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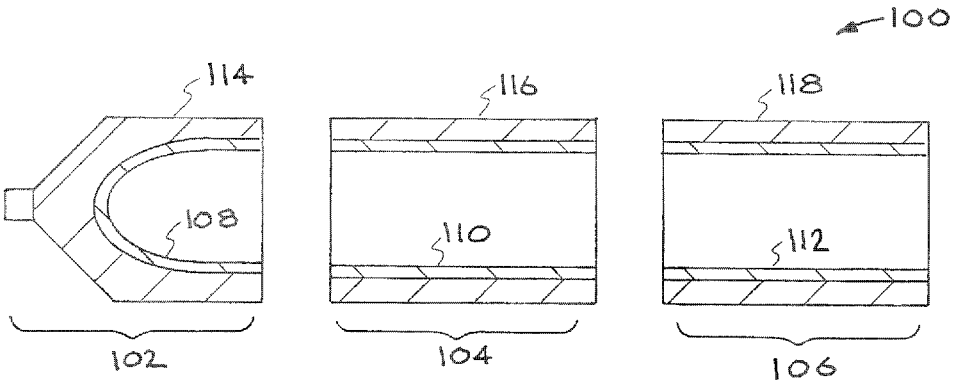


FIG. 1

(57) Abstract: A shaped charge produces a constant velocity jet. The shaped charge is comprised of individual modules which can be assembled to produce a constant velocity jet of arbitrary length. The resulting jet speed is approximately twice the detonation velocity and independent of the liner material. The modular design also allows different liner materials to be used sequentially in the same jet.

WO 2019/005243 A2

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MODULAR GRADIENT-FREE SHAPED CHARGE

STATEMENT AS TO RIGHTS TO APPLICATIONS MADE UNDER FEDERALLY SPONSORED RESEARCH AND DEVELOPMENT

[0001] The present application claims benefit under 35 U.S.C. § 119(e) of United States Provisional Patent Application No. 62/485,029 filed April 13, 2017 the disclosure of which is hereby incorporated by reference in its entirety for all purposes. This application claims priority to and claims the benefit of U.S.S.N. 15/685,486 filed August 24, 2017 which is incorporated herein by reference.

[0002] The United States Government has rights in this application pursuant to Contract No. DE-AC52-07NA27344 between the United States Department of Energy and Lawrence Livermore National Security, LLC for the operation of Lawrence Livermore National Laboratory.

BACKGROUND

Field of Endeavor

[0003] The present disclosure relates to shaped charges and more particularly to a modular gradient-free shaped charge.

State of Technology

[0004] This section provides background information related to the present disclosure which is not necessarily prior art.

[0005] The simplest configuration for a shaped charge is a right circular cylinder, comprised of an annulus of explosive surrounding a thin-walled metal or other material tube (commonly referred to as the liner). When the explosive is initiated at one end, the progressing detonation will collapse the liner along the axis of the charge. The collapse process progresses along the charge at the same velocity speed as the detonation. An analytic solution exists to describe the

progressive collapse of the liner and under certain conditions forms a jet of liner material in the forward direction. The resulting jet from a cylindrical collapse has a speed of twice the detonation speed and no velocity gradient from tip to tail of the jet. This simple relationship between detonation speed and jet speed, which is constant along the entire length of the charge enables the creation of a jet limited in length only by the length of the charge. The length of traditional shaped charge jets can only be increased in length by increasing the diameter as well as the length of the charge. This is a massive penalty as charge weight increases by a factor of 8 to accomplish a doubling of jet length. This invention allows the jet length to be doubled with only a factor of two increase in charge weight.

[0006] The use of a cylindrical shaped charge liner is not a new concept; however, its implementation has not been realized because it requires an explosive with detonation speed less than the sound speed of the liner material. For common solid explosives and metal liners, this combination of material properties does not exist. While the theory is not new, the realization is new. This invention enables the sound speed criteria to be met, by using a heavily metal loaded explosive referred to as multiphase blast explosive (MBX) to drive a standard liner material. The particulate loading of the explosive has the effect of reducing the detonation speed below the sound speed of common metals such as copper, steel, aluminum, etc, thus enabling the formation of a stable jet of these liner materials. Note that the particulate loading of the explosive serves to reduce the rate of propagation of the detonation along the axial direction of the charge, while maintaining a relatively high detonation pressure. This combination of reduced effective detonation speed without a corresponding reduction in detonation pressure results in an increased deflection angle of the liner under

explosive loading, which serves to increase the diameter of the jet. Note also that it may not be necessary to utilize a high density metal particulate fill in the explosive, as the operative mechanism in MBX is the obstruction of direct forward progression of the detonation. The required obstruction can potentially be obtained by particles of any density, as long as they serve to provide sufficient obstruction to the straight-forward detonation propagation.

