



DEPARTMENT OF THE NAVY

OFFICE OF COUNSEL
NAVAL UNDERSEA WARFARE CENTER DIVISION
1176 HOWELL STREET NEWPORT RI 02841-1708

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TECHNOLOGY PARTNERSHIP OFFICE
NAVAL UNDERSEA WARFARE CENTER
1176 HOWELL ST.
CODE 00T2, BLDG. 102T
NEWPORT, RI 02841

Serial Number 17/015,164
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Inventor Lucas A. Bomback

Address any questions concerning this matter to the
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LINE-CUTTER APPARATUS

STATEMENT OF GOVERNMENT INTEREST

[0001] The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

CROSS REFERENCE TO OTHER PATENT APPLICATIONS

[0002] None.

BACKGROUND OF THE INVENTION

Field of the Invention

[0003] The present disclosure relates to the field of towed sensor arrays. More specifically, the present disclosure relates to a line-cutter apparatus, capable of being mounted on a tow cable and used in conjunction with towed sensor arrays.

Description of the Prior Art

[0004] Towed sonar arrays (referred to herein in the singular as a towed array) are typically used by military and commercial entities to detect and locate underwater targets. In military applications, the targets may be submarines. In commercial applications, the targets may be shipwrecks on the ocean floor

or underwater structures, both manufactured and natural, related to oil exploration and drilling, for example.

[0005] Towed sonar arrays typically consist of a lengthwise series of underwater passive acoustic sensing elements referred to as hydrophones. Active sound emitting elements and other types of sensor elements may be included in the towed array. The elements of the towed array are typically housed in a fluid filled flexible structure that may be made of a waterproof material such as polyurethane or polyethylene, for example. In general, references made to a towed array herein are directed to the fluid filled flexible structure.

[0006] The towed array may be electromechanically coupled to a ship via a tow cable. The towed array and tow cable are typically stored on a storage reel. The towed array and tow cable can be unreeled from this reel and deployed behind a ship. Weights or some other arrangement may be used to locate the towed array at a given depth. Electrical power and signal conductors, including fiber optics if used, may be used carry power to the towed array and to carry signals (including control and data) to and from the towed array via the tow cable. For example, conductors and fiber optics may be located within a central lumen of the tow cable or coiled about the outer surface of the tow cable. The tow cable is the last to be unreeled from

the storage reel as the towed array is deployed from the ship and the first to be reeled onto the storage reel as the tow cable is retrieved. To isolate the towed array from vibrations of the ship transferred along the tow cable, as well as from vibrations of the tow cable itself as it is pulled through the water, a vibration isolation module (VIM) may be coupled between the end of the tow cable and the beginning of the towed array.

[0007] Debris filled maritime domains present unique challenges to the reliability of towed sonar arrays. The harmful impacts of commercial fishing tackle, natural debris, trash, and other flotsam are a recognized danger to towed sonar arrays. Both the towed sonar array and the VIM are susceptible to punctures from this flotsam. The tow cable may contact the flotsam, for example a fishing line, and may guide a hook coupled to that line to the VIM and the towed array following the VIM. A VIM and/or the towed array snagged and possibly penetrated by the hook (or other flotsam) may fail. As the VIM is closest to the ship (at the end of the tow cable), a failed VIM may result in an entire towed array being taken out of commission. The time it takes to retrieve the towed array, repair, or replace the VIM, deploy the towed array, and return to underwater sonar operations is wasted time. Therefore, it would be desirable to develop an apparatus to protect the VIM

and/or the towed array following the VIM, from the harmful effect of flotsam.

SUMMARY OF THE INVENTION

[0008] The present disclosure relates to a line-cutter apparatus capable of being mounted on a tow cable. A body is formed from two releasably coupled housings having a central bore when combined. A plurality of longitudinal grooves are formed in the body that divide the body into a respective plurality of longitudinal segments. Guard portions on the body correspond to the longitudinal segments. The body has fin portions that correspond to the longitudinal segments. Blades corresponding to the segments are received within the body and have a cutting edge that protrudes into one respective passageway of a longitudinal segment.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Reference is made to the accompanying drawings in which are shown an illustrative embodiment of the invention, wherein corresponding reference characters indicate corresponding parts, and wherein:

[0010] **FIG. 1** illustrates a deployed towed array coupled to an end of a tow cable with a plurality of line-cutter apparatuses mounted on the tow cable according to some aspects of the disclosure;

[0011] **FIG. 2** is an elevation view of a towed array installation aboard a ship according to some aspects of the disclosure;

[0012] **FIG. 3** is a left-front-top perspective view of a line-cutter apparatus according to some aspects of the disclosure;

[0013] **FIG. 4** is a rear-bottom-right perspective view of the line-cutter apparatus of **FIG. 3** according to some aspects of the disclosure;

[0014] **FIG. 5** is a left-side view of the line-cutter apparatus of **FIG. 3** according to some aspects of the disclosure;

[0015] **FIG. 6** is a front view of the line-cutter apparatus of **FIG. 3** according to some aspects of the disclosure;

[0016] **FIG. 7** is a cross-section, taken along the plane 7-7 identified in **FIG. 6**, of the line-cutter apparatus of **FIG. 3**, according to some aspects of the disclosure;

[0017] **FIG. 8** is an alternate shaded representation of the left-front-top perspective view of the line-cutter apparatus of **FIG. 3** according to some aspects of the disclosure;

[0018] **FIG. 9** is an alternate shaded representation of the rear-bottom-right perspective view of the line-cutter apparatus of **FIG. 4** according to some aspects of the disclosure; and

[0019] **FIG. 10** is a block diagram describing a method of manufacture of a line-cutter apparatus according to some aspects of the disclosure.

DETAILED DESCRIPTION OF THE INVENTION

[0020] The detailed description set forth below in connection with the appended drawings is intended as a description of various configurations and is not intended to represent the only configurations in which the concepts described herein may be practiced. The detailed description includes specific details for the purpose of providing a thorough understanding of various concepts. However, it will be apparent to those skilled in the art that these concepts may be practiced without these specific details. In some instances, details of well-known structures and components are shown in simplified form in order to avoid obscuring such concepts.

[0021] **FIG. 1** illustrates a deployed towed array **102** coupled to an end of a tow cable **104** with a plurality of line-cutter apparatuses **112, 114, 116, 118** mounted on (e.g., coupled to) the tow cable **104** according to some aspects of the disclosure. The towed array **102** may include a vibration isolation module (VIM) **108**. The VIM **108** may be coupled to the towed array **102** using a coupling structure known to those of skill in the art. The tow cable **104** may be coupled to the VIM **108** using a coupling

structure known to those of skill in the art. The VIM **108** may isolate vibrations from the ship **110** (e.g., vibrations caused by the engines of the ship **110**), as well as vibrations due to motion of the tow cable **104** as it passes through the aquatic medium **120**, from being sensed by the acoustic sensors (e.g., hydrophones) of the towed array **102**.

[0022] The towed array **102**, including the VIM **108**, and the tow cable **104** may be deployed from a stern of the ship **110** through a fairlead **106** (see inset). The fairlead **106** may be an opening that penetrates the hull of the ship **110** as shown. In general, the fairlead **106** may be a structure used to guide a line, rope, or cable clear of obstructions. The fairlead **106** may prevent the line, rope, or cable from moving laterally and/or prevent the line, rope, or cable from being cut or chafed. The fairlead **106** of the exemplary illustration of **FIG. 1** has a bell-horn type shape. Other shapes or other types of fairleads are within the scope of the disclosure. The fairlead **106** may be made of metal and may have a plated surface. The plated surface of the fairlead **106** may be configured to provide a smooth surface on which the towed array **102**, including the VIM **108**, and the tow cable **104** may slide during deployment and retrieval of the towed array **102**. The fairlead **106**, or at least a plated surface of the fairlead **106** (if plated), may have a hardness that may

resist being scratched by the motion of the towed array **102** and tow cable **104**.

[0023] Similarly, the fairlead **106**, may have a finish that is smooth so as to not impart any scratches or cuts in the sheathing of the tow cable **104** or the surface of the towed array **102** as they pass through the fairlead **106**. Use of one or more of the line-cutter apparatuses **112, 114, 116, 118** should not be a cause of compromised finish for the fairlead **106**. Scratches, cuts, or gouges in the surface of the fairlead **106** may lead to undesirable rusting of the fairlead **106** and may in turn lead to undesirable scratches, cuts, or gouges in the relatively soft outer jacket of the towed array **102**, including the VIM **108**. Scratches, cuts, or gouges imparted to the towed array **102**, the VIM **108**, and/or the tow cable **104** from, for example, the fairlead **106** may operationally harm the towed array **102**, the VIM **108**, and/or the tow cable **104**. For example, marine organisms may take hold of or within the scratches, cuts, or gouges. The growth of the marine organisms may lead to undesirable turbulence of the water passing along the tow cable **104**, the VIM **108**, and towed array **102**. **FIG. 1** is not drawn to any scale. The size relationships and orientations of all aspects of the figure are purely for illustrative and non-limiting purposes.

[0024] According to some aspects, the line-cutter apparatus described herein may serve to combat flotsam, such as, but not limited fishing tackle, stranded braided fishing line of synthetic or metal, stranded braided rope of synthetic or metal, nets, and other trawls that may be associated with commercial fishing. Such flotsam may include hooks that may puncture, scratch, tear, or gouge the VIM **108** and/or towed array **102**. The line-cutter apparatus described herein may also serve to repel, or at least not attract, marine predators such as sharks. According to some aspects, the line-cutter apparatus described herein may be made of or coated with a dark (e.g., black) material to absorb light. The line-cutter apparatus described herein may additionally or alternatively be coated with a non-reflective material to avoid reflecting light. Additionally, the plurality of blades (e.g., **348** of **FIG. 3**) may be enclosed or recessed within passageways internal to the line-cutter apparatus. The exemplified configurations of the line-cutter apparatus may expose only small portion of the plurality of (e.g., metallic, reflective) blades, thereby reducing a probability of a reflection from a blade.

[0025] **FIG. 2** is an elevation view of a towed array installation **200** aboard a ship according to some aspects of the disclosure. The towed array installation **200** may include a towed

array **202**, including a VIM **208**, and a tow cable **204**. The tow cable **204** and the towed array **202**, including the VIM **208**, may pass through a fairlead **206** in the stern **210** of a ship (similar to the fairlead **106** in the stern of the ship **110** of **FIG. 1**). The tow cable **204** and the towed array **202** including the VIM **208** may be stored on a reel **218**.

