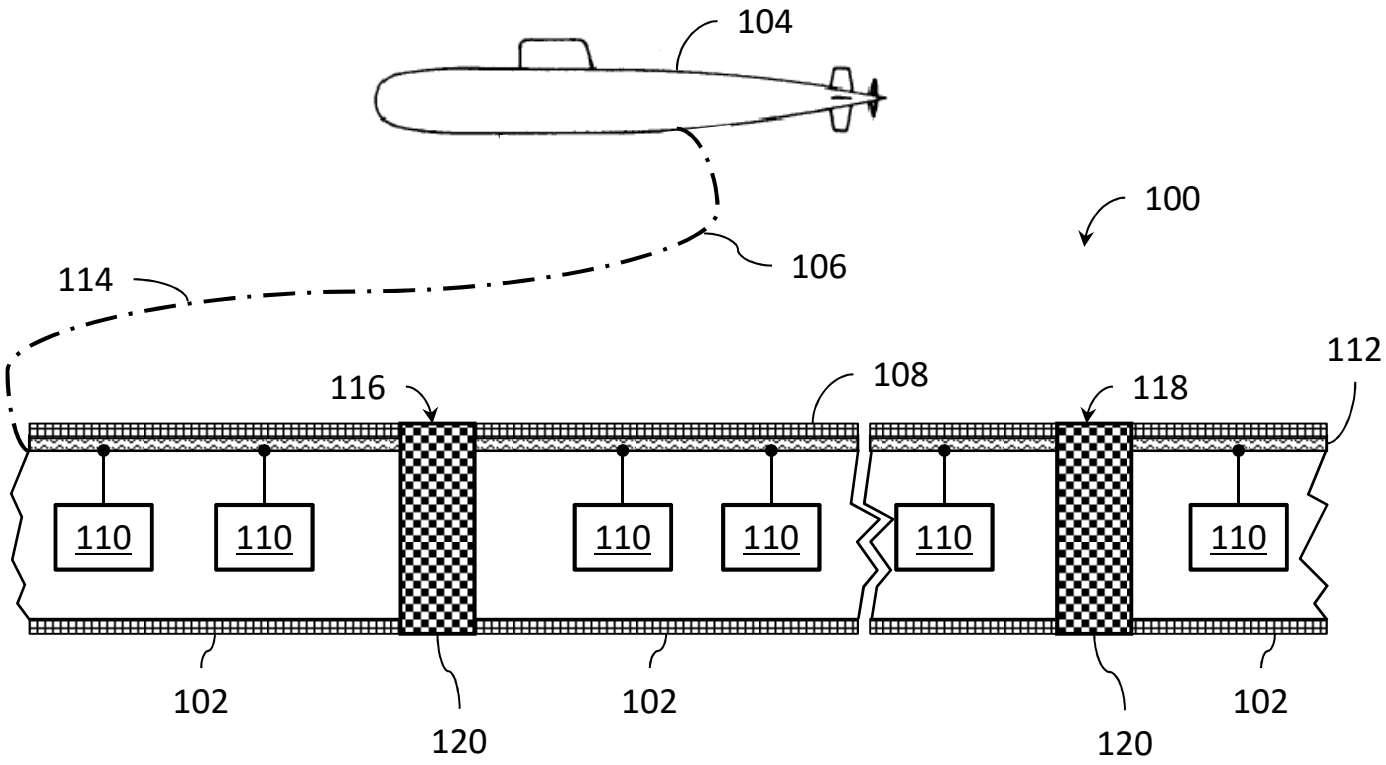
art within the principle and scope of the invention as expressed in the appended claims.

[0061] The invention has been described with references to specific embodiments. While particular values, relationships, materials, and steps have been set forth for purposes of describing concepts of the present disclosure, it will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the disclosed embodiments without departing from the spirit or scope of the basic concepts and operating principles of the invention as broadly described. It should be recognized that, in the light of the above teachings, those skilled in the art could modify those specifics without departing from the invention taught herein.

HYDROPHONE MODULE

ABSTRACT OF THE DISCLOSURE

An assembly with a first coupling having a forward bulkhead device is provided. The forward bulkhead device contains a first connector insert having first end connections for wires and optical fibers of an acoustic array. The assembly also includes a second coupling having an aft bulkhead device therein. The aft bulkhead device contains a second connector insert having second end connections for the wires and optical fibers of the acoustic array. The forward bulkhead device further includes an alignment assembly. The alignment assembly is matable with the aft bulkhead device to align the first connector insert with the second connector insert. The forward bulkhead device further includes a locking ring connecting the forward bulkhead device with the aft bulkhead device.