SUMMARY

[0007] Features and advantages of the disclosed apparatus, systems, and methods will become apparent from the following description. Applicant is providing this description, which includes drawings and examples of specific embodiments, to give a broad representation of the apparatus, systems, and methods. Various changes and modifications within the spirit and scope of the application will become apparent to those skilled in the art from this description and by practice of the apparatus, systems, and methods. The scope of the apparatus, systems, and methods is not intended to be limited to the particular forms disclosed and the application covers all modifications, equivalents, and alternatives falling within the spirit and scope of the apparatus, systems, and methods as defined by the claims.

[0008] An invention is described which is a shaped charge design which produces a constant velocity jet. The charge design can be comprised of individual modules which can be assembled to produce a constant velocity jet of arbitrary length. The resulting jet speed is approximately twice the detonation velocity and independent of the liner material. The modular design also allows different liner materials to be used sequentially in the same jet.

[0009] A constant velocity jet does not undergo the particulation inherent in a stretching jet. Thus, the charge can be used in applications requiring a long standoff distance between the charge and target. Past and current uses of charges designed for gradient free operation are not modular and thus have an inherent limit to jet length, and require large diameters to increase jet length. Military uses include anti-armor and anti-submarine warheads, disablement tool for explosive ordnance disposal, and render safe operations. Non-Military uses include a perforator for use in perforation of well casing. The well can be an oil well, a gas well, a geothermal well, a water well, an injection well, a withdrawal well or other type of well.

[00010] The apparatus, systems, and methods are susceptible to modifications and alternative forms. Specific embodiments are shown by way of example. It is to be understood that the apparatus, systems, and methods are not limited to the particular forms disclosed. The apparatus, systems, and methods cover all modifications, equivalents, and alternatives falling within the spirit and scope of the application as defined by the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[00011] The accompanying drawings, which are incorporated into and constitute a part of the specification, illustrate specific embodiments of the apparatus, systems, and methods and, together with the general description given above, and the detailed description of the specific embodiments, serves to explain the principles of the apparatus, systems, and methods.

[00012] FIG. 1 illustrates one embodiment of the invention wherein a shaped charge produces a constant velocity jet.

[00013] FIG. 2 illustrates another embodiment of the invention wherein a shaped charge produces a constant velocity jet.

[00014] FIG. 3 illustrates another embodiment of the invention wherein the detonator unit has a different shape.

[00015] FIGS. 4A and 4B illustrate a perforator for use in perforation of well.

[00016] FIGS. 5A and 5B illustrates another embodiment of the invention wherein a torpedo includes a warhead.

[00017] FIGS. 6Aand 6B illustrate another embodiment of the invention wherein a shell contains a shaped charge.

[00018] FIG. 7 illustrates another embodiment of the invention wherein a shaped charge produces a constant velocity jet and demonstrates that the base unit (detonator) does not require a liner.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[00019] Referring to the drawings, to the following detailed description, and to incorporated materials, detailed information about the apparatus, systems, and methods is provided including the description of specific embodiments. The detailed description serves to explain the principles of the apparatus, systems, and methods. The apparatus, systems, and methods are susceptible to modifications and alternative forms. The application is not limited to the particular forms disclosed. The application covers all modifications, equivalents, and alternatives falling within the spirit and scope of the apparatus, systems, and methods as defined by the claims.

[00020] The phenomenon of forming a forward traveling jet of material when explosively collapsing a conical or other shaped liner material is well

known and has been studied and tested extensively for nearly 100 years. The shape of the liner material is typically a simple geometric configuration such as a cone, hemisphere, flared cone (trumpet), ellipse, for example. The speed of the jet resulting from the progressive collapse of the liner material along the axis of symmetry of the liner is dependent on the detonation speed of the surrounding explosive and the angle at which the collapsing liner impacts the centerline of the charge. The length of the jet is determined and limited by the length of the charge and the rate the jet stretches after formation due to axial velocity gradients in the jet. Increases in jet length are typically gained by increasing the size (length and diameter) of the charge. To gain a factor of two increase in length requires a charge having twice the length and twice the diameter, which then results in a factor of 8 increase in charge weight.

