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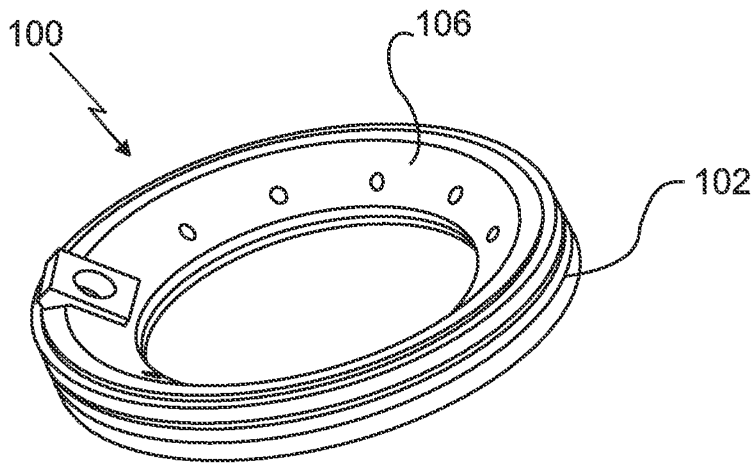
(54) **Explosive cutting charge**

(57) A ring shaped explosive cutting charge (100) is formed by machining or otherwise forming a cavity (104) of a desired configuration within a circular ring (102) of metal cutting material such as copper or aluminum. The cavity (104) may then be filled with an explosive material. The cutting characteristics of the cutting charge may be controlled by the selected cross- section configuration of the cavity. The ring may contain a booster explosive charge (110) with connections to the active portion of the ring having the cutting metal material.

FIG. 1



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Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Serial No. 61/091,468, entitled "Explosive Cutting Charge", filed August 25, 2008, which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates in general to an explosive cutting charge device, and in particular, to an explosive cutting charge device that is hermetically sealed and has a varying explosive charge weight disposed throughout the device to adjust the cut performance around the entire profile of the device.

BACKGROUND OF THE INVENTION

[0003] Explosive cutting charges are typically comprised of two basic constructions. Perhaps the most common type is to use a metal-clad linear explosive product such as a linear shaped charge ("LSC"). The LSC is generally a tube-shaped device that is cut to a predetermined length, formed to conform to the shape of the surface to be cut, and then secured into a multi-piece housing to keep the LSC in that shape and to provide a means for mounting it to the surface to be cut.

[0004] Problems with linear shaped charges include the fact that cut performance cannot be tailored as desired around the entire cutting perimeter by varying the explosive charge weight. This is because the LSC design process normally produces a consistent (i.e., a "fixed core load"), and not a varying charge weight along the entire length of the LSC. Also, the process of forming an LSC to a specific cut profile involves bending into different shapes, which creates density gradients, even cracks sometimes, within the explosive core, thus degrading cut performance. One way to avoid this problem is to limit the radius of curvature of the LSC when making a bend; however, this limits the shapes that the LSC can be manufactured into. Also, an LSC typically has a "no-cut zone" and may also need a "piggy back charge" to bridge the gap between the ends of an LSC to allow for redundant initiation. Further, the material used to manufacture LSC is limited to those materials with sufficient ductility to allow for LSC manufacture using swaging and drawing processes.

[0005] Also, with LSC designs, the initiation interface is preferentially parallel to one of the LSC legs. Other orientations are possible, but design complexity is oftentimes thereby increased so as to preserve reliability. In addition, initiating explosive charge requirements change with LSC sheath material and core load. With LSC-based designs, the cut profile is limited by LSC formability. Factors that affect formability are LSC core load, the metal material used for the sheath or tube, and the direction of cut relative to the bend plane. Although an LSC can be used to make 3-D cutters, known designs comprise multiple LSC segments that are joined together. Still further, an LSC that is hermetically sealed is difficult to achieve because an LSC typically uses adhesive to seal the exposed cord ends, and adhesive seals generally only seal to the environmental level (1 x 10^{-5} cc sec of He). Hermetic seals can also be achieved by welding end closures on the LSC. However, this welding is difficult due to the LSC shape and the safety risks associated with welding on product that contains explosive material.