104
100
106
114
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102
120
102
120
102

FIG. 1

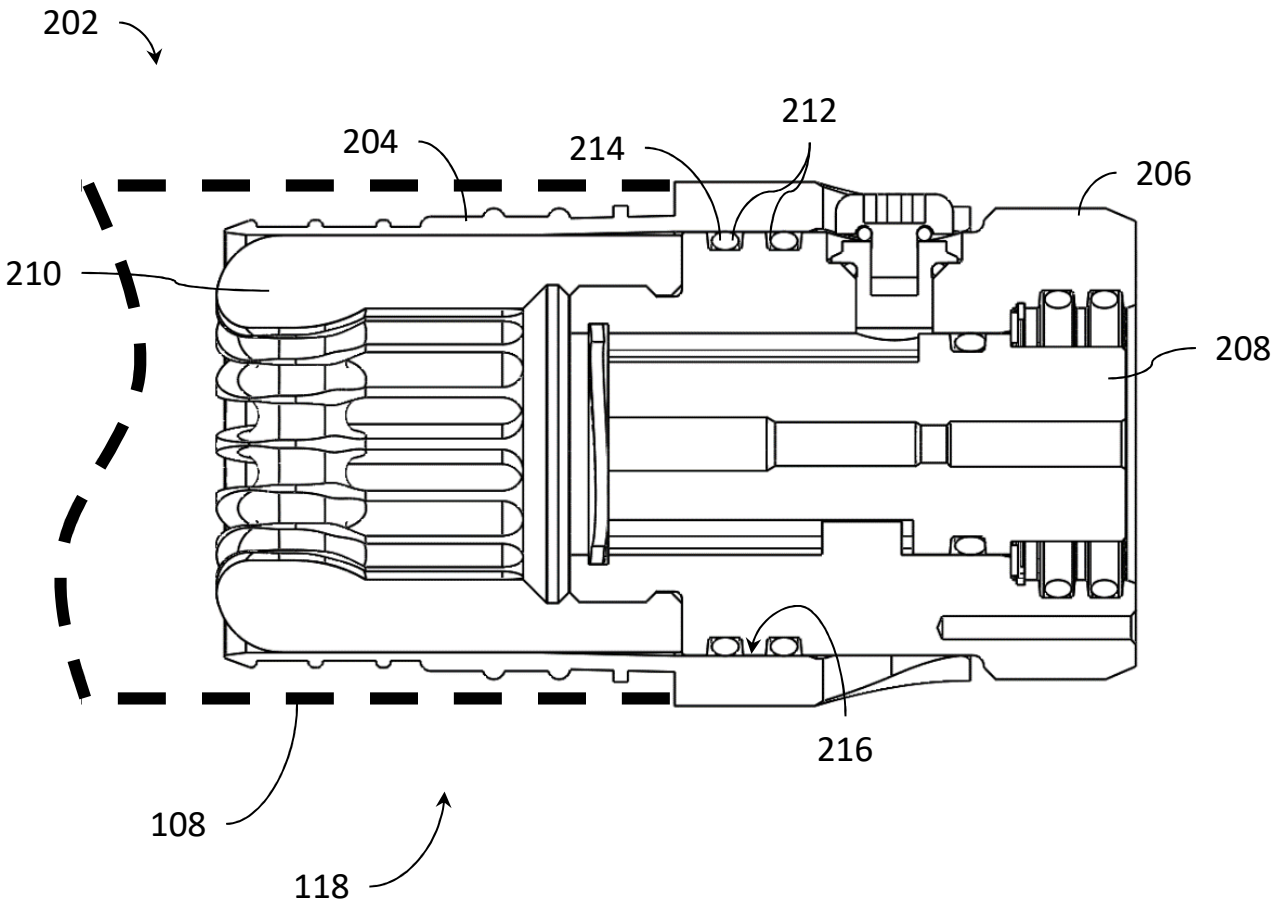
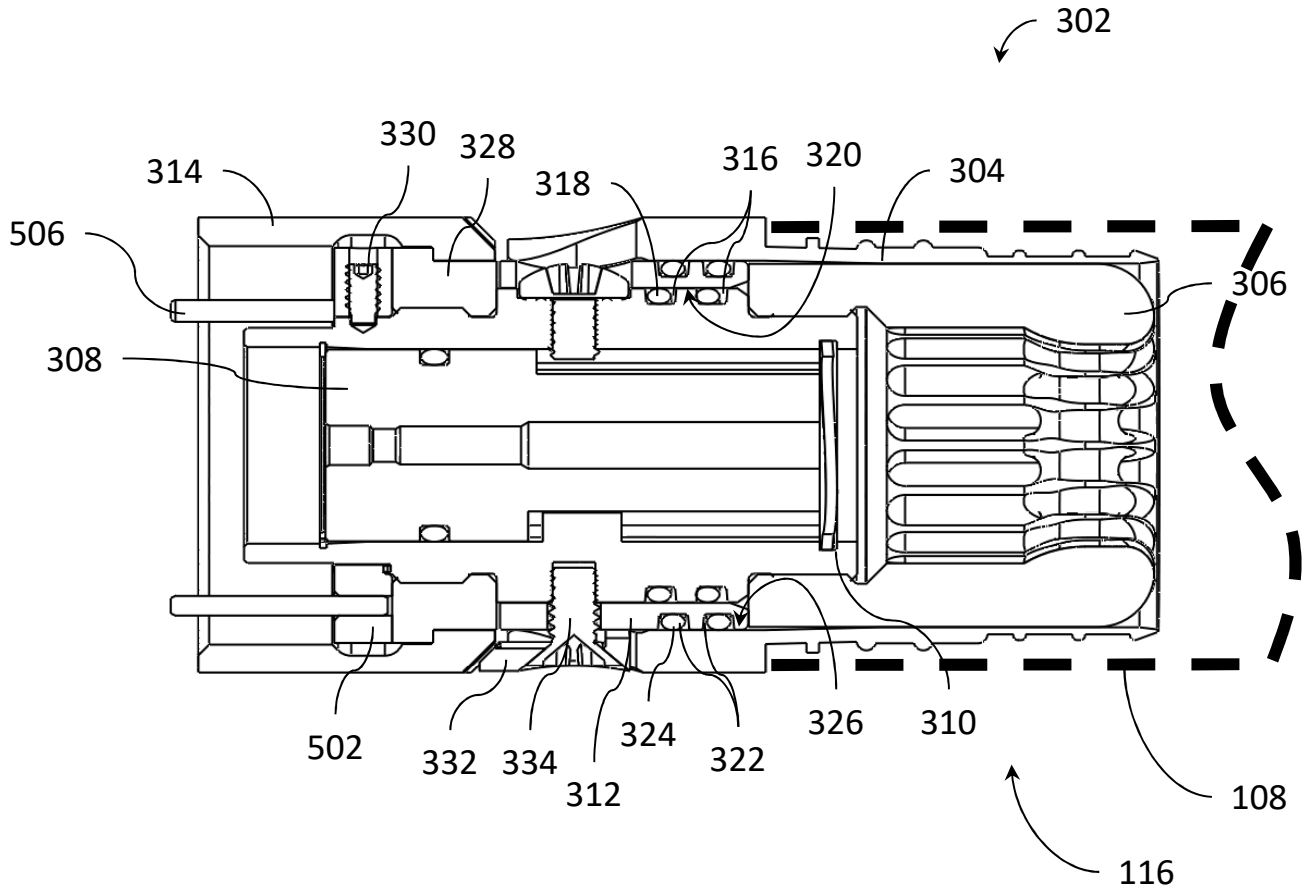