[00021] A particularly simple charge configuration which in theory allows longer jets without a corresponding increase in charge diameter is a cylindrical liner, in which charge length can be increased without a corresponding diameter increase. Doubling the length of a cylindrical charge should produce twice the jet length, with no increase in diameter and thus only a factor of two increase in charge weight. The properties of a cylindrical jetting configuration are well known and can be calculated from analytic formulations. However, the formation of a stable, coherent jet requires that the detonation speed of the explosive be less than the local speed of sound in the liner material at the point of collapse, i.e. a stable jet is always formed when the collision process at the axis of the charge is subsonic. This stability criteria is difficult to achieve in practice as detonation speeds for common explosives are typically greater than the sound speed of common liner materials. A stable jet is commonly achieved by utilizing

a conic or similar liner wherein the collapse angle of the liner is adjusted to meet the subsonic criterion.

[00022] This invention proposes using a cylindrical charge and liner geometry, in conjunction with multiphase blast explosive (MBX) which provides a mechanism for reducing the axial rate of propagation (speed) of the detonation front to a value below that of common liner materials such as copper. This combination of MBX, copper liner, and cylindrical geometry meets the subsonic criterion for stable jet formation and allows a linear increase in jet length with a corresponding linear increase in charge weight. The resulting jet is also a constant velocity jet, no tip to tail velocity gradient, at approximately twice the detonation velocity of the MBX formulation.

[00023] The MBX material used for this invention is a uniform mixture of a conventional explosive infiltrated with inert particles. The role of the particles is to disrupt the normal detonation propagation rate by forcing the detonation to propagate around the inert particulates in the mixture. In practice, detonation rates have been reduced to less than 5 km/sec in HMX based explosives, which allows stable jets to form using cylindrical liners of copper or any other material with sound speed less than the MBX detonation velocity. It is also a property of a cylindrical liner that the resulting jet speed is independent of the liner material and thus different liner materials can be incorporated in the same charge, resulting in a jet of sequential materials of different densities.

[00024] The cylindrical geometry of this invention allows for the coupling together of multiple modules, each module producing a gradient-free jet at the same speed, thereby producing an arbitrarily long jet. Note that the jet speed is not dependent on the liner material and thus different modules can incorporate

different liner materials, producing a jet comprised of sequentially different materials.

[00025] A particular configuration of modules can consist of a base unit which serves to initiate the detonation propagation and the formation of a jet. This base unit can be comprised of a conventional explosive driving a conventional simple shaped charge liner configuration, such as a cone or tulip geometry. The base unit is directly coupled to an MGF cylindrical module incorporating MBX, with the shaped liner of the base unit directly aligned with the cylindrical liner of the module and the detonation in the base unit directly shock initiating the MBX. Thus the added modules require no independent initiation system, as they are contact initiated directly from the base unit or prior module. The present application relates to nanowire suspensions and more particularly to fabrication of nanoporous aerogels via freeze substitution of nanowire suspensions.

[00026] The modular aspect of this invention allows for in-field assembly of a modular components to adjust the length as well as the material(s) in a continuous jet. The modular aspect also allows for easy portability of a individual modules which can be easily assembled to produce deep penetration. These features are unique to this invention.

[00027] Referring now to the drawings and in particular to FIG. 1, one embodiment of Applicant's apparatus, systems, and methods is illustrated. This embodiment is designated generally by the reference numeral 100. The embodiment 100 provides a shaped charge design which produces a constant velocity jet. The charge design is comprised of individual modules which are assembled to produce a constant velocity jet of arbitrary length. The embodiment 100 includes the following components:

base unit – 102,

first modular unit – 104,

second modular unit – 106,

base unit liner material - 108

first modular unit liner material – 110,

second modular unit liner material – 112,

base unit conventional explosive – 114,

first modular unit multiphase blast explosive – 116, and

second modular unit multiphase blast explosive – 118.

[00028] The embodiment 100 of the inventor's apparatus, systems, and methods provides a shaped charge design which produces a constant velocity jet. The charge design includes the individual modules: base unit 102, first modular unit 104, and second modular unit 106. The individual modules are assembled to produce a constant velocity jet of a predetermined length. The resulting jet speed is approximately twice the detonation velocity and independent of the liner materials: base unit liner material 108, first modular unit liner material 110, and a second modular unit liner material 112. The modular design also allows different liner materials to be used sequentially in the same jet.