[0006] A second type of explosive cutting charge is formed by pressing bulk explosive against an explosive liner and into a housing. Other pieces may be needed to seal the explosive charge, provide the necessary attachment features to secure it against the surface to be severed, and provide the interface for attachment of the initiation explosive device. Although most commonly applied to conical shaped charges, which punch holes through target materials, the pressed charge may be used to as a cutting charge.

[0007] Problems with pressed charges include the fact that cut performance also cannot be tailored around the entire cutting perimeter because changes in geometry necessary to change the explosive charge weight make the press tooling relatively complicated and difficult to control. Also, density gradients typically occur within pressed charges as the geometry changes. Even changes in the effective length to diameter ratio of the pressed charge result in density gradients. Further, pressed powder designs are limited in cutting shape, where the limitations are due to the shape of tooling that can be used to press charges and with the difficulties associated with getting powder into complex shapes before pressing. A 3-D cutting charge may require multiple pressings and may likely be costly to make and unreliable in function.

[0008] What is needed is an explosive cutting charge that can be hermetically sealed and in which cut performance can be tailored around the entire cutting perimeter by varying the explosive charge weight.

SUMMARY OF THE INVENTION

[0009] According to an embodiment of the invention, an explosive cutting charge is formed by machining or otherwise forming a cavity of a desired configuration within a circular ring of metal cutting material such as copper or aluminum. The cavity may then be filled with an explosive material. The cutting characteristics of the cutting charge may be controlled by the selected cross-section configuration of the cavity. The ring may contain a booster explosive charge with connections to the active portion of the ring having the cutting metal material. The invention is not limited to circular rings and can be of any closed or open form (for example, a generally rectangular or a straight length).

[0010] Advantages of the explosive cutting charge of embodiments of the invention include the fact that the explosive cutting charge can be hermetically sealed. Also, cut performance can be tailored around the entire cutting perimeter by varying the explosive charge weight. Also, cut consistency, which is related to explosive density, is relatively less variable than prior art explosive cutting charges. Further, cut performance is consistent around the entire cut profile, which is due to the continuous explosive cutting charge liner and explosive load. A corollary to the use of a continuous explosive liner is that the explosive can be hermetically sealed (1 x 10^{-6} cc sec of He), for example, by welding the liner to a second piece to achieve a hermetic seal before loading with explosive material. In addition, initiation reliability is relatively high and is not affected by cutting charge design.

[0011] In embodiments of the invention, the initiation interface can be located in any orientation relative to the cutting charge and the explosive interface can be identical within the entire product family. The product family can include charges that cut radially inward, radially outward or any angle in between. Further, the cut profile of the explosive cutting charge of embodiments of the invention can be relatively more complex that with either an LSC charge or a pressed charge and can have a three-dimensional cut. The cut profile limitation of embodiments of the invention are primarily based upon what shape can be made and that can later be filled with explosive material. Thus, the limitations come from what can be machined, formed, molded, extruded, etc. A limitation from the filling process may exist, but are not quantified at this time.

BRIEF DECRIPTION OF THE DRAWINGS

[0012] The various embodiments of the present invention can be understood with reference to the following drawings. The components are not necessarily to scale. Also, in the drawings, like reference numerals designate corresponding parts throughout the several views.

[0013] Figure 1 is a perspective view of a ring-shaped explosive cutting charge in accordance with an embodiment of the invention;

[0014] Figure 2 is a cross-sectional view of the explosive cutting charge of the embodiment of Figure 1;

[0015] Figure 3 is a perspective view of a ring-shaped explosive cutting charge in accordance with another embodiment of the invention;

[0016] Figure 4 is a cross-sectional view of the explosive cutting charge of the embodiment of Figure 3;

[0017] Figure 5 is a cross-sectional view of an alternative embodiment of the explosive cutting charge of the embodiment of Figure 3;

[0018] Figure 6 is a top view of another embodiment of an explosive cutting charge as part of a breaching system according to the invention; and

[0019] Figure 7 is a cross-sectional view of the embodiment of the explosive cutting charge within the breaching system of Figure 6.