[0026] A level wind **216** may operate to keep the tow cable **204** and towed array **202** level as it is being retrieved and wound onto the reel **218**. In operation, the level wind **216** may travel into and out of the plane of the figure, parallel to the axis of the reel **218**. The level wind **216** may be configured to evenly wind the tow cable **204** and the towed array **202** including the VIM **208** onto the reel **218** along the axis of the reel **218**. The level wind **216** may also serve to prevent unwanted crossing/overlap of the tow cable **204** and towed array **202** as they are being retrieved and wound onto the reel **218**. The level wind **216** serves at least the same function, but in reverse, as the towed array **202** and tow cable **204** are being deployed from the reel **218**. The directions of deployment and retrieval are illustrated with double headed arrows in **FIG. 2**. A winch, not shown, may be used to rotate the reel **218**. The level wind **216** may be operationally coupled to the winch and/or the reel **218**.

[0027] Also depicted in **FIG. 2** are a first line-cutter apparatus **212** (shown in an inset) and a second line-cutter apparatus **214**, both mounted on (e.g., coupled to) the tow cable **204**. The first line-cutter apparatus **212** and the second line-cutter apparatus **214** may be configured to be removably mounted (e.g., removably coupled) to the tow cable **204**. According to some aspects, each of the first line-cutter apparatus **212** and the second line-cutter apparatus **214** may be configured as clam-shell (e.g., clam-shell-like) structure that clamps onto and about the tow cable **204** through a central opening (referred to herein as a bore **310** as shown in **FIG. 3**). A bore **310** may run through each of the first line-cutter apparatus **212** and the second line-cutter apparatus **214** along a longitudinal axis (also referred to in connection with **FIG. 3** as a polar axis **304** of the body **300**) of each of the first line-cutter apparatus **212** and the second line-cutter apparatus **214**.

[0028] In an operational configuration, one or more line-cutter apparatuses may be clamped onto the tow cable **204**. For example, in the illustration of **FIG. 1**, a first line-cutter apparatus **112**, a second line-cutter apparatus **114**, a third line-cutter apparatus **116**, and a fourth line-cutter apparatus **118** are depicted as being clamped onto the tow cable **104**, while in the example of **FIG. 2**, the first line-cutter apparatus **212** and a

second line-cutter apparatus **214** are depicted as being clamped onto (e.g., mounted on, coupled to) the tow cable **204**. According to some aspects, an outer diameter of a line-cutter apparatus may be about 2.5 inches and a length of a line-cutter apparatus may be about 4 inches. These values of diameter and length are exemplary and non-limiting. Other diameters and lengths are within the scope of the disclosure.

[0029] In practice, as a portion of the tow cable **204** is deployed from the reel **218**, after passing through the level wind **216** and before passing through the fairlead **206**, a sailor may close the clam-shell structure of a line-cutter apparatus **212**, **214** around the tow cable **204** and secure the line-cutter apparatus **212**, **214** in a closed position using, for example, a closure device, such as a cotter pin, or other type of removably fixed pin, shaft, or post, that passes through interlaced aligned knuckles of opposing shells (housings) of the clam-shell structure of the line-cutter apparatus **212**, **214**, for example. Other ways to secure the line-cutter apparatus **212**, **214** are within the scope of the disclosure.

[0030] According to some aspects, a sailor may wrap electrical tape, or some other type of tape that may have a plasticity greater than that of a sheathing of the tow cable **204**, around the tow cable **204**. The sailor may then clamp the

line-cutter apparatus **212, 214** over that tape and around the tow cable **204**. According to some aspects, the line-cutter apparatus **212, 214** may have grip tape (e.g., **702** of **FIG. 7**) adhered to the inner surfaces (e.g., **312, 314** of **FIG. 3**) of the body (e.g., **300** of **FIG. 3**) of the line-cutter apparatus **212, 214**. The grip tape may be suitable for underwater use and may be adhered to the inner surfaces of the line-cutter apparatus **212, 214** (e.g., adhered to the inner surfaces **312, 314** within the bore **310**) prior to the coupling the line-cutter apparatus **212, 214** to the tow cable **204**. An example of such grip tape may be the sort of tape used to provide a rough surface on steps beneath the surface of the water leading into a swimming pool. Another embodiment of the body **300** may have small radial protrusions formed within the bore **310** to grip the tow cable.

[0031] According to some aspects, the sheathing around a tow cable **204** may be hard and may not readily deform when the rough surface of the grip tape is clamped about the tow cable **204**. However, the electrical tape, or tape with plasticity greater than that of the sheathing of the tow cable **204**, may deform when the rough surface of the grip tape is clamped about the tow cable **204**. Using the electrical tape, or tape with plasticity greater than that of the sheathing of the tow cable **204**, may provide a greater sliding coefficient of friction than realized

if no tape was wrapped around the tow cable **204**. Increasing a sliding coefficient of friction may help to prevent the line-cutter apparatus **212, 214** from sliding along the tow cable **204** if, for example, flotsam, such as fishing tackle, lines, ropes, nets, trawls, or hooks, acts to drag the line-cutter apparatus **212, 214** along the tow cable **204**. Of course, the preceding was only exemplary. The additional tape (e.g., electrical tape) is not required for operation of the line-cutter apparatus **212, 214**. Furthermore, alternative ways to provide improved gripping strength and improving the sliding coefficient of friction are within the scope of this disclosure.

[0032] When the tow cable **204** is retrieved onto the reel **218**, the sailor may remove (e.g., unclamp) each line-cutter apparatus **212, 214** from its respective location on the tow cable **204**, when the line-cutter apparatus **212, 214** is again located between the fairlead **206** and the level wind **216**. In some examples, adding or removing each of the line-cutter apparatuses **212, 214** described herein is determined to take only about 10 seconds.

[0033] A maximum diameter of the line-cutter apparatus **212, 214** may be less than a maximum diameter of the towed array **202** to facilitate passage of the line-cutter apparatus **212, 214** through the fairlead **206**. Although not intended to be clamped about the tow cable **204** when the tow cable **204** is stored on the

reel **218**, the maximum diameter of the line-cutter apparatus **212**, **214**, may also be less than the maximum diameter of the towed array **202** to allow for temporary storage on the tow cable **204** in a scenario where the tow cable **204** and towed array **202** are retrieved onto the reel **218** in an emergency, for example. In general, according to aspects herein, the line-cutter apparatus **212**, **214** may have a diameter less than that of the towed array **202**; however, in any case, a maximum diameter of the line-cutter apparatus **212**, **214** should allow for the line-cutter apparatus **212**, **214** to pass through the fairlead **206** and any similar aperture limited structure in the level wind **216** (e.g., for emergency retrieval and storage scenarios).

[0034] In some examples, under some test conditions, a single line-cutter apparatus (e.g., similar to **212** or **214**) on a tow cable (similar to **204**) realized about a 70% probability of cutting target lines under test beneath the surface of water. Statistically, the probability of cutting target lines increased to about 97% when three line-cutter apparatuses were used in series. Even when reducing the probability of cutting target lines to about 30% (for a worst case statistical analysis, for example), a set of three spaced apart line-cutter apparatuses in series was found to be able to achieve about a 66% probability of successfully cutting target lines under test. The number of

line-cutter apparatuses coupled to a tow cable may be 1, 2 (as in **FIG. 2**), 3 (as in the just-described statistical tests), 4 (as in **FIG. 1**), or any other number. The depiction of four and two line-cutter apparatuses in **FIGs. 1** and **2**, respectively, is made for illustrative and non-limiting purposes.

[0035] **FIG. 3** is a left-front-top perspective view of a line-cutter apparatus **301** according to some aspects of the disclosure. In the example of **FIG. 3**, grip tape (e.g., grip tape **702** of **FIG. 7**) is not present. In the example of **FIG. 3**, the line-cutter apparatus **301** may include a body **300** having an outer surface **302**. According to some aspects, the outer surface **302** of the body **300** may have a shape of a frusto-prolate spheroid rotated about a polar axis **304** of the body **300** as depicted in **FIG. 3**. One example of a prolate spheroid shape is the shape of a football. In geometry, a frustum is a portion of an object (typically a solid cone or pyramid, but in the present example a non-solid "football" shape) that lies between two parallel planes cutting through the object. As a frusto-prolate spheroid, the front and rear tips of the football are sheared off, leaving the remaining portion of the football between two parallel planes. The projection of an outline of the line-cutter apparatus **301** on a plane parallel to and spaced apart from the polar axis **304** of **FIG. 3** may substantially correspond to such a

shape. Other shapes, including, but not limited to frusto-ovoid, and frusto-spheroid are within the scope of the disclosure.

[0036] The exemplary frusto-prolate-spheroid shape of the line-cutter apparatus **301** may provide a benefit when clamped to (e.g., mounted on, coupled to) a tow cable. The frusto-prolate-spheroid shape may provide a gradual (non-discontinuous) incline leading to and from the line-cutter apparatus **301**. The gradual incline may allow the line-cutter apparatus **301** to slide over an interior edge of the fairlead (e.g., fairlead **106** of **FIG. 1**) as it is being deployed from a ship and slide over an exterior edge of the fairlead as it is being retrieved into the ship. Additionally, the frusto-prolate-spheroid shape may aerodynamically slide through the aquatic medium in an operational space of the line-cutter apparatus **301** (in comparison to other shapes).

[0037] The body **300** may include at least two releasably coupled housings, for example, a first housing **306** and a second housing **308** (collectively referred to as the at least two releasably coupled housings **306, 308**). The at least two releasably coupled housings **306, 308** may be fabricated by at least one of: three-dimensional printing or injection molding. In the example of **FIG. 3**, the releasably coupled housings are coupled together with interlaced hinge knuckles and pins (e.g.,

a closure pin **808** of **FIG. 8** such as a cotter pin and a joint pin **908**, such as a pin, rod, or shaft of **FIG. 9**). Other ways to releasably couple the at least two releasably coupled housings **306**, **308** to one another are within the scope of the disclosure. For example, a circumferential groove can be formed in combined housings **306**, **308** and linear fastener such as a zip tie can be positioned in the groove to secure the combined housings **306**, **308** about tow cable **204**.