[00029] The embodiment 100 utilizes base unit 102 to initiate the detonation propagation and the formation of a jet. The base unit 102 is directly coupled to and aligned with the first modular unit 104 and the second modular unit 106.

[00030] The base unit 102 is comprised of a conventional explosive 114 driving a conventional simple shaped charge liner 108 configuration, such as a cone or tulip geometry. The first modular unit 104 incorporates multiphase blast explosive 116 with the first modular unit liner material 110. The second modular

unit 106 incorporates multiphase blast explosive 116 with the second modular unit liner material 112.

[00031] The embodiment 100 utilizes a cylindrical charge and liner geometry, in conjunction with multiphase blast explosive (MBX) 116 which provides a mechanism for reducing the axial rate of propagation (speed) of the detonation front to a value below that of common liner materials 110/112 such as copper. This combination of MBX, copper liner 110/112, and cylindrical geometry meets the subsonic criterion for stable jet formation and allows a liner increase in jet length with a corresponding liner increase in charge weight. The resulting jet is also a constant velocity jet, no tip to tail velocity gradient, at approximately twice the detonation velocity of the MBX formulation.

[00032] The MBX material 116 and 118 used for this invention is a uniform mixture of a conventional explosive infiltrated with inert particles. The role of the particles is to disrupt the normal detonation propagation rate by forcing the detonation to propagate around the inert particulates in the mixture. In practice, detonation rates have been reduced to less than 5 km/sec in HMX based explosives, which allows stable jets to form using cylindrical liners of copper or any other material with sound speed less than the MBX detonation velocity. It is also a property of a cylindrical liner that the resulting jet speed is independent of the liner material and thus different liner materials can be incorporated in the same charge, resulting in a jet of sequential materials of different densities.

[00033] The added modules require no independent initiation system, as they are contact initiated directly from the base unit or prior module. The modular aspect of the embodiment 100 allows for in-field assembly of a modular components to adjust the length as well as the material(s) in a continuous jet. The

modular aspect also allows for easy portability of individual modules which can be easily assembled to produce deep penetration.

[00034] Referring now FIG. 2, a second embodiment of Applicant's apparatus, systems, and methods is illustrated. This embodiment is designated generally by the reference numeral 200. The embodiment 200 provides a shaped charge design comprised of a larger number of individual modules. The individual modules are assembled to produce a constant velocity jet of arbitrary length. The embodiment 200 includes the following components:

base unit – 202;

modular units – 204a, 204b, 204c, 204d, and 204e;

base unit liner material – 208;

modular unit liner materials – 210a, 210b, 210c, 210d, and 210e; and

modular unit multiphase blast explosives – 216a, 216b, 215c, 216d, and 216e.

[00035] The embodiment 200 of the inventor's apparatus, systems, and methods provides a shaped charge design which produces a constant velocity jet. The embodiment 200 charge design includes base unit 202 multiple individual modular units 204a, 204b, 204c, 204d, and 204e. The individual modular units are assembled to produce a constant velocity jet of a predetermined length. The resulting jet speed is approximately twice the detonation velocity and independent of base unit liner material 208 and modular units liner materials 210a, 210b, 210c, 210d, and 210e. The modular design also allows different liner materials to be used sequentially in the same jet.

[00036] The embodiment 200 utilizes base unit 202 to initiate the detonation propagation and the formation of a jet. The base unit 202 is directly coupled to

and aligned with the modular units 204a, 204b, 204c, 204d, and 204e; particularly modular unit multiphase blast explosives 210a, 210b, 210c, 210d, and 210e.

[00037] The base unit 202 is comprised of a conventional explosive 214 driving a conventional simple shaped charge liner 208 configuration, such as a cone or tulip geometry. The modular units 204a, 204b, 204c, 204d, and 204e incorporate multiphase blast explosives 210a, 210b, 210c, 210d, and 210e with the units liner materials 210a, 210b, 210c, 210d, and 210e. The MBX material 210a, 210b, 210c, 210d, and 210e used for this invention is a uniform mixture of a conventional explosive infiltrated with inert particles. The role of the particles is to disrupt the normal detonation propagation rate by forcing the detonation to propagate around the inert particulates in the mixture. In practice, detonation rates have been reduced to less than 5 km/sec in HMX based explosives, which allows stable jets to form using cylindrical liners of copper or any other material with sound speed less than the MBX detonation velocity. It is also a property of a cylindrical liner that the resulting jet speed is independent of the liner material and thus different liner materials can be incorporated in the same charge, resulting in a jet of sequential materials of different densities.