DETAILED DESCRIPTION OF THE INVENTION

[0020] The present invention is more particularly described in the following description and examples that are intended to be illustrative only since numerous modifications and variations therein will be apparent to those skilled in the art. As used in the specification and in the claims, the singular form "a," "an," and "the" may include plural referents unless the context clearly dictates otherwise. Also, as used in the specification and in the claims, the term "comprising" may include the embodiments "consisting of" and "consisting essentially of." Furthermore, all ranges disclosed herein are inclusive of the endpoints and are independently combinable.

[0021] As used herein, approximating language may be applied to modify any quantitative representation that may vary without resulting in a change in the basic function to which it is related. Accordingly, a value modified by a term or terms, such as "about" and "substantially," may not to be limited to the precise value specified, in some cases. In at least some instances, the approximating language may correspond to the precision of an instrument for measuring the value.

[0022] In an embodiment of the invention, an explosive cutting charge is formed by machining or otherwise forming a cavity of a desired configuration within a circular ring of metal cutting material such as copper or aluminum. The cavity may then be filled with an explosive material. The cutting characteristics of the cutting charge may be controlled by the selected cross-section configuration of the cavity. The ring may contain a booster explosive charge with connections to the active portion of the ring having the cutting metal material.

[0023] The foregoing and other features of various disclosed embodiments of the invention will be more readily apparent from the following detailed description and drawings of the illustrative embodiments of the invention wherein like reference numbers refer to similar elements.

[0024] Referring to Figure 1, there illustrated is a perspective view of a ring-shaped explosive cutting charge 100 in accordance with an embodiment of the invention. Referring also to Figure 2, there illustrated is a cross-sectional view of the explosive cutting charge 100 of the embodiment of Figure 1. The ring-shaped cutting charge 100 may comprise a first ring or "liner" 102 with a cavity 104 formed therein. The cavity 104 runs the entire circumference of the ring-shaped charge 100, thereby eliminating any "no-cut" zones inherent in prior art LSC designs and also eliminating the need for a "piggy back charge" to bridge the gap between the ends of a prior art LSC to allow for redundant initiation. The first ring 102 may be made from a relatively ductile material, such as a metal (e.g., copper or aluminum) and may have a thickness contoured for enhanced cutting performance.

[0025] The embodiment of the ring-shaped cutting charge 100 of Figures 1 and 2 also includes a second, manifold ring 106 made from a metal material. The second ring 106 may be welded to the first ring 102 prior to the insertion or loading of the explosive material into the cavity 104. The explosive may comprise a cast cured explosive material. An advantage of embodiments of the explosive cutting charge 100 of the present invention includes the fact that the weight of the explosive charge loaded into the cavity 104 may be made to vary throughout the cavity, thereby tailoring the amount of explosive force emitted at locations around the ring 100 (i.e., the "cut performance"). Also, by welding the continuous liner ring 102 to the continuous manifold ring 106, a hermetic seal (1 x 10^6 cc sec of He) can be achieved.

[0026] Figure 2 illustrates the cut profile of the embodiment of the ring-shaped cutting charge 100 of the invention. The cut profile includes a chevron-shaped cutting charge area 108 above which is a cylindrically-shaped booster charge area 110. In general, the cut profile of the ring-shaped cutting charge 100 of embodiments of the invention can be relatively more complex than with either a prior art LSC or pressed charge. The cut profile may take on a three-dimensional shape. A limitation of the cut profile for embodiments of the invention is primarily based on the shape that can be made by, e.g., machining, and that can later be filled with explosive material. Thus, any limitation on the cut profile comes from what can be machined, formed, molded, extruded, etc.

[0027] In the explosive cutting charge 100 of various embodiments of the invention, initiation reliability of the explosive is relatively high and is not affected by the cutting charge design. The initiation interface (e.g., the booster charge area) can be located in any orientation relative to the cutting charge and the explosive interface can be identical throughout the entire product family. The product family can include charges that cut radially inward, radially outward or any angle in between.