[0038] The body **300**, when in a closed configuration as shown in **FIG. 3**, may form a bore **310** defined by inner surfaces **312**, **314** (collectively an inner surface **312**, **314**) of the body **300**. According to one aspect, the bore **310** may have a bore axis (or the body **300** may have a bore axis) that is at least one of: parallel with the polar axis **304**, coaxial with the polar axis **304**, or not parallel with the polar axis **304**. According to some aspects, a length of the body **300** along the polar axis **304** between geometric centers of the leading opening **320** and the trailing opening **406** of **FIG. 4** may be greater than an equatorial diameter **614** of **FIG. 6** of the body **300**. By way of example, the frusto-prolate spheroid shape of the line-cutter apparatus **301** of **FIGs. 3-9** may have a length of body **300** along the polar axis **304** between geometric centers of the leading opening **320** and the

trailing opening **406** that is greater than an equatorial diameter **614** of the line-cutter apparatus **301**.

[0039] First edges **316**, **318** (collectively a first edge **316**, **318**) of the outer surface **302** of the body **300** may define a leading opening **320** of the line-cutter apparatus **301**. The leading opening in **320** may be coincident with the bore **310**. Second edges **402**, **404** of **FIG. 4** (collectively referred to as the second edge **402**, **404**) of the outer surface **302** of the body **300** may define a trailing opening **406** of **FIG. 4** of the line-cutter apparatus **301**. The trailing opening **406** of **FIG. 4** may be coincident with the bore **310** and spaced apart from the leading opening **320**. According to the examples illustrated herein, the leading opening **320** and trailing opening **406** of **FIG. 4** are parallel (in keeping with the definition of a frustrum as previously explained). However, non-parallel relationships are within the scope of the disclosure.

[0040] The line-cutter apparatus **301** may also include the following features, which will be described below in association with descriptions of the figures that follow. For example, the body **300** of the line-cutter apparatus **301** may have a plurality of longitudinal grooves formed therein that may divide the body **300** into a respective plurality of longitudinal segments. The body **300** of the line-cutter apparatus **301** may also have a

plurality of passageways formed in the body **300** that correspond to respective ones of the plurality of longitudinal segments, each of the plurality of passageways defined by a floor proximal to the bore, a ceiling distal from the bore, a passageway entrance, and a passageway rear wall distal from the passageway entrance. The line-cutter apparatus **301** may further include a plurality of guard portions **328** on the body **300** that correspond to respective ones of the plurality of longitudinal segments. Each of the plurality of guard portions may be located between the leading opening and the respective passageway entrance. The line-cutter apparatus **301** may further include a plurality of fin portions on the body that correspond to respective ones of the plurality of longitudinal segments, each of the plurality of fin portions located between the respective passageway entrance and the trailing opening. The line-cutter apparatus **301** may further include a plurality of blades that correspond to respective ones of the plurality of longitudinal segments, each of the plurality of blades received within the body having a cutting edge that protrudes into one respective passageway and seats against the respective passageway rear wall.

[0041] **FIG. 4** is a rear-bottom-right perspective view of the line-cutter apparatus **301** of **FIG. 3** according to some aspects of the disclosure. In the example of **FIG. 4**, grip tape (e.g., grip

tape **702** of **FIG. 7**) is not present. Depicted in **FIG. 4** are the body **300**, the outer surface **302** of the body **300**, the polar axis **304**, and the bore **310**. Also depicted are the second edge **402**, **404** of the outer surface **302** of the body **300**. The second edge **402**, **404** of the outer surface **302** of the body **300** may define the trailing opening **406** of the line-cutter apparatus **301**. The second edge **402**, **404** of the outer surface **302** of the body **300** may be coincident with the bore **310** and the trailing opening **406** may be spaced apart from the leading opening **320** of **FIG. 3**. Also identified in **FIG. 4** are a plurality of screws **408**. Each respective one of the plurality of screws **408** may fix a respective blade **348** of **FIG. 3** in an operational configuration of the line-cutter apparatus **301**. Blades **348** may be fabricated from metal. Selection of the type of metal (e.g., stainless steel, hardened) may be based on the knowledge of one of skill in the art.

[0042] **FIG. 5** is a left-side view of the line-cutter apparatus **301** of **FIG. 3** according to some aspects of the disclosure. In the example of **FIG. 5**, grip tape (e.g., grip tape **702** of **FIG. 7**) is not present. In an operational state, the line-cutter apparatus **301** would receive a tow cable (e.g., tow cable **204** of **FIG. 2**) within the bore **310** and would be pulled toward the viewer (in a direction pointing out of the plane of

drawing sheet toward the viewer). Flotsam, such as a fishing tackle, lines, ropes, nets, trawls, or hooks, for example, may be pulled into a passageway **604** and may be cut by the blade **348** at a rear zone (e.g., **718** of **FIG. 7**) of the passageway **604**. Also visible in the illustration of **FIG. 5** are the left-side views of the first hinge **802** (e.g., a hinge used for securing the line-cutter apparatus **301** clam-shell structure halves closed) and second hinge **902** (e.g., a hinge about which the clam-shell structure halves rotate open or closed).

[0043] As indicated in **FIG. 5**, the body **300** of the line-cutter apparatus **301** may have a plurality of longitudinal grooves **502** formed therein that may divide the body **300** (e.g., the first housing **306** and the second housing **308**) into a respective plurality of longitudinal segments **504**. Each of the plurality of longitudinal segments **504** may have sides perpendicular to a plane tangent to the outer surface **302** of the longitudinal segment **504** and parallel with the polar axis **304**. Other configurations are within the scope of the disclosure. Hinge knuckles may be formed on a first side and a second side of certain spaced apart ones of the plurality of longitudinal segments **504**.

[0044] Each of the plurality of longitudinal segments **504** may include a guard portion **602**, a passageway **604**, and a fin portion

606. Each one of a plurality of blades **348** may occupy the rear zone (e.g., **718** of **FIG. 7**) of one respective passageway **604** as illustrated in the exemplary and non-limiting geometries of **FIG. 5**. Only one of six guard portions **602**, one of six passageways **604**, one of six fin portions **606**, and one of six blades **348** are identified with reference numbers in **FIG. 5** to avoid cluttering the drawing. According to some aspects, the plurality of longitudinal grooves **502** may reduce at least one of: an amount of material used to fabricate the line-cutter apparatus **301** (e.g., by three-dimensional printing or injection molding), or an amount of time needed to fabricate the line-cutter apparatus **301** using three-dimensional printing. (Of course, the apparatus could be formed by conventional machining.) According to some aspects, each of a respective fin portion **606** formed between adjacent pairs of the plurality of longitudinal grooves **502** may define each of the plurality of longitudinal grooves **502** in a configuration to facilitate entrance of flotsam (e.g., fishing tackle, lines, ropes, nets, trawls, or hooks) into a respective passageway **604**. In one example, the plurality of longitudinal grooves **502** may provide improved fluid flow of the aquatic medium as that medium passes through the plurality of longitudinal grooves **502** on both sides of respective ones of the plurality of blades **348**.

[0045] **FIG. 6** is a front view of the line-cutter apparatus **301** of **FIG. 3** according to some aspects of the disclosure. The leading opening **320** is identified at the left of the illustration, the trailing opening **406** is identified at the right of the illustration. In an operational state, the line-cutter apparatus **301** may be pulled through the aquatic medium in the direction of arrow **610**.

[0046] As described in connection with **FIG. 5**, each of the plurality of longitudinal segments **504** may include a guard portion **602**, a passageway **604**, and a fin portion **606**. A plurality of blades **348** each occupy a respective rear zone (e.g., **718** of **FIG. 7**) of one respective passageway **604**. One or more of the guard portions **602** may be at least one of: solid, hollow, or bridge-like (e.g., having an open through-space below a peak of the guard portion **602**). One or more of the fin portions **606** may be at least one of: solid, hollow, or bridge-like. According to aspects of the disclosure, each fin portion **606** may include a channel (e.g., **720** of **FIG. 7**) that may be formed as a slot and may be configured to receive a respective blade **348**. Two of a plurality of channel openings **612** are depicted in **FIG. 6**. Two of the plurality of screws **408** are depicted in an engaged operational state (e.g., secured against blades seated in the channel **720** of **FIG. 7**), at or below the

outer surface **302** of the body **300** of the line-cutter apparatus **301**.

[0047] **FIG. 7** is a cross-section, taken along the plane 7-7 identified in **FIG. 6**, of the line-cutter apparatus **301** of **FIG. 3**, according to some aspects of the disclosure. The leading opening **320** is identified at the left of the illustration, the trailing opening **406** is identified at the right of the illustration. In the example of **FIG. 7**, grip tape **702** is depicted for illustrative and non-limiting purposes.

[0048] A plurality of passageways **604** formed in the body of the line-cutter apparatus **301** may correspond to respective ones of the plurality of longitudinal segments **504**. Each of the plurality of passageways **604** may be defined by a floor **704** proximal to the bore **310**, a ceiling **706** distal from the bore **310**, a passageway entrance **708**, and a passageway **604** rear wall **714** distal from the passageway entrance **708**. The passageway **604** rear wall **714** may be distal from the passageway entrance **708** and may be shared with a channel **720** within which a blade **348** is received. The passageway entrance **708** may be defined by a third edge **710** and a fourth edge **712**. According to some aspects, the third edge **710** may be located between the outer surface of the guard portion **602** and the floor **704** of the passageway **604** proximal to the leading opening **320**. According to some aspects,

the fourth edge **712** may be located between the outer surface **302** of the fin portion **606** and the ceiling **706** distal from the leading opening **320**. The third edge **710** and the fourth edge **712** may have a defined peak, or, as in the example of **FIG. 7**, a non-defined (e.g., curved) peak. Other geometries are within the scope of the disclosure.

[0049] According to some aspects, a respective one of the plurality of guard portions **602** and a corresponding respective fin portion **606** may be spaced apart by a longitudinal distance corresponding to a predetermined distance D **716**, and the predetermined distance D **716** may be less than a diameter of an average human finger. In other words, the third edge **710** may be spaced apart from the fourth edge **712** by the predetermined distance D **716**. The predetermined distance D **716** may be based on a diameter of an average human finger (e.g., an average male finger diameter, an average female finger diameter, or an average of the averages of the male and female finger diameters). According to some aspects, the diameter of an average human finger may be about 0.5 inches, although other diameters are within the scope of the disclosure. The predetermined distance D **716** may be selected to be less than the diameter of the average human finger to prevent accidental insertion of the average human finger into the passageway **604**

where it may be cut by the blade **348**. While the predetermined distance D **716** according to some aspects may be less than the average human finger diameter, it should not be made so small as to reduce a probability that flotsam, intended to be cut by the blade **348**, is unable to enter the passageway **604** through the passageway entrance **716**. Therefore, a tradeoff may be made during design and manufacture of the line-cutter apparatus **301** as to a minimum size of the predetermined distance D **716** in view of possibly competing goals of injury prevention during handling and probability of successfully cutting target objects, such as flotsam (e.g., fishing tackle, lines, ropes, nets, trawls, or hooks).