FIG. 2


302
330
328
314
316
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318
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506
306
308
502
332
334
312
324
322
326
310
108
116

FIG. 3

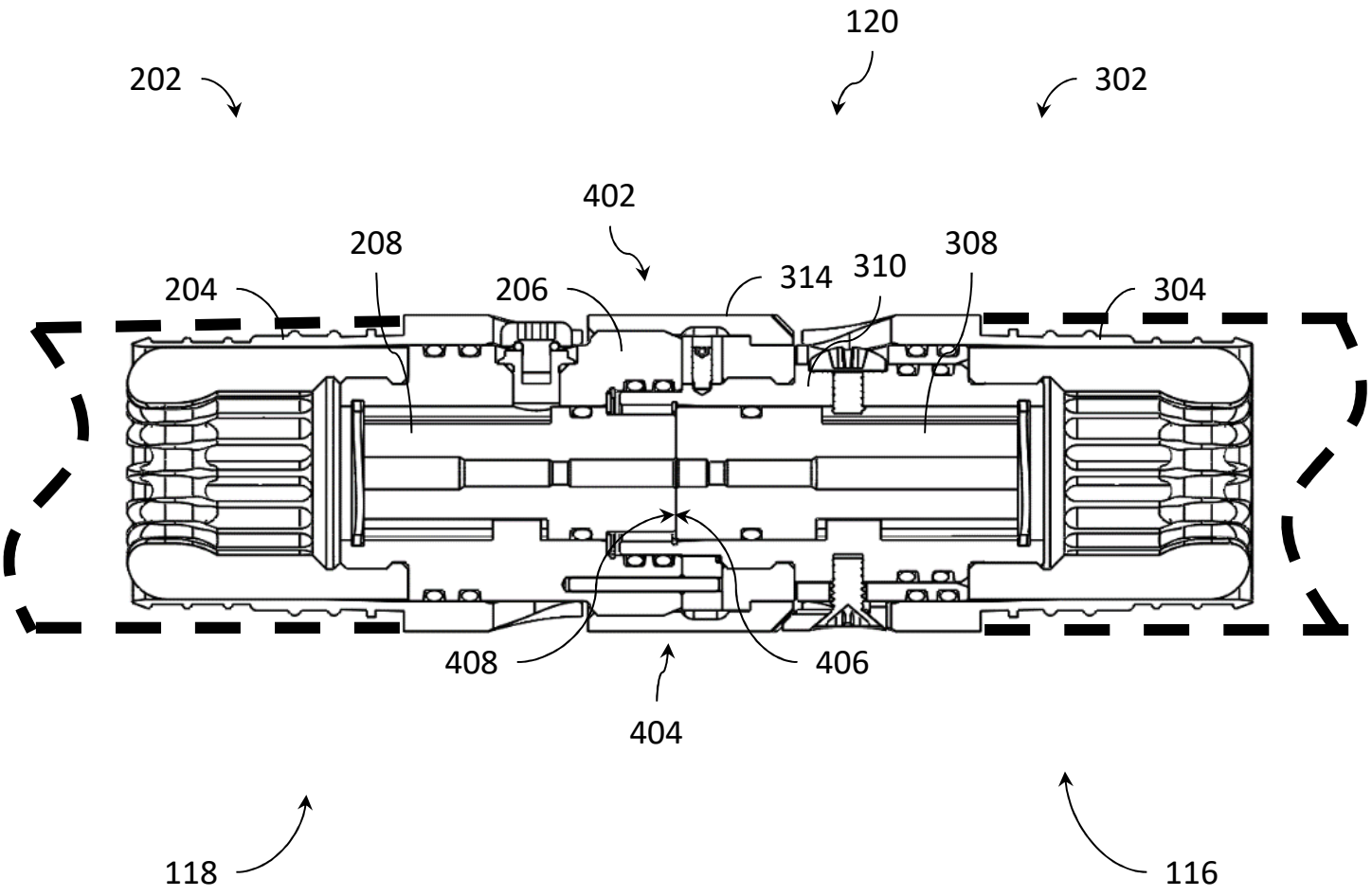

FIG. 4

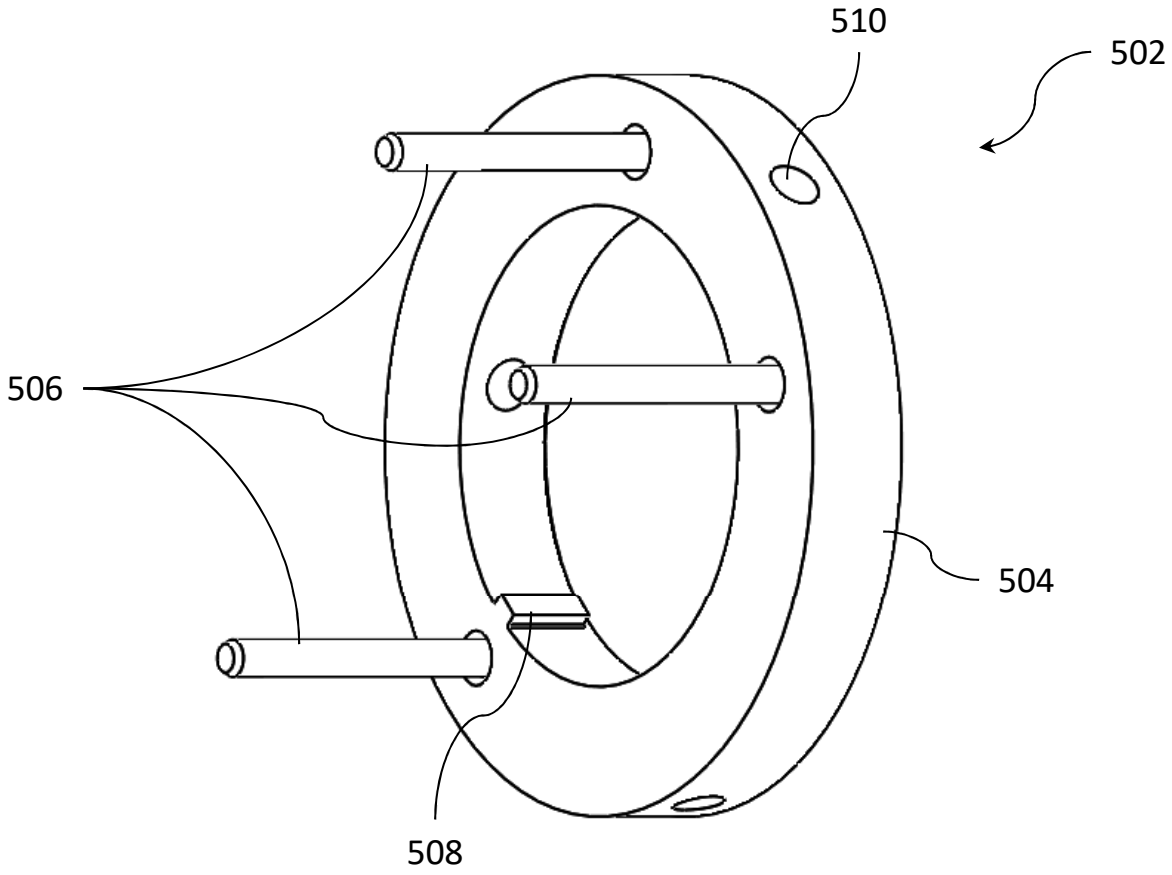

FIG. 5

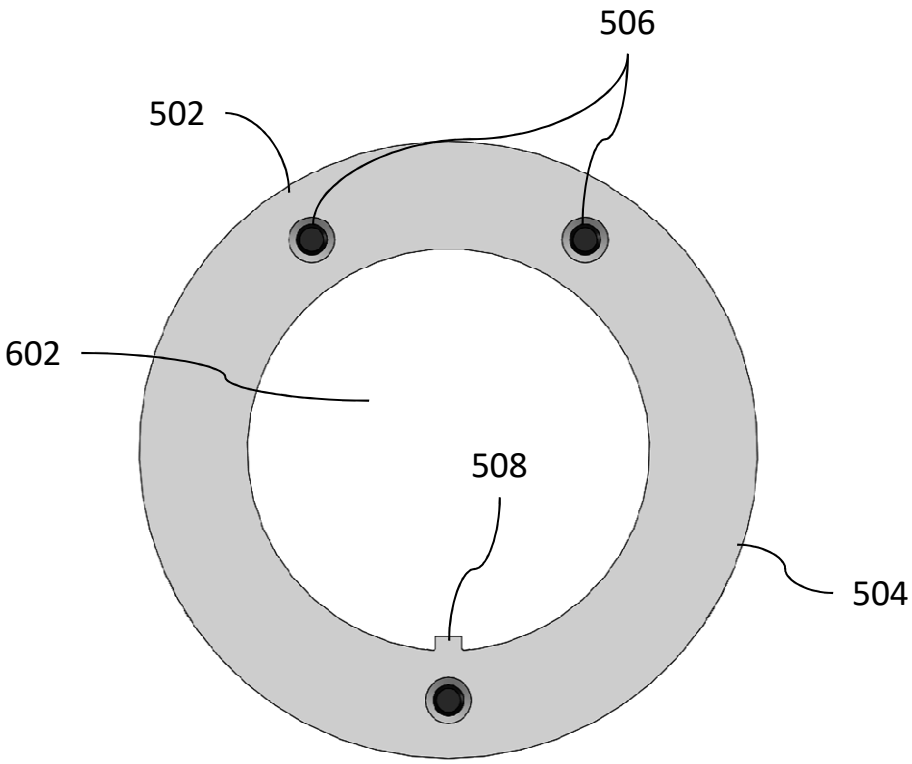

FIG. 6A

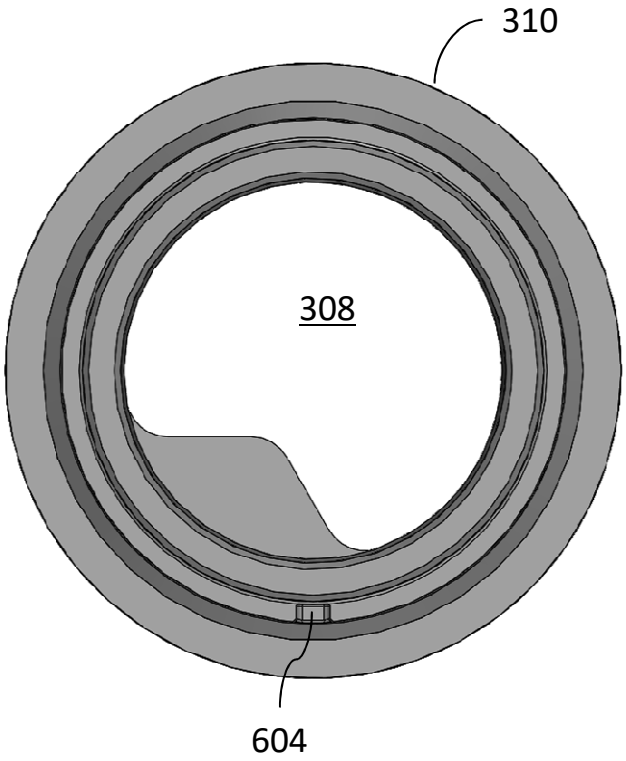

FIG. 6B

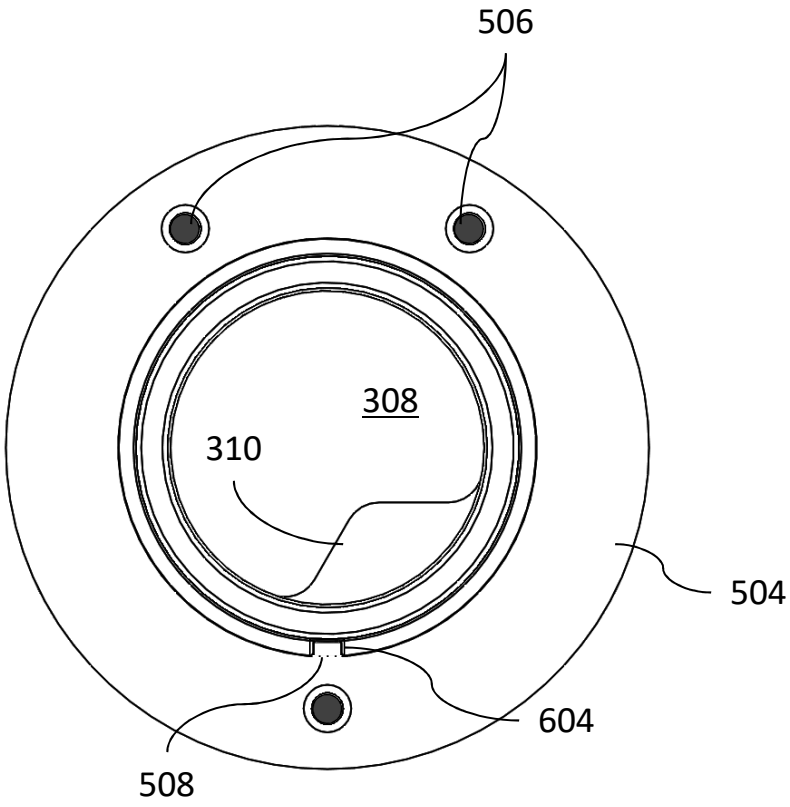