[0028] Referring to Figures 3 and 4, there illustrated is another embodiment of an explosive cutting charge 300 in accordance with the invention. The charge 300 is again ring-shaped, similar to the cutting charge 100 in Figures 1 and 2, and thus the explosive charge loaded therein is continuous throughout the cutting charge 300. The charge includes a liner ring 302 and a manifold ring 304 welded together. The chevron-shaped cutting charge area 306 is oriented to point vertically downward. Located above the cutting charge area 306 is the area 308 that houses the booster explosive charge.

[0029] In the alternative embodiment of Figure 5, the explosive cutting charge 300 has the chevron-shaped cutting charge area 306 oriented horizontally. Further, more than one cutting charge area can be included in a single explosive cutting charge device 300. That is, for example, the horizontally oriented cutting charge area 306 of Figure 5 can be combined with the vertically oriented cutting charge area 306 of Figure 4 in the same explosive cutting charge device 300.

[0030] Referring to Figures 6 and 7, there illustrated is another embodiment of an explosive cutting charge 600 as part of a breaching system according to the invention. The explosive cutting charge 600 of this embodiment comprises a generally oval, closed design with one or more straight sections 602 connected with a corner section 604. The charge 600 may be used to produce a breach point in, e.g., steel-reinforced concrete or block structures. An amount of charge required for a typical roof breaching application needs to have penetrations at least as deep as a 5400 gr/ft charge into steel. The goal of the breaching system 600 of Figures 6 and 7 is to enhance the cutting capability of prior designs.

[0031] The cutting charge or breaching system 600 in accordance with this embodiment of the invention may have one foot long straight sections 602 of shaped charge, wherein these sections 602 being linked together by the corner sections 604 to form the overall breaching system breach point size of interest. This design allows more options for shaped charge design that result in lower explosive core loading. The breaching system 600 takes advantage of a solid copper liner 606 that has a higher density than the prior art copper polymer liners. This change, coupled with an optimized charge configuration and non-fragmenting tamper, enhances severance capability.

[0032] Optimizing linear shaped charge cutting performance is a function of many design variables that work together to form the penetrating explosive jet. Some of the primary design variables include apex angle, apex height, charge width, charge height, liner material, liner thickness, explosive material, explosive loading, explosive height above the apex and the charge ends, standoff, as well as the top angle. The design goal is to provide an elongated explosive jet that penetrates to the depth of interest.

[0033] The breaching system 600 of this embodiment of the invention comprises two charge configurations. The first configuration is a straight twelve inch section 602 and the second is a corner configuration 604 that connects together the straight sections 602. Multiple pieces of each configuration can be used together to form the overall breaching system 600 to cover the breaching area of interest. A breach point size of one foot by one foot may be expanded using multiple lengths of the twelve inch straight sections 602 to form a hole three feet by three feet. The sections 602-604 may fit together using linkages molded into a plastic housing 608 that houses the explosive charge 610 and the copper liner 606. By having separate sections of linear shaped charge, twelve inches or less, the piece parts can be easily carried by a soldier in the field.

[0034] Each individual linear charge segment 602 has a cap well to allow end initiation by a #12 strength detonator or standard military detonator. This design feature allows for flexibility for initiation of the breaching system 600. The operator can choose to initiate in locations that are best for the situation at hand. The cap well may be designed into the plastic housing 608 on one end of the charge above where the charges meet. The friable plastic housing 608 holds the explosive charge and the copper liner 606 and provides feet 612 to add stability for optimum standoff to the target as well as providing access for a #12 strength or military detonator. The explosive charge 610 may comprise PBXN-112, which is cast cured into the friable plastic housing 608. Using a cast cured explosive makes manufacturing of the breaching elements efficient. The plastic housing 608 holds the explosive 610 while minimizing the fragments compared to those products made from a metal tamper. The goal is to utilize a relatively brittle low-density plastic that shatters upon impact. Soldier safety is a key concern when designing any new breaching system. With a 3000 gr/ft (i.e., constant or non-varying) shaped charge design used to breach a 3 ft by 2 ft hole, there exists approximately 10 ft of explosive charge (4.3 1b of explosive). At 30 feet away, the predicted overpressure from 4.3 lbs of PBXN-112 is under 0.5 psi. This value is within the safe zone for human exposure.