[0050] **FIG. 7** depicts cross-sections of two of the plurality of guard portions **602** on the body of the line-cutter apparatus **301**. Each of the plurality of guard portions **602** may correspond to respective ones of the plurality of longitudinal segments **504**, each of the plurality of guard portions **602** may be located between the leading opening **320** and the respective passageway entrance **708** located between the leading opening **320** and a respective one of the plurality of passageway entrances **708**.

FIG. 7 also depicts cross-sections of two fin portions **606** on the body of the line-cutter apparatus **301**. Each fin portion **606** may correspond to respective ones of the plurality of

longitudinal segments **504**, each fin portions **606** may be located between the respective passageway entrance **708** and the trailing opening **406**.

[0051] The cross-sectional plane of **FIG. 7** passes through the first housing **306** at the top of the illustration and through the second housing **308** at the bottom of the illustration. In **FIG. 7**, one of the plurality of blades **348** is omitted to allow viewing of one of a respective plurality of channels **720** that may be defined by sidewalls within the body **300** (or equivalently expressed as one of a respective plurality of channels **720** that may be defined by sidewalls within one of the at least two releasably coupled housings **306, 308**). In other words, the body **300** of the line-cutter apparatus **301** may have a plurality of channels **720** formed therein. Each of the plurality of channels **720** may be configured to receive a respective one of the plurality of blades **348** through a respective channel opening **612** defined by edges of the outer surface **302** of the body **300**.

[0052] Each of the plurality of channels **720**, that may be defined by sidewalls within the body (or housing), may be configured to receive a respective one of the plurality of blades **348** and share the respective passageway **604** rear wall **714** and an opening, defined by edges of the rear wall **714**, between the passageway **604** and the channel **720**. Each of the respective

plurality of blades **348** may be received through a respective channel opening **612** defined by edges of the outer surface **302** of the body **300**, or of the at least two releasably coupled housings **306**, **308**. According to some aspects, the channel opening **612** may have a height H **722** that may be sufficient to allow passage of the blade **348** yet not so great as to allow unwanted travel of the blade **348** within the channel **720**.

[0053] **FIG. 7** depicts one example (in dashed line) of a curvature of the floor **704** and ceiling **706** in the passageway **604** rear zone **718**. As exemplified, the rear zone **718** extends into the channel **720**, which allows the blade **348**, in turn, to extend into the passageway **604**. Use of this configuration may allow each of the plurality of blades **348** received within respective ones of the plurality of channels **720** to have a cutting edge of the blade **348** protrude into one respective passageway **604** and seat against the respective passageway **604** rear wall **714**, shared by the one respective passageway **604** and the channel **720**.

[0054] According to some aspects, a blade **348** may be received, through a channel opening defined by edges of the outer surface **302**, into a channel **720** defined by sidewalls within the body **300** (or within at least one of the at least two releasably coupled housings **306**, **308**). The channel **720** may be configured to slidably receive the blade **348** in at least one

of: a direction parallel to the polar axis **304** or a direction perpendicular to the polar axis **304**. That is, the exemplary line-cutter apparatus **301** illustrated and described in **FIGs. 3-9** depicts the channel opening **612** as being located adjacent to the trailing opening **406**, where the blade **348** enters the channel **720** by sliding into the channel **720** in a direction parallel to the polar axis **304**, from the trailing opening **406** side of the line-cutter apparatus **301** toward the leading opening **320** side of the line-cutter apparatus **301**. This may be one example. According to another example (not shown) the channel opening may be located in the fin portion **606**, perpendicularly spaced apart from the polar axis **304**, and the blade **348** may enter the channel **720** by sliding in a direction perpendicular to the polar axis **304**, from an outermost equatorial diameter of the line-cutter apparatus **301** toward the polar axis **304**.

[0055] According to some aspects, the plurality of screws **408** may each corresponding to a respective one of the plurality of blades **348**. In one example, the each of the plurality of screws **408** may be self-threading. According to some aspects, each of the plurality of screws may be configured to releasably fix a respective blade **348** in a respective channel **720**. In other words, each of the plurality of screws may be configured to releasably fix a respective blade **348** in the body. In some

examples, an outermost surface of a head of the screw **408** may be proximate to (e.g., at or below) the outer surface **302** of the body **300**. A screw bore hole **724** having a diameter substantially similar to the minimum thread diameter of the screw **408** may be provided to receive the screw **408**.

[0056] According to some aspects, each of the first housing **306** and second housing **308** may be printed using a three-dimensional (3D) printer. Three-dimensional printing may add layers to the mass of the component being printed. The layers may be referred to as slices. The 3D printing may be performed, for example, by building each of the first housing **306** and second housing **308** from the second edge **402, 404** of the trailing opening **406** toward the first edge **316, 318** of the leading opening **320**, or from the first edge **316, 318** of the leading opening **320** toward the second edge **402, 404** of the trailing opening **406**. Using the orientation of **FIG. 7** as an example. successive slices may be added to the y-z plane, atop one another, and building up in the x axis direction.

[0057] Some examples of materials that may be used to fabricate the line-cutter apparatus **301** using a 3D printer include, for example, 3D printable thermo-plastics such as nylon, polyester, and/or acrylonitrile butadiene styrene-electrostatic dissipative (ABS-ESD) (e.g., ABS-ESD7, which is

one example of durable thermoplastic with static dissipative properties), 3D printable organic material such as 3D printable bamboo, and/or 3D printable metals. In some examples, the material selected to fabricate the line-cutter apparatus **301** may be selected based, at least in part, on the hardness of the material. For example, the body **300** of the line-cutter apparatus **301** may be made of a material that slides over a surface of a fairlead (e.g., **106** of **FIG. 1**) through which the line-cutter apparatus **301** slides without marring. That is, the body **300** of the line-cutter apparatus **301** may be made of a material that does not mar a surface of a fairlead through which the line-cutter apparatus **301** slides during deployment and retrieval of the line-cutter apparatus **301**.

[0058] In 3D printing, an object may be formed by layering slices of material atop one another. According to one aspect, the body **300** (e.g., at least one of the at least two releasably coupled housings **306**, **308**) of the line-cutter apparatus **301** may be formed using a 3D printing process by layering slices of material atop one another in the y-z plane. This process, in this orientation, may produce an unexpected result, which may be a feature of the fin portion **606**.

[0059] According to one example of such a feature, a fin tip **726** of a respective fin portion **606** may be constructed (e.g.,

configured) to break away from the respective fin portion **606** along a break-away plane **728** in the y-z plane. A parameter that may quantify the force required for the break may be referred to as a bending stress force. According to some aspects, a rated bending stress force of each fin tip **726** may be configured to be less than a minimum ripping force of a uniform that is typically used by personnel handling (e.g., deploying, retrieving, or both) a towed array such as the towed array **202** and the attendant tow cable **204** of **FIG. 2**. According to some examples, the ripping force for uniform fabrics may be rated at about 200 pounds. Constructing the fin portion **606** such that a fin tip **726** of a respective fin portion **606** breaks away from the fin portion **606** when a bending force applied to the fin tip **726** is less than the ripping force of the uniform may reduce a probability of the fin tip **726** snagging on and tearing a uniform, or of the fin tip **726** snagging on the uniform and pulling or dragging the sailor when the line-cutter apparatus **301** is mounted on a tow cable and moving with the tow cable.

[0060] A direction of an outward force, F , is graphically represented in **FIG. 7**. In some examples, the outward force, F , may represent the bending force applied to the fin tip **726**. According to some aspects, a plurality of fin portions **606** may be constructed to allow (or to cause) a fin tip **726** to break

away from one of the plurality of fin portions **606** when an outward force, less than a predetermined value (e.g., less than a predetermined magnitude of force), is applied to the fin tip **726**. In other words, a maximum rated bending force of a fin tip **726** may be less than the predetermined value. According to such aspects, the predetermined value may be less than a minimum ripping force of a uniform (e.g., a textile article of manufacture worn by personnel). In one example, the predetermined value may be set at (e.g., designed into a 3D printed line-cutter apparatus by selection of one or more materials and 3D printing parameters known to one of skill in the art) about 150 psi for a corresponding minimum ripping force of about 200 psi. Other values of the predetermined value, the minimum ripping force, and of a margin between the predetermined value and the minimum ripping force are within the scope of the disclosure.

[0061] **FIG. 8** is an alternate shaded representation of the left-front-top perspective view of the line-cutter apparatus **301** of **FIG. 3** according to some aspects of the disclosure. **FIG. 9** is an alternate shaded representation of the rear-bottom-right perspective view of the line-cutter apparatus **301** of **FIG. 4** according to some aspects of the disclosure. The configurations may be referred to as at least two releasably coupled housings.

According to the example of **FIGs. 8** and **9**, the at least two releasably coupled housings may include a first housing **306** and an opposing second housing **308** that may be configured as a clam-shell structure. The coupling may be achieved using, for example, a first hinge **802** (that may be referred to as a closure) and a second hinge **902** (that may be referred to as a joint). The following description considers an observation of the line-cutter apparatus **301** of **FIG. 3** with the cotter pin (closure pin **808**) removed and the line-cutter apparatus **301** opened (rotated open about the joint pin **908**) so that the observer is looking toward the inner surfaces of the at least two releasably coupled housings **306, 308** with the first housing **306** on the left and the second housing **308** on the right.

[0062] In greater detail, the at least two releasably coupled housings **306, 308** may include a closure pin **808**, a joint pin **908**, a first plurality of longitudinally spaced apart first hinge knuckles **804** formed at a first side of the first housing **306** and configured to removably receive the closure pin **808**, a second plurality of longitudinally spaced apart second hinge knuckles **904** formed at a second side of the first housing **306** and configured to fixedly receive the joint pin **908**, a third plurality of longitudinally spaced apart third hinge knuckles **906** formed at a first side of the second housing **308**, interlaced

with the second hinge knuckles **904** and having the joint pin **908** fixedly received in the second hinge knuckles **904** and rotatably received in the third hinge knuckles **906**, a fourth plurality of longitudinally spaced apart fourth hinge knuckles **806** formed at a second side of the second housing **308** and configured to interlace with the first hinge knuckles **804** and have the closure pin **808** releasably fixed through the first hinge knuckles **804** and the fourth hinge knuckles **806**.