[00038] The added modules require no independent initiation system, as they are contact initiated directly from the base unit or prior module. The modular aspect of the embodiment 200 allows for in-field assembly of a modular components to adjust the length as well as the material(s) in a continuous jet. The modular aspect also allows for easy portability of individual modules which can be easily assembled to produce deep penetration.

[00039] Referring now to FIG. 3, an embodiment of Applicant's apparatus, systems, and methods wherein the detonator unit has a different shape is

illustrated. This embodiment is designated generally by the reference numeral 300. The embodiment 300 includes the following components:

base unit – 302,

first modular unit – 304,

second modular unit – 306,

base unit liner material - 308

first modular unit liner material – 310,

second modular unit liner material – 312,

base unit conventional explosive – 314,

first modular unit multiphase blast explosive – 316, and

second modular unit multiphase blast explosive – 318.

[00040] The embodiment 300 of the inventor's apparatus, systems, and methods provides a shaped charge design which produces a constant velocity jet. The charge design includes the individual modules: base unit 302, first modular unit 304, and second modular unit 306. The individual modules are assembled to produce a constant velocity jet of a predetermined length. The resulting jet speed is approximately twice the detonation velocity and independent of the liner materials: base unit liner material 308, first modular unit liner material 310, and or second modular unit liner material 312. The modular design also allows different liner materials to be used sequentially in the same jet.

[00041] The embodiment 300 utilizes base unit 302 to initiate the detonation propagation and the formation of a jet. The base unit 302 is directly coupled to and aligned with the first modular unit 304 and the second modular unit 306.

[00042] The base unit 302 is comprised of a conventional explosive 314 having a conical driving a conventional configuration. The embodiment 300

includes a simple shaped charge liner 308. The first modular unit 304 incorporates multiphase blast explosive 316 with the first modular unit liner material 310. The second modular unit 306 incorporates multiphase blast explosive 316 with the first modular unit liner material 310.

[00043] The embodiment 300 utilizes a cylindrical charge and liner geometry, in conjunction with multiphase blast explosive (MBX) 316 which provides a mechanism for reducing the axial rate of propagation (speed) of the detonation front to a value below that of common liner materials 310/312 such as copper. This combination of MBX, copper liner 310/312, and cylindrical geometry meets the subsonic criterion for stable jet formation and allows a liner increase in jet length with a corresponding liner increase in charge weight. The resulting jet is also a constant velocity jet, no tip to tail velocity gradient, at approximately twice the detonation velocity of the MBX formulation.

[00044] The MBX material 316/318 used for this invention is a uniform mixture of a conventional explosive infiltrated with inert particles. The role of the particles is to disrupt the normal detonation propagation rate by forcing the detonation to propagate around the inert particulates in the mixture. In practice, detonation rates have been reduced to less than 5 km/sec in HMX based explosives, which allows stable jets to form using cylindrical liners of copper or any other material with sound speed less than the MBX detonation velocity. It is also a property of a cylindrical liner that the resulting jet speed is independent of the liner material and thus different liner materials can be incorporated in the same charge, resulting in a jet of sequential materials of different densities.

[00045] The added modules require no independent initiation system, as they are contact initiated directly from the base unit or prior module. The modular aspect of the embodiment 300 allows for in-field assembly of a modular

components to adjust the length as well as the material(s) in a continuous jet. The modular aspect also allows for easy portability of individual modules which can be easily assembled to produce deep penetration.

[00046] Referring now to FIGS. 4A and 4B, another embodiment of Applicant's apparatus, systems, and methods is illustrated. The embodiment is designated generally by the reference numeral 400. The embodiment 400 provides a perforator 420 for use in perforation of well 422. The well 422 can be an oil well, a gas well, a geothermal well, a water well, an injection well, a withdrawal well or other type of well. The perforator 420 is a shaped charge that produces a jet 424 for punching a hole 426 in the casing or liner 428 of the well 422. The perforator 420 produces a jet 424.

[00047] Referring now to FIG. 4A, a multiplicity of shaped charge perforators 420 are used for perforation of well 422. The multiplicity of shaped charge perforators 420 are used to punch holes 426 in the casing or liner 428 of the well 422.

[00048] Referring now to FIG. 4B, the shaped charge of the perforator 422 is shown in greater detail. The shaped charge is identified generally by the reference numeral 430. The shaped charge 430 includes the following components:

base unit – 402,

first modular unit – 404,

second modular unit – 406,

base unit liner material - 408

first modular unit liner material – 410,

second modular unit liner material – 412,

base unit conventional explosive – 414,

first modular unit multiphase blast explosive – 416, and

second modular unit multiphase blast explosive – 418.