[0035] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to make and use the invention. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims. All citations referred herein are expressly incorporated herein by reference.

Claims

1. An explosive cutting charge device, comprising:

cutting material arranged in a configuration;
a cavity formed in the cutting material configuration; and
cast cured explosive material filling the cavity, wherein a weight of the explosive material is varying or non-varying along a length of the cavity, thereby forming a cutting charge with a predetermined cut profile shape in the explosive cutting charge device.

2. The explosive cutting charge device of claim 1, wherein the cutting material comprises a metal.

3. The explosive cutting charge device of claim 1, wherein the cutting material comprises one of aluminum and copper.

4. The explosive cutting charge device of claim 1, wherein the cutting material configuration comprises an enclosed configuration, wherein the cavity is formed throughout the entire enclosed cutting material configuration.

5. The explosive cutting charge device of claim 1, wherein the cutting material configuration comprises a closed ring, wherein the cavity is formed throughout the entire closed ring.

6. The explosive cutting charge device of claim 1, further comprising a manifold connected with the cutting material configuration, thereby forming a hermetic seal of the cutting material configuration.

7. The explosive cutting charge device of claim 1, further comprising a manifold connected with the cutting material configuration, wherein the manifold includes a cavity formed therein, wherein a booster charge is located within the manifold cavity, wherein the booster charge is in communication with the explosive material within the cavity of the cutting material configuration.

8. The explosive cutting charge device of claim 1, wherein one or more cut profile cutting charge shapes are formed in the explosive cutting charge device.

9. An explosive cutting charge device, comprising:

cutting material arranged in an enclosed configuration;
a cavity formed throughout the entire cutting material enclosed configuration; and
cast cured explosive material filling the cavity, wherein a weight of the explosive material is varying or non-varying along a length of the cavity, thereby forming a cutting charge with a predetermined cut profile shape in the explosive cutting charge device.

10. The explosive cutting charge device of claim 9, wherein the enclosed configuration comprises a ring.

11. The explosive cutting charge device of claim 9, wherein the cutting material comprises a metal.

12. The explosive cutting charge device of claim 9, wherein the cutting material comprises one of aluminum and copper.

13. The explosive cutting charge device of claim 9, further comprising a manifold connected with the cutting material configuration, thereby forming a hermetic seal of the cutting material configuration.

14. The explosive cutting charge device of claim 9, further comprising a manifold connected with the cutting material configuration, wherein the manifold includes a cavity formed therein, wherein a booster charge is located within the manifold cavity, wherein the booster charge is in communication with the explosive material within the cavity of the cutting material configuration.

15. The explosive cutting charge device of claim 9, wherein one or more cut profile cutting charge shapes are formed in the explosive cutting charge device.

16. An explosive cutting charge device, comprising:

a plurality of explosive charge cutting segments that comprises a breaching device, wherein each segment comprises a housing that contains an amount of cast cured explosive material therein, wherein a weight of the explosive material is varying or non-varying, thereby forming a cutting charge with a predetermined cut profile shape in the explosive cutting charge device, and wherein each segment has a cap well.

17. The explosive cutting charge device of claim 16, wherein the housing comprises a friable plastic, and wherein the housing further comprises a copper liner.

18. The explosive cutting charge device of claim 16, wherein the housing comprises a friable plastic, and wherein the housing further comprises an unvulcanized copper/polymer compound liner.

19. The explosive cutting charge of claim 16, wherein the plurality of explosive cutting charge segments are arranged in an enclosed configuration.

20. The explosive cutting charge device of claim 16, wherein one or a plurality of cap wells are used to detonate the entire device.