[0063] According to some aspects, where the at least two releasably coupled housings **306**, **308** may be configured as a closed clam-shell structure secured about the tow cable (e.g., **204** of **FIG. 2**) and having the fourth hinge knuckles **806** interlaced with the first hinge knuckles **804** and having the closure pin **808** releasably fixed through the fourth hinge knuckles **806** and the first hinge knuckles **804** (that is, for example, having a cotter pin inserted to the hinge and preventing the clam-shell structure from springing open), the at least two releasably coupled housings grip the tow cable without sliding in the direction of the polar axis **304** (of the line-cutter apparatus **301**).

[0064] According to some aspects, a diameter of the bore **310** may be specified to provide a friction fit between the body **300** and the tow cable (e.g., **204** of **FIG. 2**) secured within the bore

310. Grip tape (e.g., **702** of **FIG. 7**) may be used to increase the sliding coefficient of friction between the line-cutter apparatus **301** and the tow cable. Electrical tape may be wrapped around the tow cable to provide a greater sliding coefficient of friction between the line-cutter apparatus **301** and the tow cable. As the line-cutter apparatus **301** may be designed to maximize its grip on the tow cable, a line-cutter apparatus **301** that is closed and secured with a pin, such as a cotter pin, may be applying a continuous force on the halves of the line-cutter apparatus **301** that tends to bias the line-cutter apparatus **301** toward springing open. This bias may act to hold the pin in place without having to secure the pin (such as by bending any portion of the cotter pin extending out from the hinge). In operation, the cotter pin may be slidably inserted into the knuckles of the hinge and may be slidably removed from the knuckles of the hinge with a pliers, for example.

[0065] **FIG. 10** is a block diagram describing a method of manufacture **1000** of a line-cutter apparatus (similar to the line-cutter apparatus **301** of **FIG. 3**, for example) according to some aspects of the disclosure. The method of manufacture of the line-cutter apparatus may include, at block **1002**, selecting a material to use to fabricate the line-cutter apparatus on a 3D printer. As used herein, the reference to a 3D printer

encompasses one or more 3D printers. At block **1004**, the method may include configuring the 3D printer to print, and printing, the line-cutter apparatus on the 3D printer as at least two housings. At block **1006**, the method may include removing the at least two housings from the 3D printer. The at least two housings may be printed individually (e.g., at different 3D printers or at separate times on the same 3D printer) or collectively. At block **1008**, the method may include inserting, into the at least two housings, a plurality of blades into a respective plurality of channels configured to receive the plurality of blades. At block **1010**, the method may include fixing the plurality of blades within the respective plurality of channels. According to some aspects, the plurality of blades may be fixed within the plurality of channels using at least one of: an adhesive, a screw, or a pin. At block **1012**, the method may include fixedly inserting a joint pin into a joint shared by the at least two housings to configure the line-cutter apparatus as a clam-shell structure. According to one example, the joint may be configured from interlaced aligned knuckles of the first housing **306** and the second housing **308** (e.g., opposing shells or housings).

[0066] According to some aspects, configuring the 3D printer to print, and printing the line-cutter apparatus on the 3D

printer, may cause the 3D printer to print: a body having an outer surface and having at least two releasably coupled housings, a bore defined by an inner surface of the body, a first edge of the outer surface defining a leading opening coincident with the bore, and a second side of the outer surface defining a trailing opening coincident with the bore and spaced apart from the leading opening, where the body may have a plurality of longitudinal grooves formed in the body that may divide the body into a respective plurality of longitudinal segments, and where the body may have a plurality of passageways formed in the body that each correspond to respective ones of the plurality of longitudinal segments, each of the plurality of passageways defined by a floor proximal to the bore, a ceiling distal from the bore, a passageway entrance, and a passageway rear wall distal from the passageway entrance, a plurality of guard portions on the body that correspond to respective ones of the plurality of longitudinal segments, each of the plurality of guard portions located between the leading opening and the respective passageway entrance, and a plurality of fin portions on the body that correspond to respective ones of the plurality of longitudinal segments, each of the plurality of fin portions located between the respective passageway entrance and the trailing opening.

[0067] According to some aspects, inserting, into the line-cutter apparatus, the plurality of blades may cause each of the plurality of blades to be received within the body. The method may further include causing a cutting edge of the blade to protrude into one respective passageway and to seat against the respective passageway rear wall.

[0068] One or more of the components, processes, features, and/or functions illustrated in **FIGs. 1-9** and/or **10** may be rearranged and/or combined into a single component, process, feature, or function or embodied in several components, processes, or functions. Additional elements, components, processes, and/or functions may also be added without departing from the disclosure.

[0069] The word "exemplary" is used herein to mean "serving as an example, instance, or illustration." Any implementation or aspect described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other implementations or aspects described herein.

[0070] Likewise, the term "aspects" does not require that all aspects of the disclosure include the discussed feature, advantage, or mode of operation.

[0071] The term "coupled" is used herein to refer to the direct or indirect coupling between two objects. For example, if

object A physically touches object B, and object B touches object C, then objects A and C may still be considered coupled to one another—even if they do not directly physically touch each other.

[0072] The word “coincident” may be used herein to mean “occurring together in space.” As used herein, a “segment” may be one of the constituent parts into which a body, entity, or quantity is divided. As used herein, a “pin” may be a rod, such as a rod running the length of a hinge. The pin may hold the leaves of the hinge together or secure one object to another object.

[0073] As used herein, the construct “at least one of: A, B, or C” means A, B, C, AB, AC, BC, or ABC. The construct “A and/or B” means A, B, or AB. The construct “A, B, and/or C” means A, B, C, AB, AC, BC, or ABC.

[0074] Also, it is noted that various disclosures contained herein may be described as a process that is depicted as a flowchart, a flow diagram, a structure diagram, or a block diagram. Although a flowchart may describe the operations as a sequential process, many of the operations can be performed in parallel or concurrently. In addition, the order of the operations may be re-arranged. A process is terminated when its operations are completed.

[0075] While the foregoing disclosure shows illustrative example, it should be noted that various changes and modifications could be made herein without departing from the scope of the disclosure as defined by the appended claims. The functions, steps and/or actions of the method claims in accordance with the features described herein need not be performed in any particular order. Furthermore, although elements of features may be described or claimed in the singular, the plural is contemplated unless limitation to the singular is explicitly stated.

[0076] The previous description of the disclosed features is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these features will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other features without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the features shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

[0077] Although the present disclosure and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made

herein without departing from the spirit and scope of the disclosure as defined by the appended claims. Moreover, the scope of the present application is not intended to be limited to the particular features of the process, machine, manufacture, composition of matter, means, methods and steps described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure of the present disclosure, processes, machines, manufacture, compositions of matter, means, methods, or steps, presently existing or later to be developed that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein may be utilized according to the present disclosure. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufacture, compositions of matter, means, methods, or steps.

LINE-CUTTER APPARATUS

ABSTRACT OF THE DISCLOSURE

A line-cutter apparatus capable of being mounted on a tow cable is provided. A body is formed from two releasably coupled housings having a central bore when combined. A plurality of longitudinal grooves are formed in the body that divide the body into a respective plurality of longitudinal segments. Guard portions on the body correspond to the longitudinal segments. The body has fin portions that correspond to the longitudinal segments. Blades corresponding to the segments are received within the body and have a cutting edge that protrudes into one respective passageway of a longitudinal segment.