FIG. 7

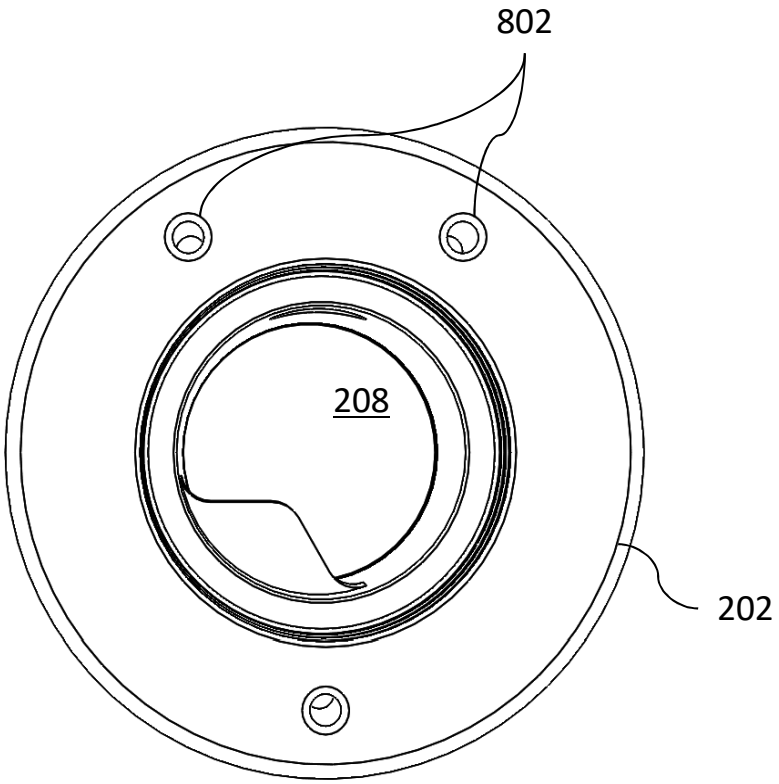

FIG. 8

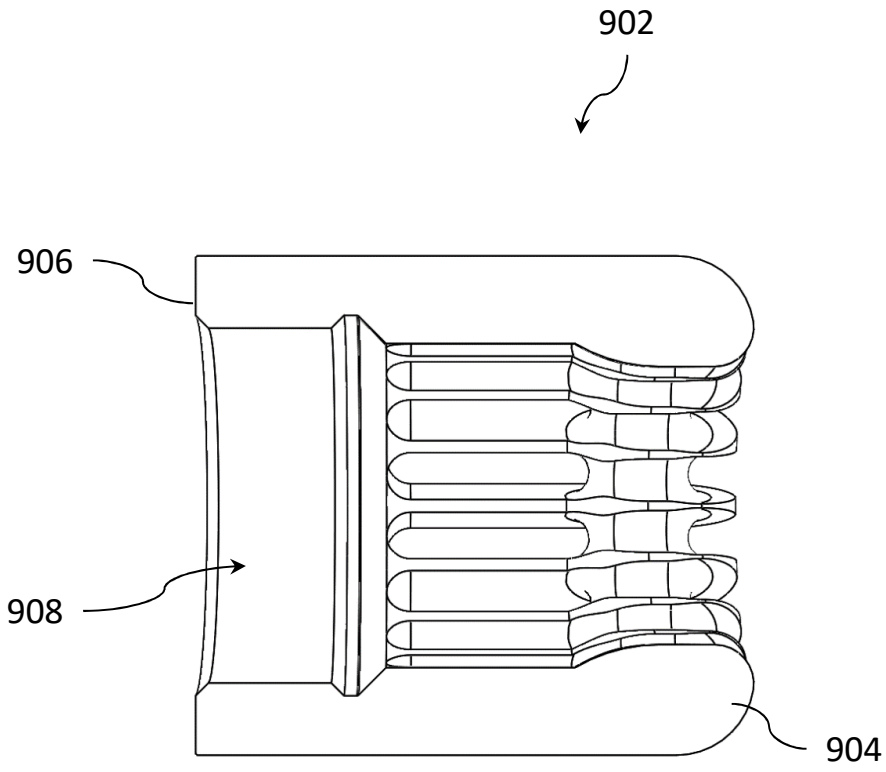

FIG. 9

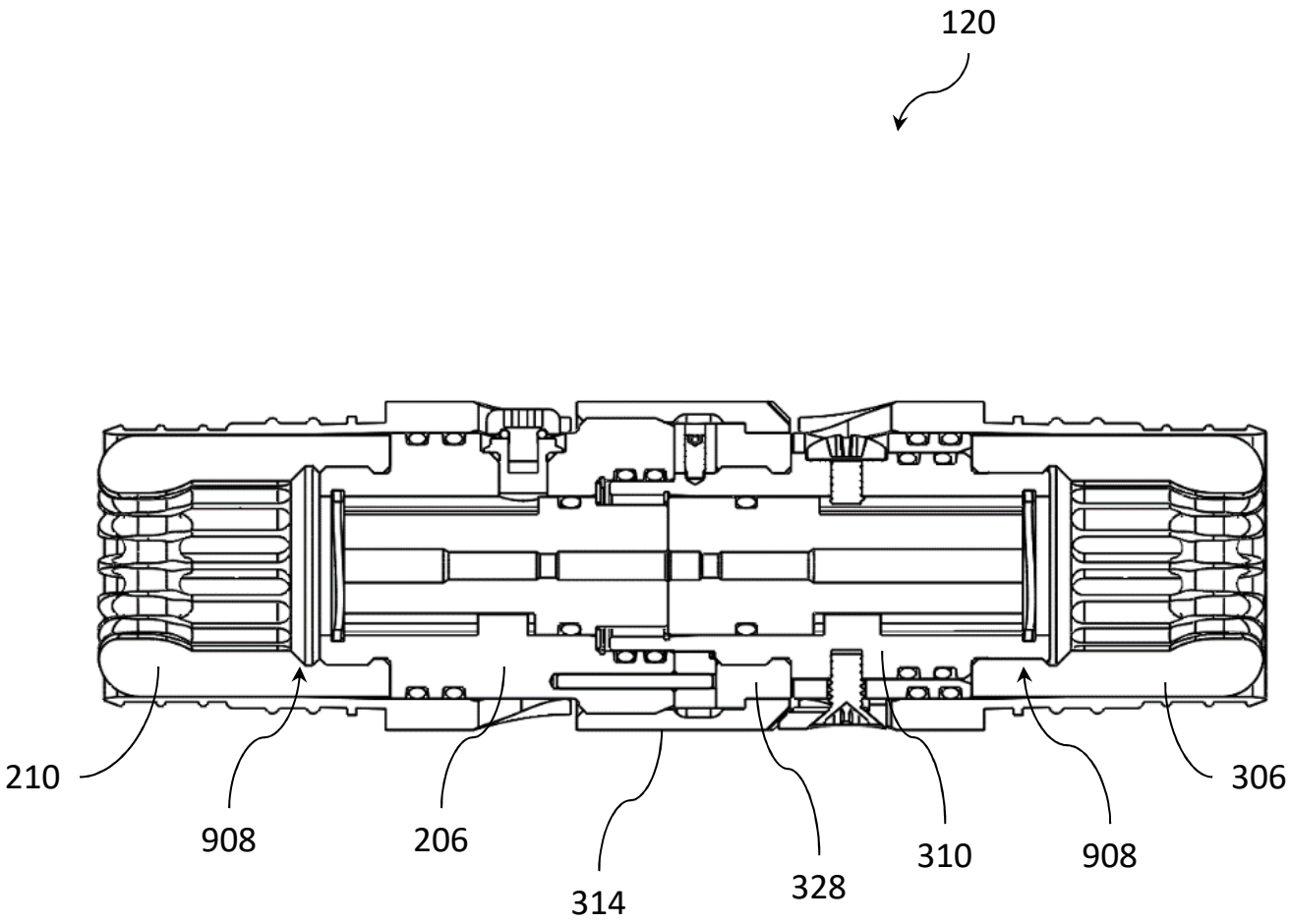

FIG. 10

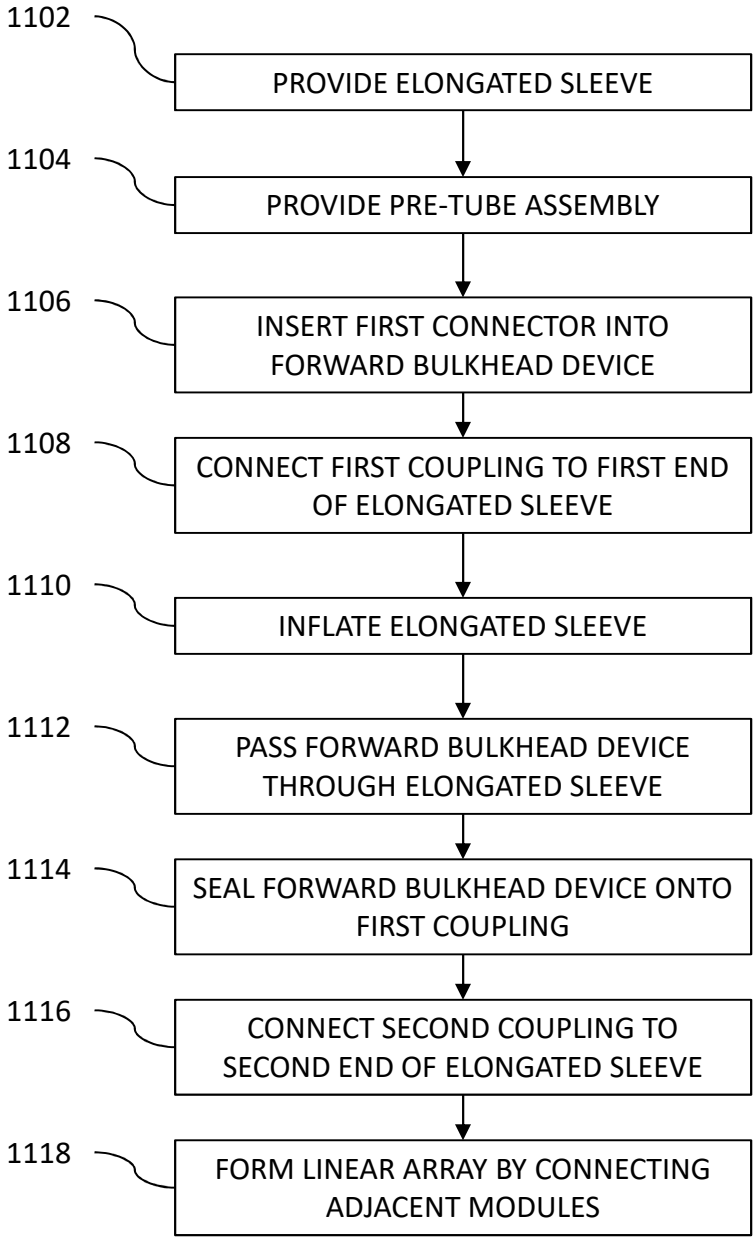
1102
PROVIDE ELONGATED SLEEVE
1104
PROVIDE PRE-TUBE ASSEMBLY
1106
INSERT FIRST CONNECTOR INTO FORWARD BULKHEAD DEVICE
1108
CONNECT FIRST COUPLING TO FIRST END OF ELONGATED SLEEVE
1110
INFLATE ELONGATED SLEEVE
1112
PASS FORWARD BULKHEAD DEVICE THROUGH ELONGATED SLEEVE
1114
SEAL FORWARD BULKHEAD DEVICE ONTO FIRST COUPLING
1116
CONNECT SECOND COUPLING TO SECOND END OF ELONGATED SLEEVE
1118
FORM LINEAR ARRAY BY CONNECTING ADJACENT MODULES

FIG. 11