FIG. 1

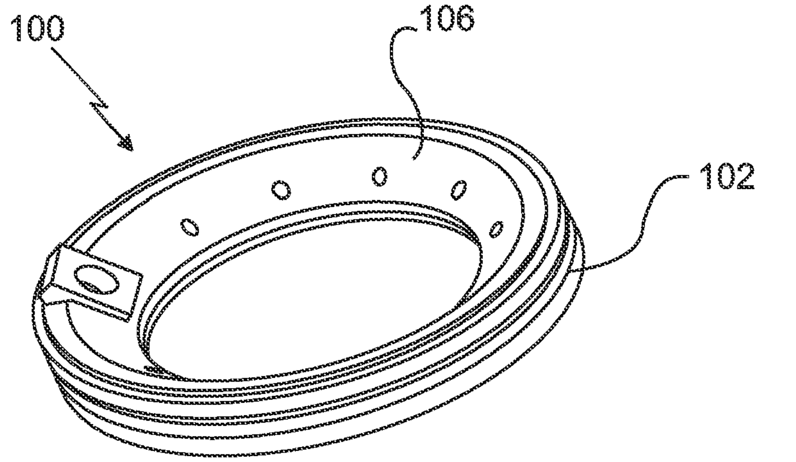


FIG. 2

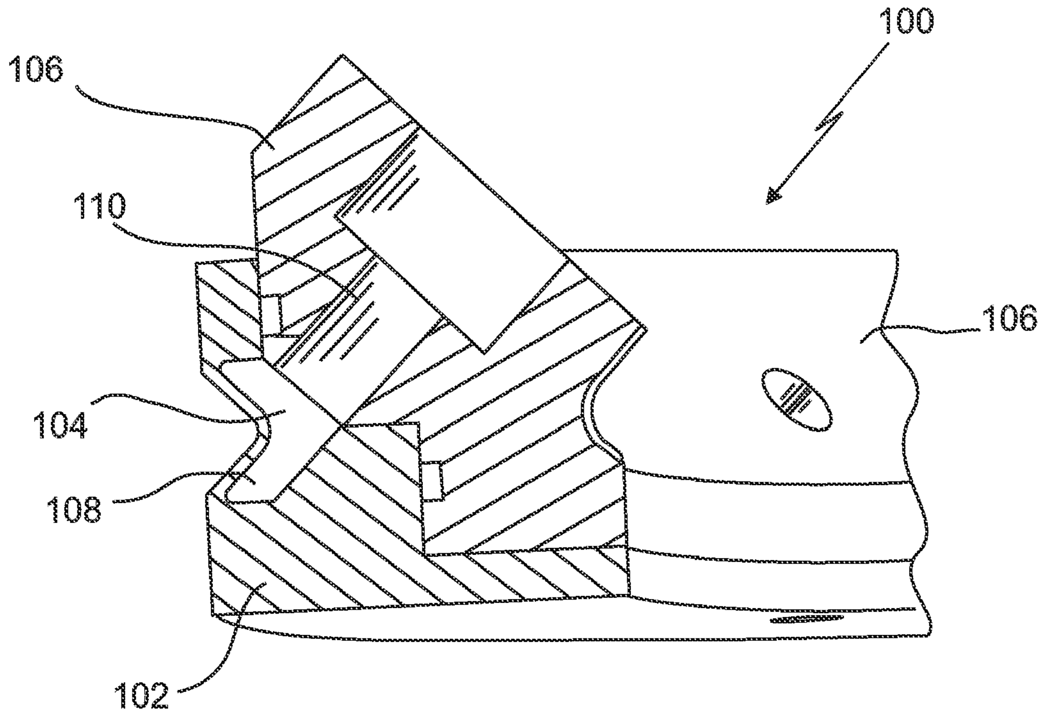


FIG. 3