[00049] The shaped charge 430 produces a constant velocity jet. The charge design includes the individual modules: base unit 402, first modular unit 404, and second modular unit 406. The individual modules are assembled to produce a constant velocity jet of a predetermined length. The resulting jet speed is approximately twice the detonation velocity and independent of the liner materials: base unit liner material 408, first modular unit liner material 410, and or second modular unit liner material 412. The modular design also allows different liner materials to be used sequentially in the same jet.

[00050] The shape charge 430 utilizes base unit 402 to initiate the detonation propagation and the formation of a jet. The base unit 402 is directly coupled to and aligned with the first modular unit 404 and the second modular unit 406.

[00051] The base unit 402 is comprised of a conventional explosive 414 driving a conventional simple shaped charge liner 408 configuration, such as a cone or tulip geometry. The first modular unit 404 incorporates multiphase blast explosive 416 with the first modular unit liner material 410. The second modular unit 406 incorporates multiphase blast explosive 418 with the second modular unit liner material 412.

[00052] The shape charge 430 utilizes a cylindrical charge and liner geometry, in conjunction with multiphase blast explosive (MBX) 416/418 which provides a mechanism for reducing the axial rate of propagation (speed) of the detonation front to a value below that of common liner materials 410/412 such as copper. This combination of MBX, copper liner 410/412, and cylindrical geometry meets the subsonic criterion for stable jet formation and allows a liner increase in

jet length with a corresponding liner increase in charge weight. The resulting jet is also a constant velocity jet, no tip to tail velocity gradient, at approximately twice the detonation velocity of the MBX formulation.

[00053] The MBX material 416 and 418 used for this invention is a uniform mixture of a conventional explosive infiltrated with inert particles. The role of the particles is to disrupt the normal detonation propagation rate by forcing the detonation to propagate around the inert particulates in the mixture. In practice, detonation rates have been reduced to less than 5 km/sec in HMX based explosives, which allows stable jets to form using cylindrical liners of copper or any other material with sound speed less than the MBX detonation velocity. It is also a property of a cylindrical liner that the resulting jet speed is independent of the liner material and thus different liner materials can be incorporated in the same charge, resulting in a jet of sequential materials of different densities.

[00054] The added modules require no independent initiation system, as they are contact initiated directly from the base unit or prior module. The modular aspect of the shape charge 430 allows for in-field assembly of a modular components to adjust the length as well as the material(s) in a continuous jet. The modular aspect also allows for easy portability of individual modules which can be easily assembled to produce deep penetration.

[00055] Referring now to FIGS. 5A and 5B, another embodiment of Applicant's apparatus, systems, and methods is illustrated. The embodiment provides a warhead for use in a torpedo.

[00056] Referring to FIG. 5A a torpedo 500 includes a warhead 501. The warhead 501 includes a shaped charge 501a that produces a jet for punching a hole in an enemy ship or other target.

[00057] Referring to FIG. 5B, the shaped charge 501a is shown in greater detail. The shaped charge 501a includes the following components:

base unit – 502,

first modular unit – 504,

second modular unit – 506,

base unit liner material - 508

first modular unit liner material – 510,

second modular unit liner material – 512,

base unit conventional explosive – 514,

first modular unit multiphase blast explosive – 516, and

second modular unit multiphase blast explosive – 518.

[00058] The shaped charge 501a produces a constant velocity jet. The charge design includes the individual modules: base unit 502, first modular unit 504, and second modular unit 506. The individual modules are assembled to produce a constant velocity jet of a predetermined length. The resulting jet speed is approximately twice the detonation velocity and independent of the liner materials: base unit liner material 508, first modular unit liner material 510, and or second modular unit liner material 512. The modular design also allows different liner materials to be used sequentially in the same jet.

[00059] The shaped charge 501a utilizes base unit 502 to initiate the detonation propagation and the formation of a jet. The base unit 502 is directly coupled to and aligned with the first modular unit 504 and the second modular unit 506.

[00060] The base unit 502 is comprised of a conventional explosive 514 driving a conventional simple shaped charge liner 508 configuration, such as a cone or tulip geometry. The first modular unit 504 incorporates multiphase blast

explosive 516 with the first modular unit liner material 510. The second modular unit 506 incorporates multiphase blast explosive 516 with the second modular unit liner material 512.