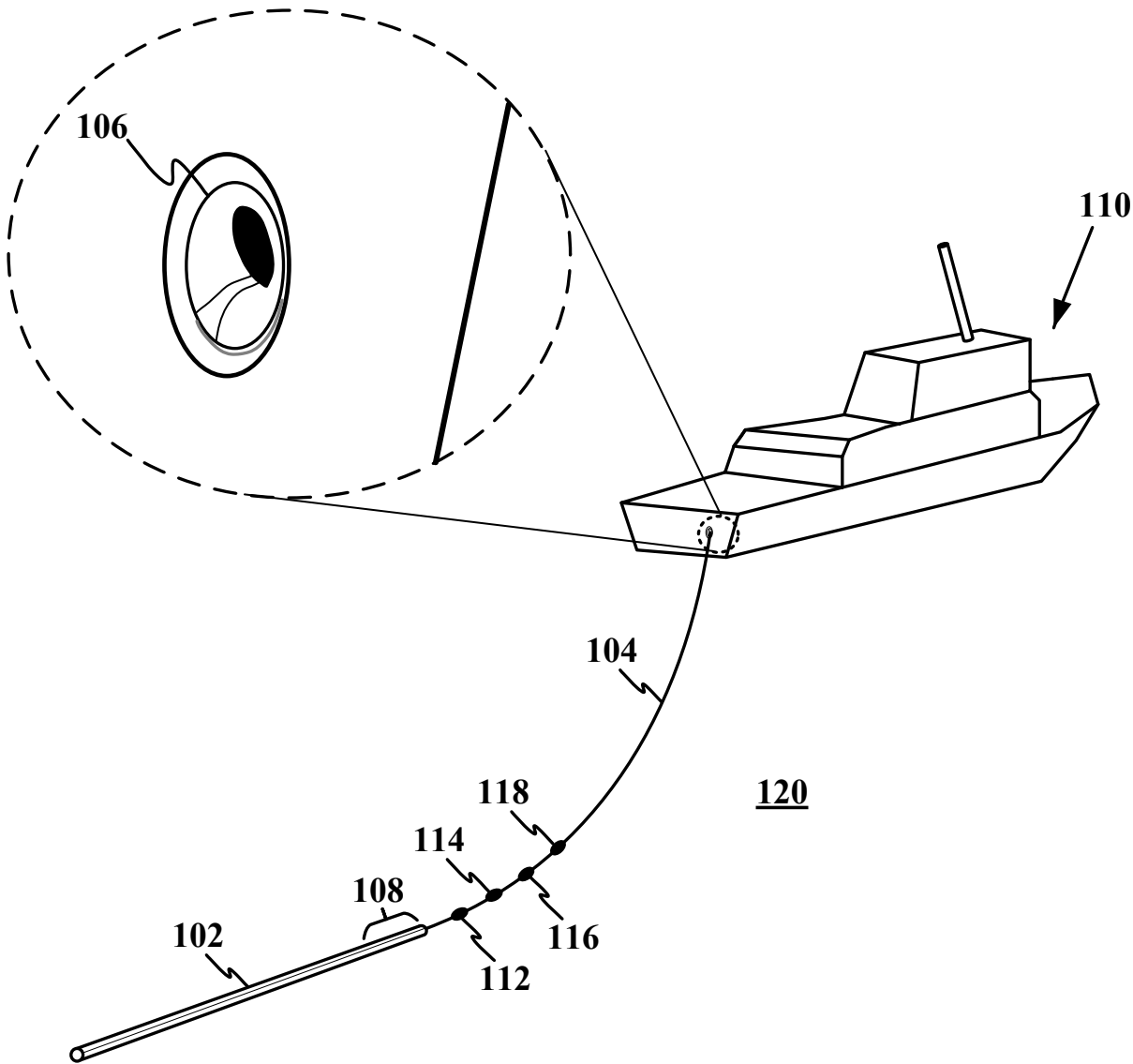


FIG. 1

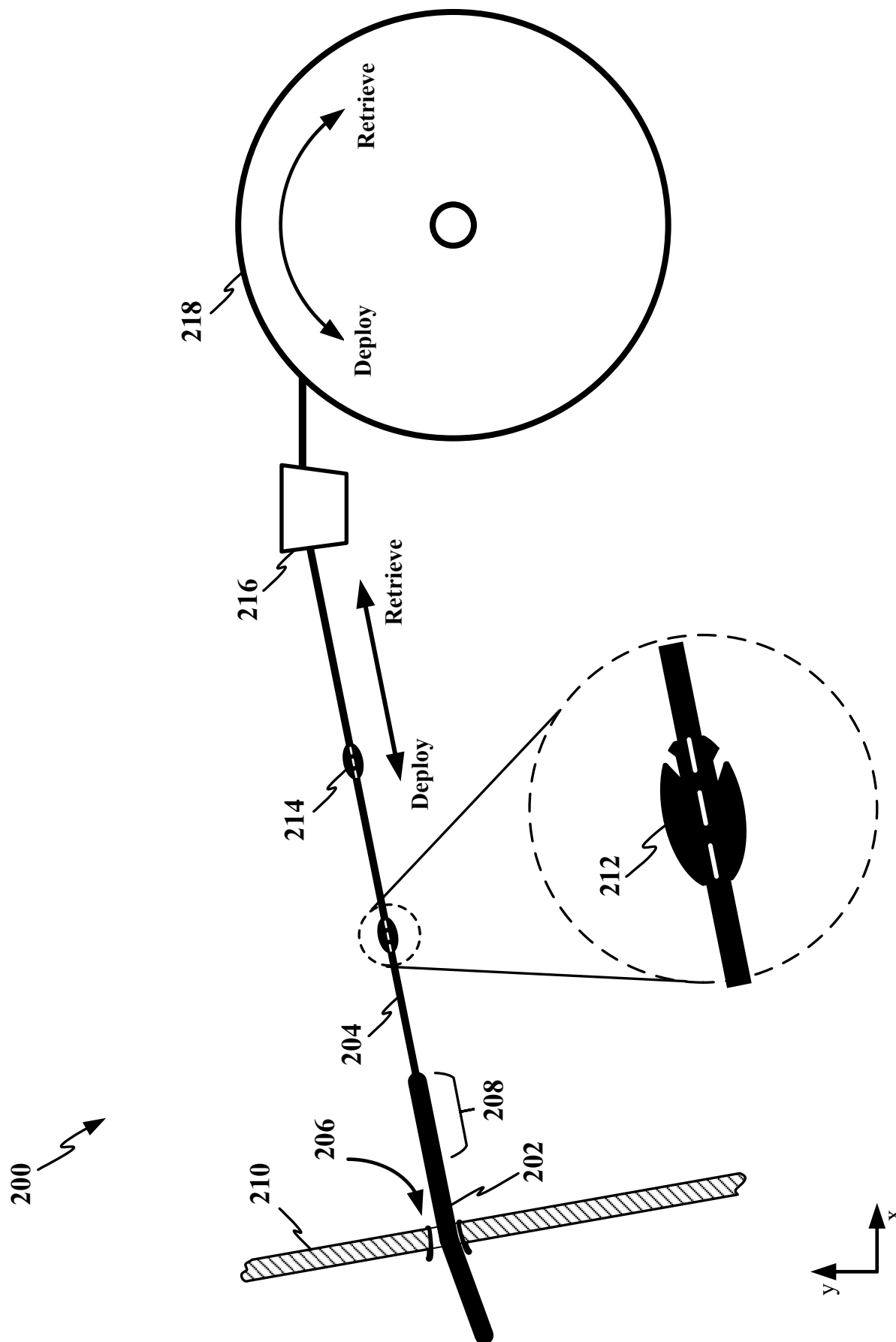


FIG. 2

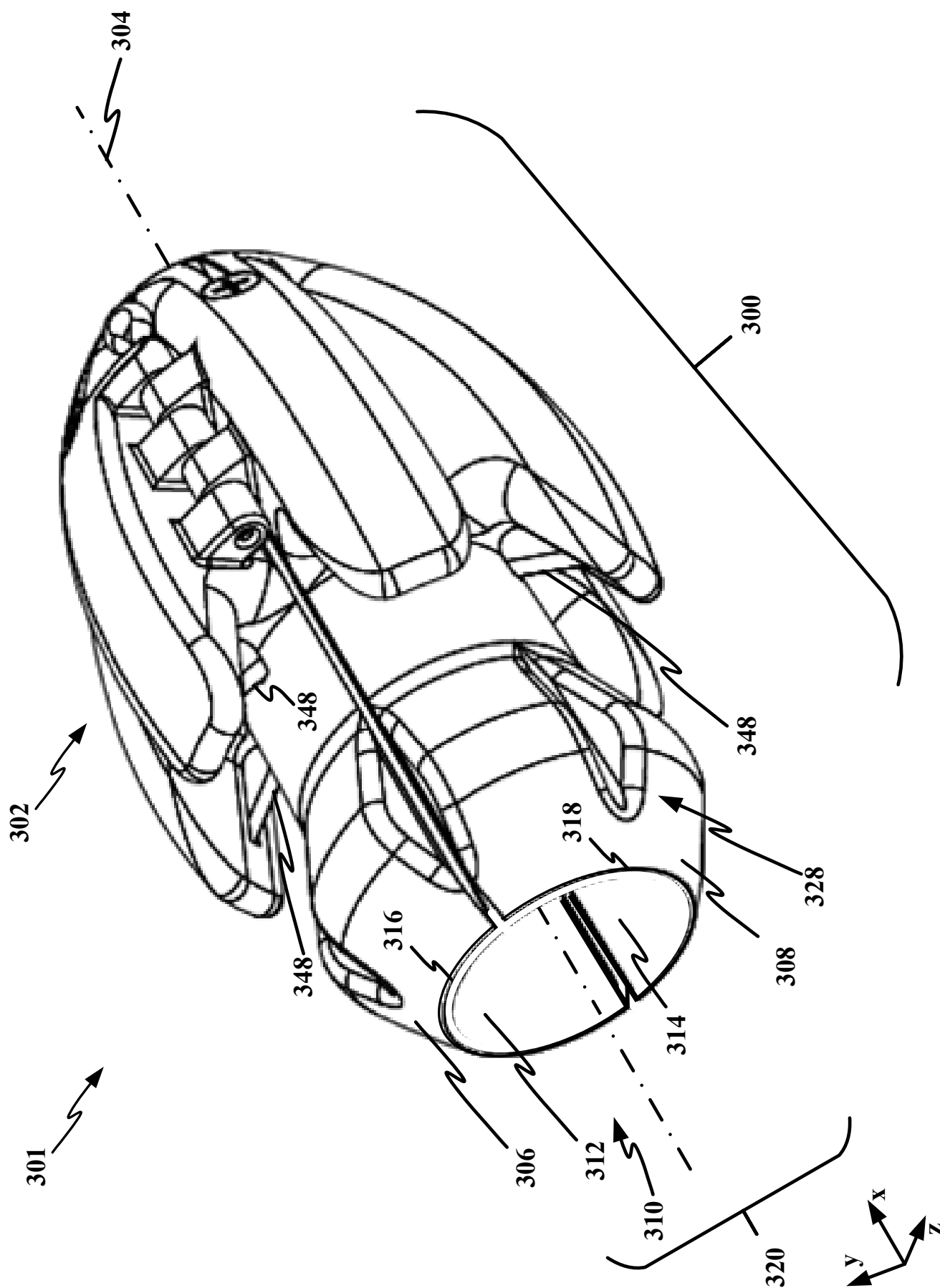
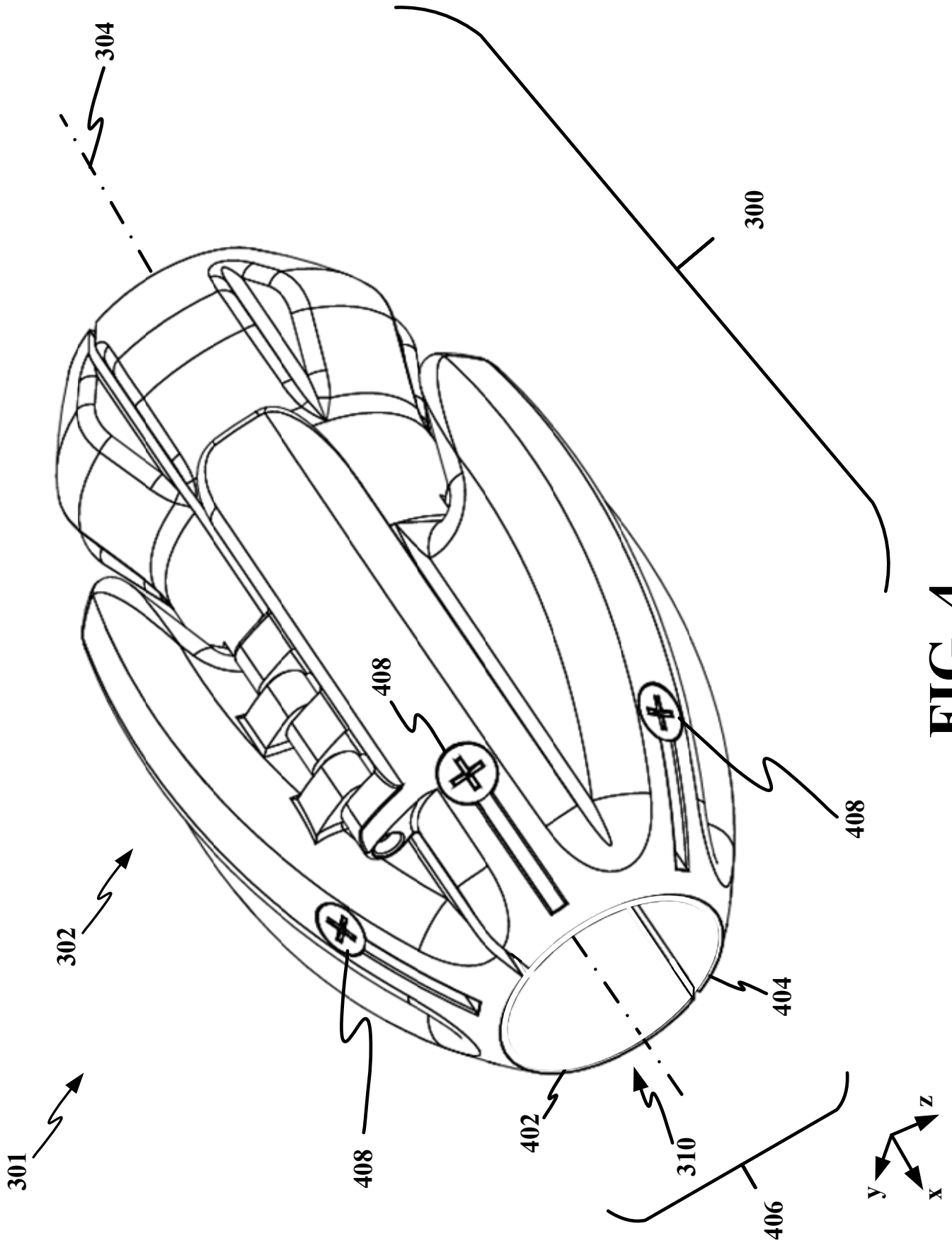