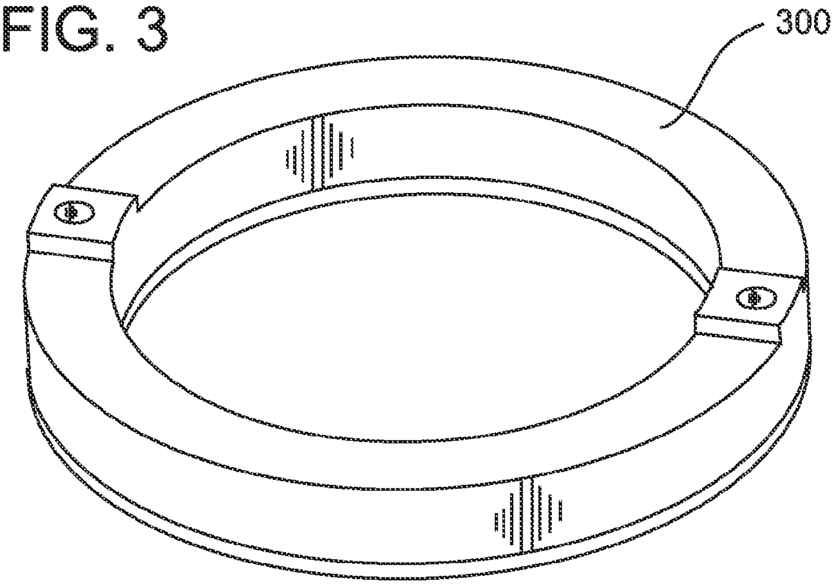


FIG. 4

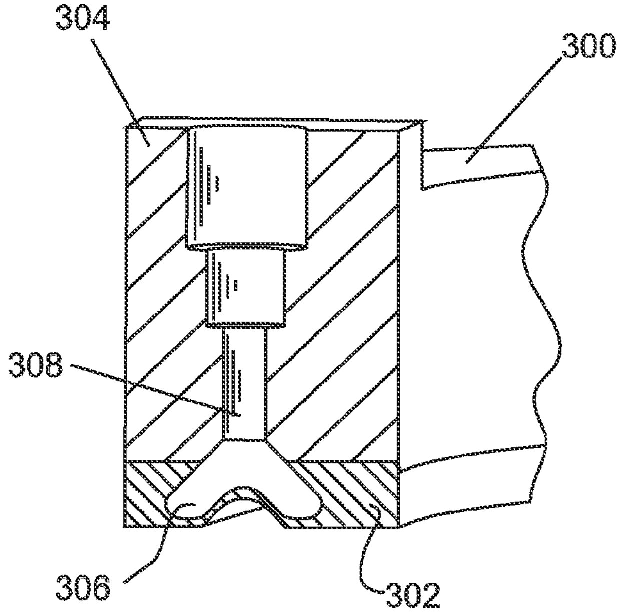
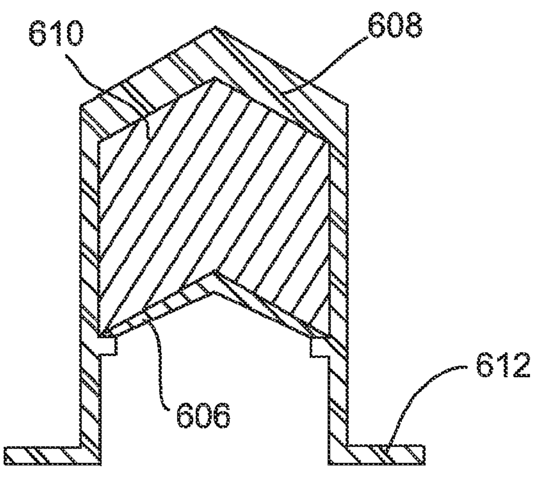