[00061] The shaped charge 501a utilizes a cylindrical charge and liner geometry, in conjunction with multiphase blast explosive (MBX) 516 and 518 which provides a mechanism for reducing the axial rate of propagation (speed) of the detonation front to a value below that of common liner materials 510/512 such as copper. This combination of MBX, copper liner 510/512, and cylindrical geometry meets the subsonic criterion for stable jet formation and allows a liner increase in jet length with a corresponding liner increase in charge weight. The resulting jet is also a constant velocity jet, no tip to tail velocity gradient, at approximately twice the detonation velocity of the MBX formulation.

[00062] The MBX material 516 and 518 used for this invention is a uniform mixture of a conventional explosive infiltrated with inert particles. The role of the particles is to disrupt the normal detonation propagation rate by forcing the detonation to propagate around the inert particulates in the mixture. In practice, detonation rates have been reduced to less than 5 km/sec in HMX based explosives, which allows stable jets to form using cylindrical liners of copper or any other material with sound speed less than the MBX detonation velocity. It is also a property of a cylindrical liner that the resulting jet speed is independent of the liner material and thus different liner materials can be incorporated in the same charge, resulting in a jet of sequential materials of different densities.

[00063] The added modules require no independent initiation system, as they are contact initiated directly from the base unit or prior module. The modular aspect of the shape charge 501a allows for in-field assembly of a modular components to adjust the length as well as the material(s) in a

continuous jet. The modular aspect also allows for easy portability of individual modules which can be easily assembled to produce deep penetration.

[00064] Referring now to FIGS. 6A and 6B, another embodiment of Applicant's apparatus, systems, and methods is illustrated. The embodiment provides a shaped charge for penetrating armor.

[00065] Referring to FIG. 6A a shell containing shaped charge 600 is directed onto the armor of tank 601. The shaped charge 600 produces a jet for punching a hole in the armor of tank 601.

[00066] Referring to FIG. 6B, the shaped charge 601a is shown in greater detail. The shaped charge 601a includes the following components:

base unit – 602,

first modular unit – 604,

second modular unit – 606,

base unit liner material - 608

first modular unit liner material – 610,

second modular unit liner material – 612,

base unit conventional explosive – 614,

first modular unit multiphase blast explosive – 616, and

second modular unit multiphase blast explosive – 618.

[00067] The shaped charge 601a produces a constant velocity jet. The charge design includes the individual modules: base unit 602, first modular unit 604, and second modular unit 606. The individual modules are assembled to produce a constant velocity jet of a predetermined length. The resulting jet speed is approximately twice the detonation velocity and independent of the liner materials: base unit liner material 608, first modular unit liner material 610, and

or second modular unit liner material 612. The modular design also allows different liner materials to be used sequentially in the same jet.

[00068] The shape charge 601a utilizes base unit 602 to initiate the detonation propagation and the formation of a jet. The base unit 602 is directly coupled to and aligned with the first modular unit 604 and the second modular unit 606.

[00069] The base unit 602 is comprised of a conventional explosive 614 driving a conventional simple shaped charge liner 608 configuration, such as a cone or tulip geometry. The first modular unit 604 incorporates multiphase blast explosive 616 with the first modular unit liner material 610. The second modular unit 606 incorporates multiphase blast explosive 616 with the second modular unit liner material 612.

[00070] The shaped charge 601a utilizes a cylindrical charge and liner geometry, in conjunction with multiphase blast explosive (MBX) 616 which provides a mechanism for reducing the axial rate of propagation (speed) of the detonation front to a value below that of common liner materials 610/612 such as copper. This combination of MBX, copper liner 610/612, and cylindrical geometry meets the subsonic criterion for stable jet formation and allows a liner increase in jet length with a corresponding liner increase in charge weight. The resulting jet is also a constant velocity jet, no tip to tail velocity gradient, at approximately twice the detonation velocity of the MBX formulation.

[00071] The MBX material 616 and 618 used for this invention is a uniform mixture of a conventional explosive infiltrated with inert particles. The role of the particles is to disrupt the normal detonation propagation rate by forcing the detonation to propagate around the inert particulates in the mixture. In practice, detonation rates have been reduced to less than 5 km/sec in HMX based

explosives, which allows stable jets to form using cylindrical liners of copper or any other material with sound speed less than the MBX detonation velocity. It is also a property of a cylindrical liner that the resulting jet speed is independent of the liner material and thus different liner materials can be incorporated in the same charge, resulting in a jet of sequential materials of different densities.