FIG. 3



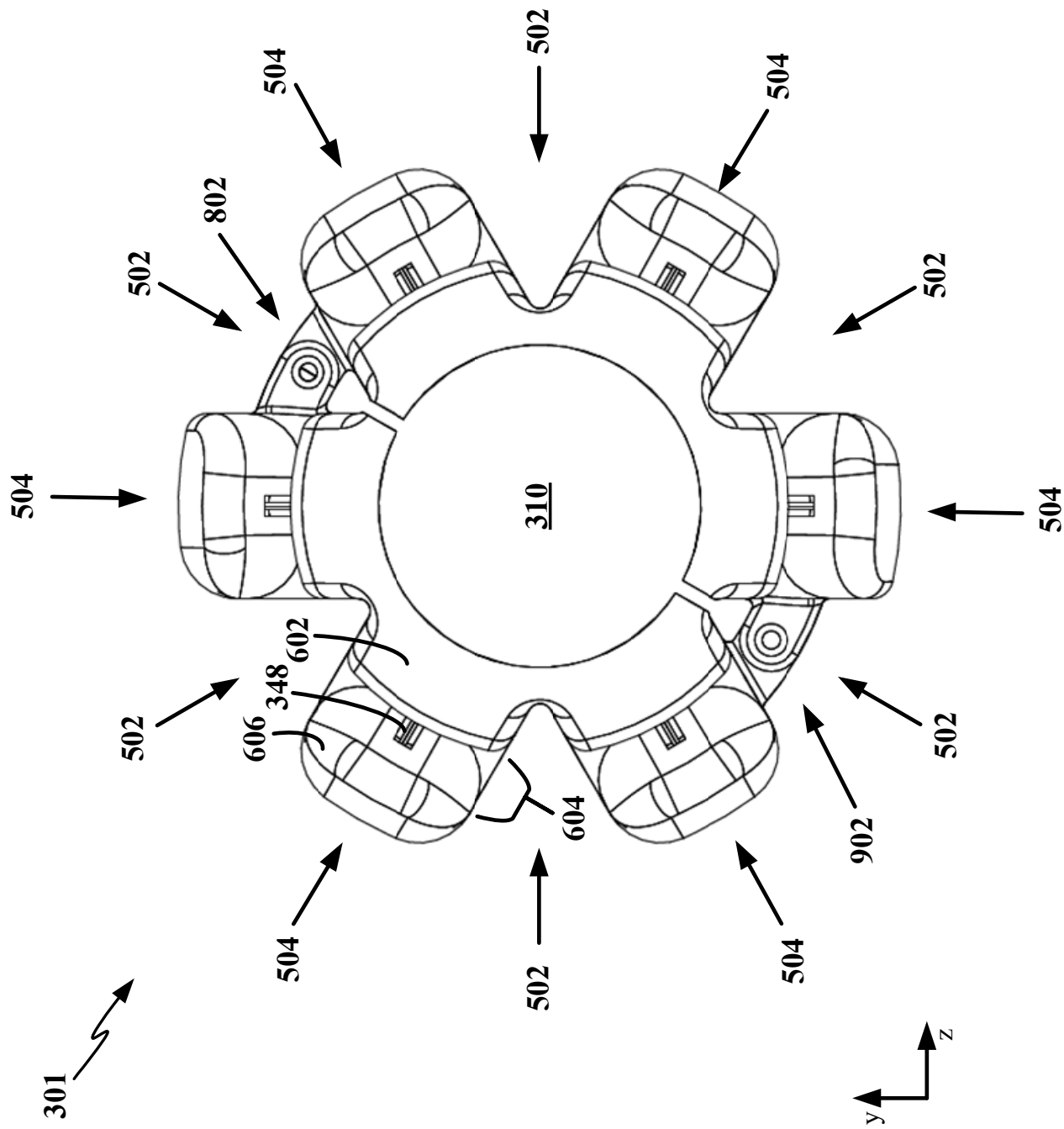


FIG. 5

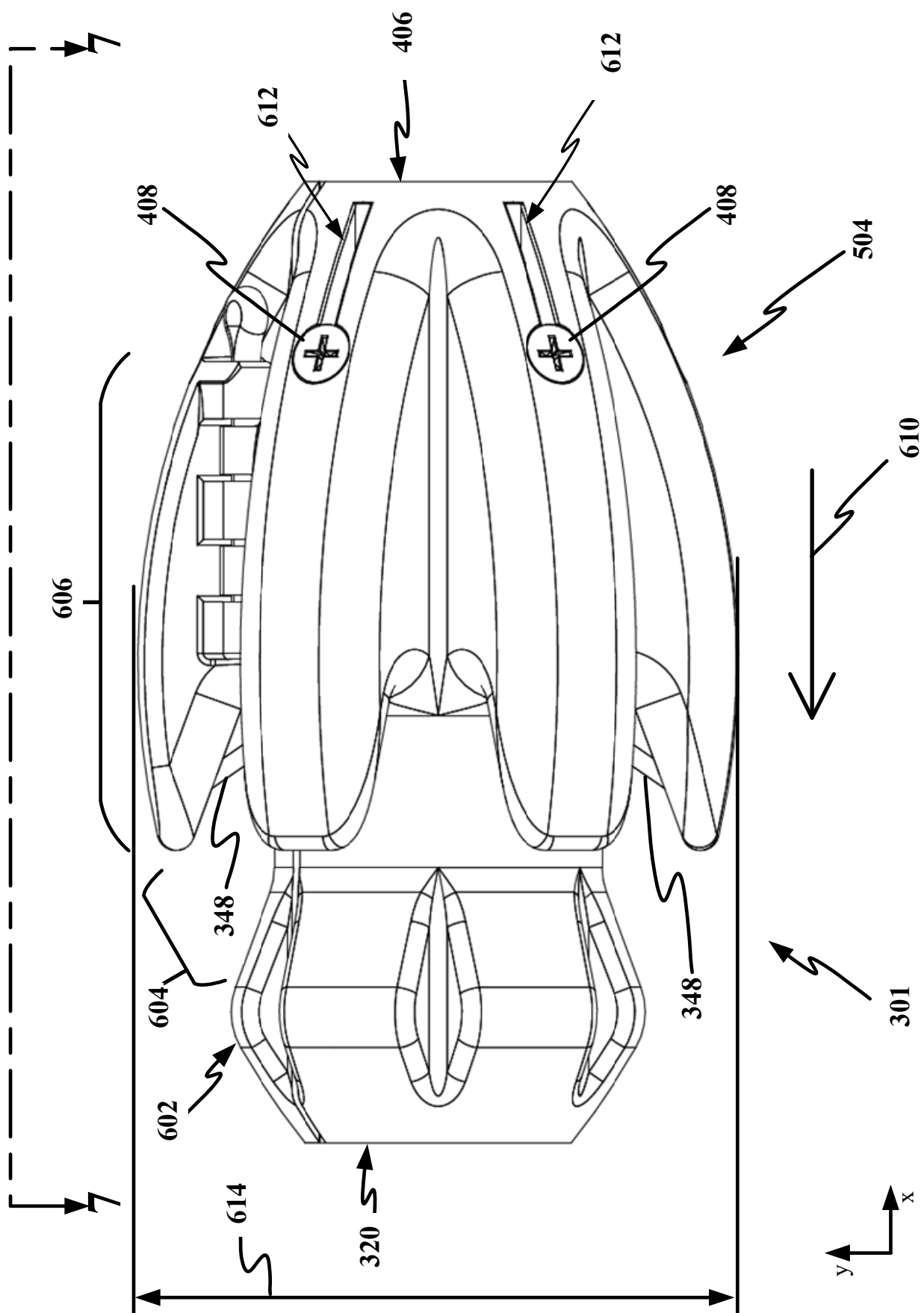


FIG. 6