FIG. 7



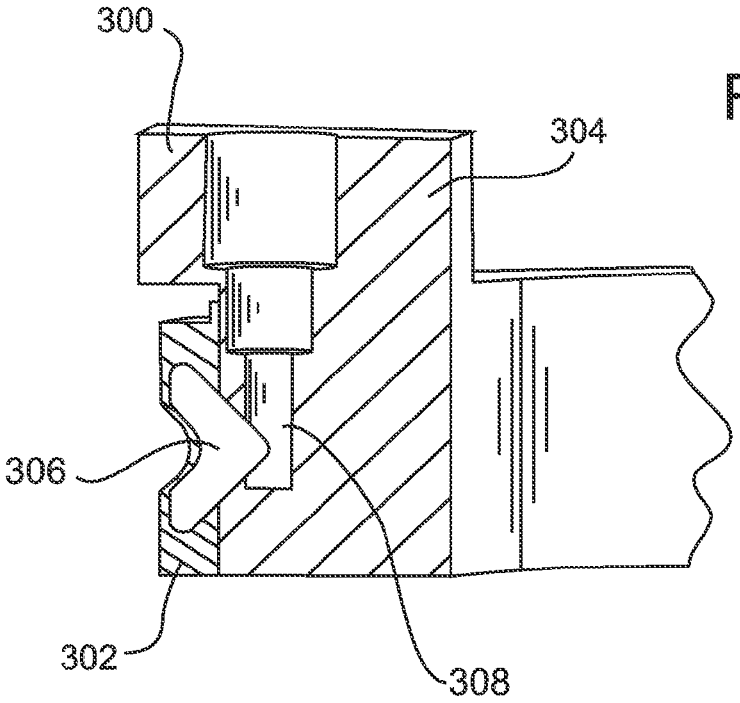


FIG. 5

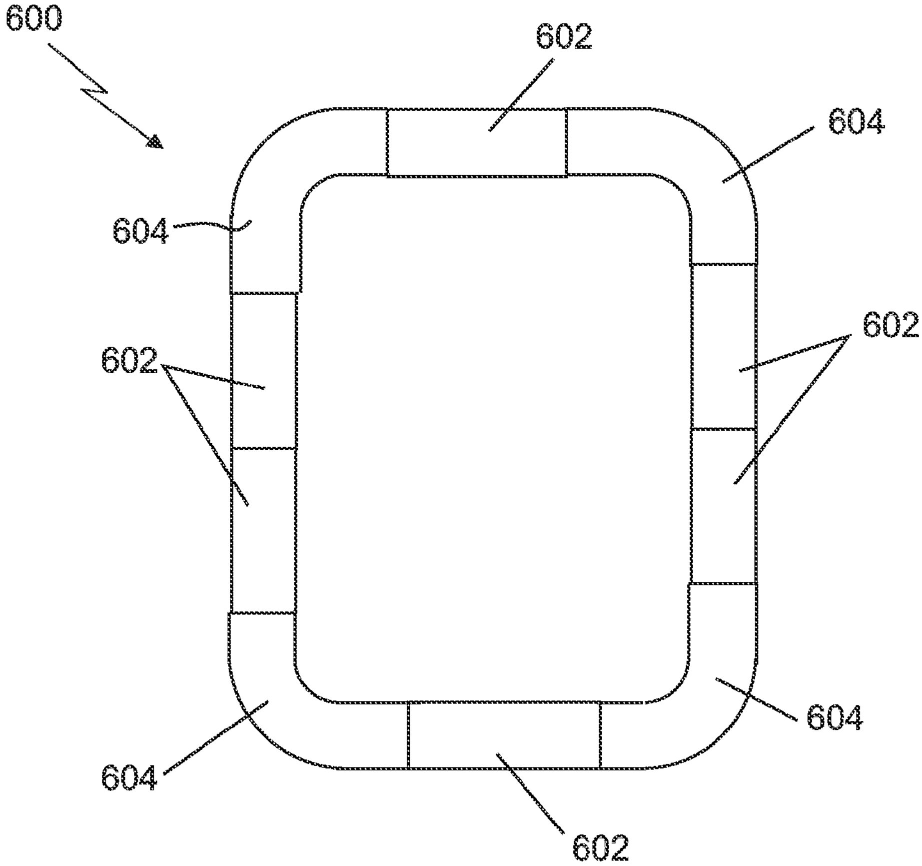


FIG. 6

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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