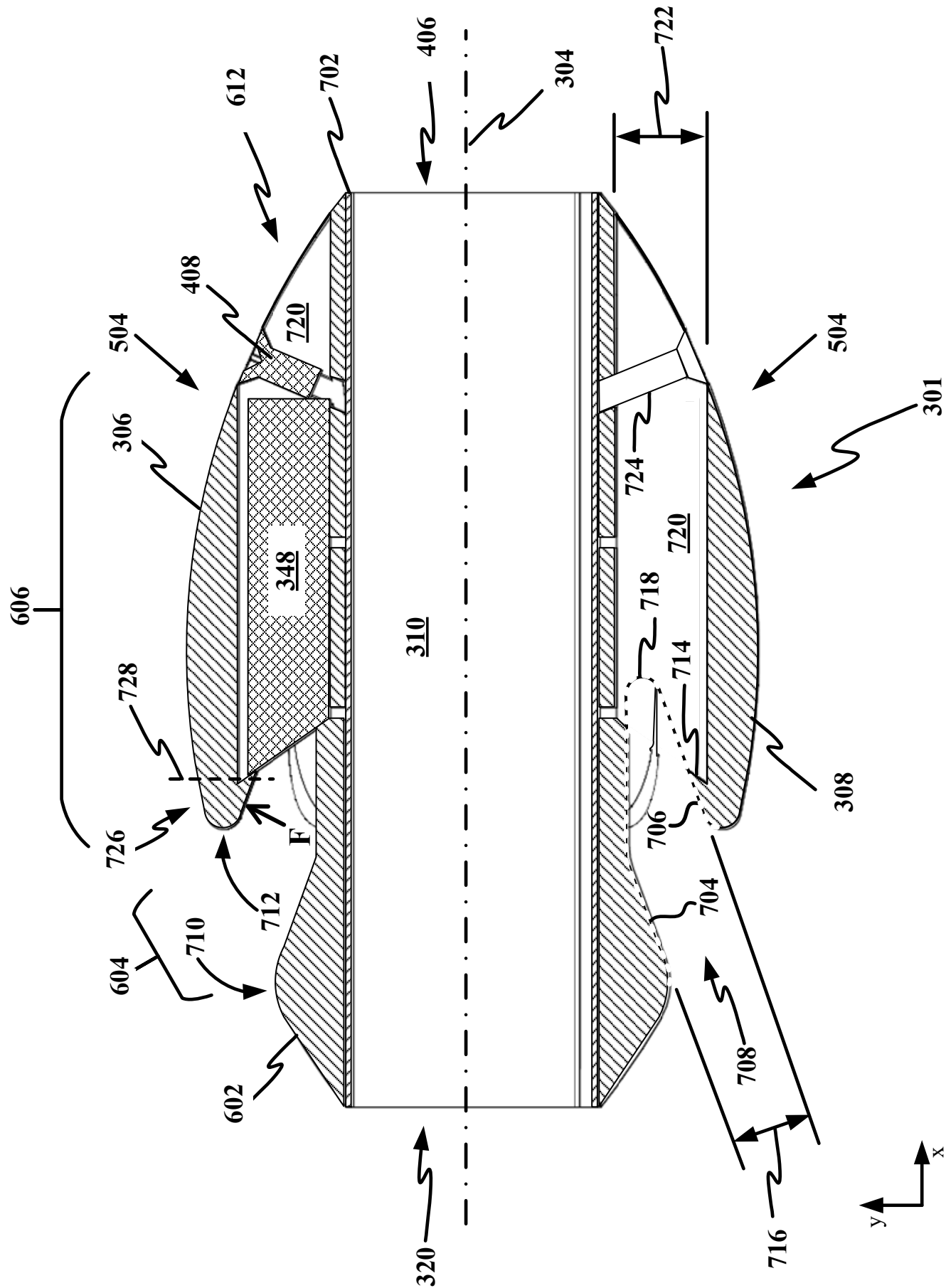


FIG. 7

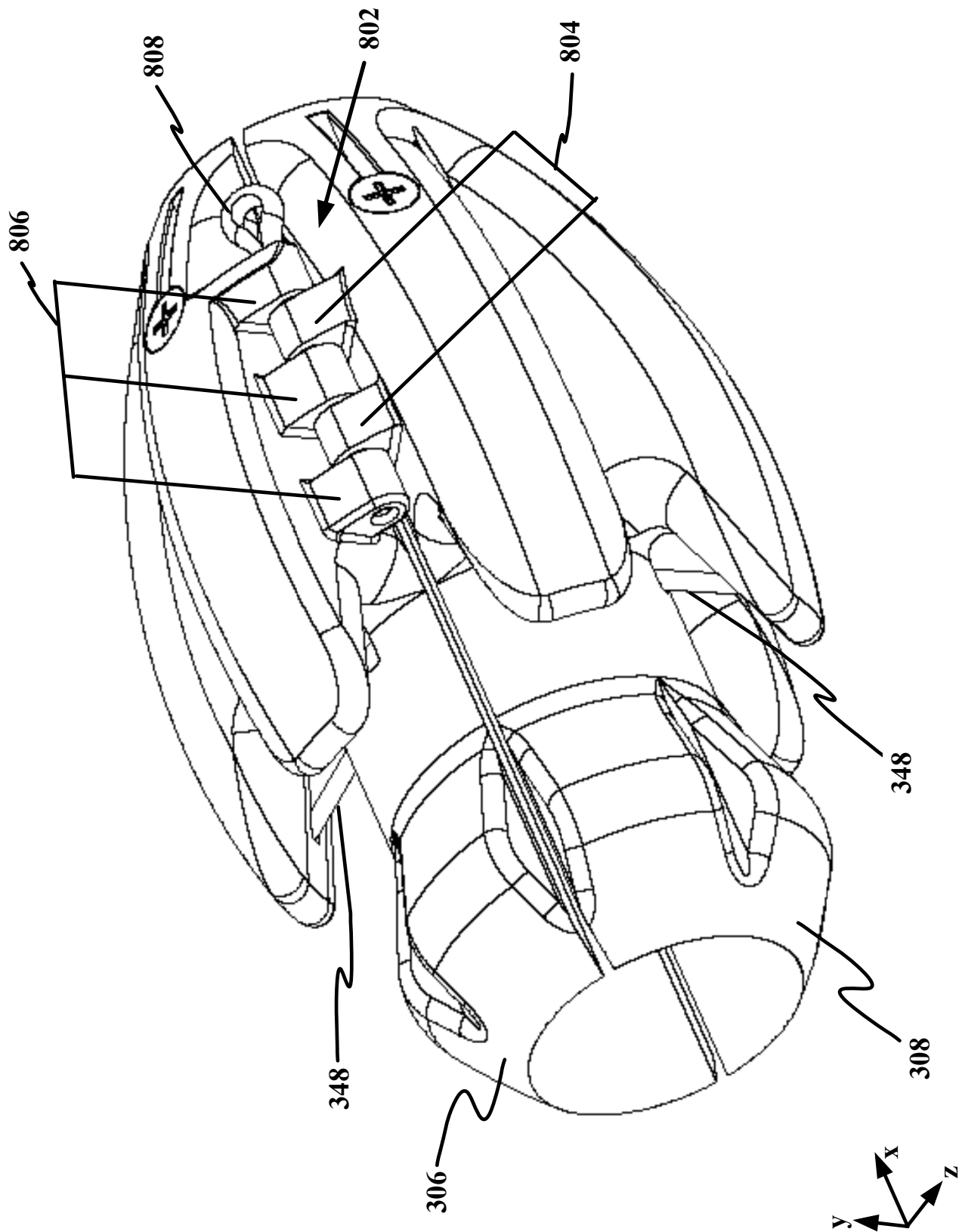


FIG. 8

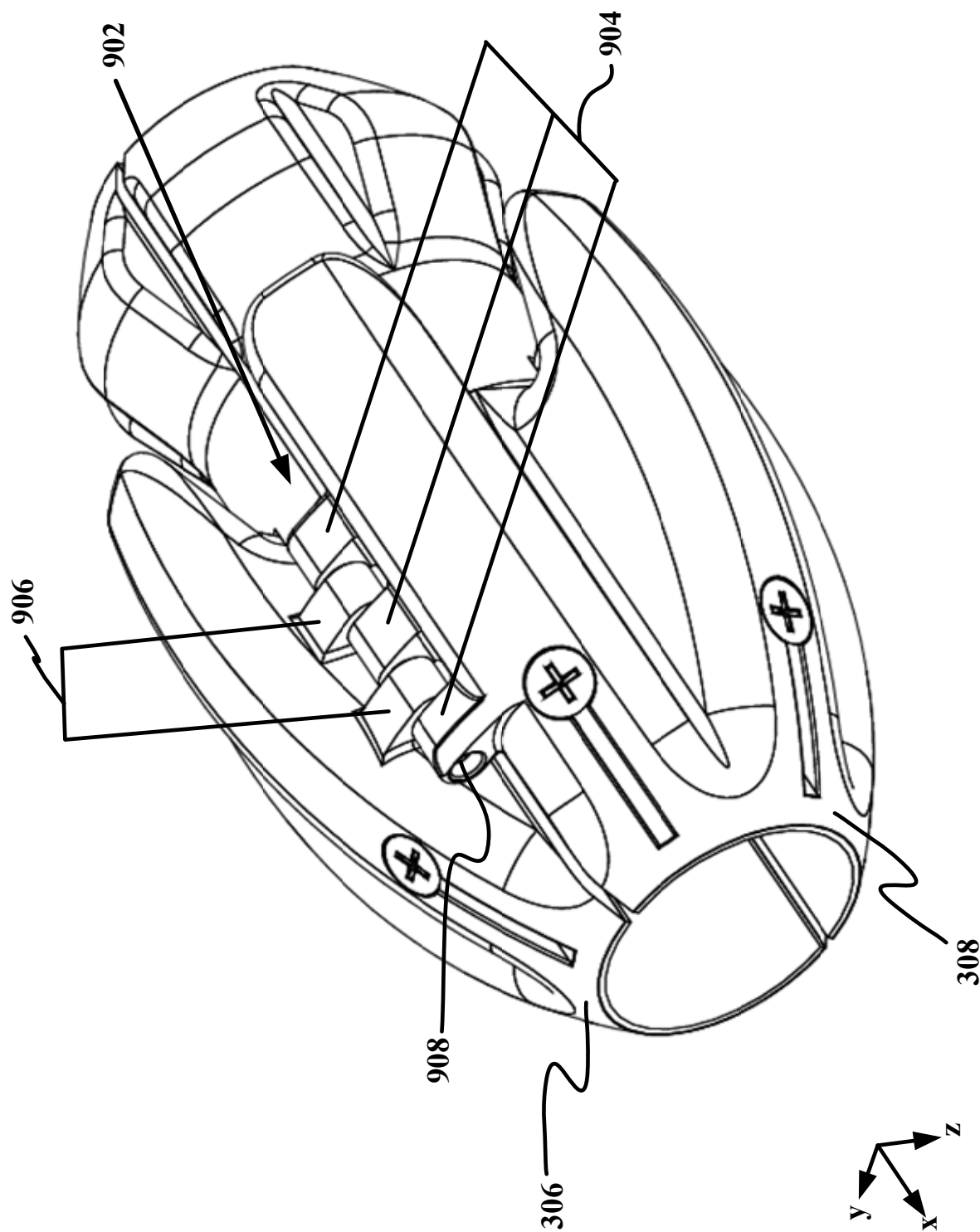


FIG. 9