[00072] The added modules require no independent initiation system, as they are contact initiated directly from the base unit or prior module. The modular aspect of the shape charge 601a allows for in-field assembly of a modular components to adjust the length as well as the material(s) in a continuous jet. The modular aspect also allows for easy portability of individual modules which can be easily assembled to produce deep penetration.

[00073] Referring now to FIG. 7, another embodiment of Applicant's apparatus, systems, and methods is illustrated. This embodiment is designated generally by the reference numeral 700. The embodiment 700 demonstrates that the base unit (detonator) does not require a liner. The embodiment 700 includes the following components:

base unit – 702,

first modular unit – 704,

second modular unit – 706,

first modular unit liner material – 710,

second modular unit liner material – 712,

base unit conventional explosive – 714,

first modular unit multiphase blast explosive – 716, and

second modular unit multiphase blast explosive – 718.

[00074] The embodiment 700 of the inventor's apparatus, systems, and methods provides a shaped charge design which produces a constant velocity jet.

The charge design includes the individual modules: base unit (detonator) 702, first modular unit 704, and second modular unit 706. The individual modules are assembled to produce a constant velocity jet of a predetermined length. The embodiment 700 utilizes base unit (detonator) 702 to initiate the detonation propagation and the formation of the jet. The base unit(detonator) 702 is directly coupled to and aligned with the first modular unit 704 and the second modular unit 706.

[00075] The base unit 702 is comprised of a conventional explosive 714, such as a cone or tulip geometry. The first modular unit 704 incorporates multiphase blast explosive 716 with the first modular unit liner material 710. The second modular unit 706 incorporates multiphase blast explosive 716 with the first modular unit liner material 710. The added modules require no independent initiation system, as they are contact initiated directly from the base unit or prior module. The modular aspect of the embodiment 700 allows for in-field assembly of a modular components to adjust the length as well as the material(s) in a continuous jet. The modular aspect also allows for easy portability of individual modules which can be easily assembled to produce deep penetration.

[00076] Although the description above contains many details and specifics, these should not be construed as limiting the scope of the application but as merely providing illustrations of some of the presently preferred embodiments of the apparatus, systems, and methods. Other implementations, enhancements and variations can be made based on what is described and illustrated in this patent document. The features of the embodiments described herein may be combined in all possible combinations of methods, apparatus, modules, systems, and computer program products. Certain features that are described in this patent document in the context of separate embodiments can

also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment can also be implemented in multiple embodiments separately or in any suitable subcombination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a subcombination or variation of a subcombination. Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. Moreover, the separation of various system components in the embodiments described above should not be understood as requiring such separation in all embodiments.

[00077] Therefore, it will be appreciated that the scope of the present application fully encompasses other embodiments which may become obvious to those skilled in the art. In the claims, reference to an element in the singular is not intended to mean "one and only one" unless explicitly so stated, but rather "one or more." All structural and functional equivalents to the elements of the above-described preferred embodiment that are known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the present claims. Moreover, it is not necessary for a device to address each and every problem sought to be solved by the present apparatus, systems, and methods, for it to be encompassed by the present claims. Furthermore, no element or component in the present disclosure is intended to be dedicated to the public regardless of whether the element or component is

explicitly recited in the claims. No claim element herein is to be construed under the provisions of 35 U.S.C. 112, sixth paragraph, unless the element is expressly recited using the phrase "means for."

[00078] While the apparatus, systems, and methods may be susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and have been described in detail herein. However, it should be understood that the application is not intended to be limited to the particular forms disclosed. Rather, the application is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the application as defined by the following appended claims.

[0079] All elements, parts and steps described herein are preferably included. It is to be understood that any of these elements, parts and steps may be replaced by other elements, parts and steps or deleted altogether as will be obvious to those skilled in the art.

[0080] Broadly, this writing discloses at least the following: A shaped charge produces a constant velocity jet. The shaped charge is comprised of individual modules which can be assembled to produce a constant velocity jet of arbitrary length. The resulting jet speed is approximately twice the detonation velocity and independent of the liner material. The modular design also allows different liner materials to be used sequentially in the same jet.

CONCEPTS

This writing also presents at least the following concepts.

Concept 1. A shaped charge apparatus that produces a jet, comprising:

a detonator base unit, said detonator base unit including a conventional explosive;

a first modular unit including a first modular unit liner material and a first modular unit multiphase blast explosive surrounding said first modular liner material;

and

a second modular unit including a second modular unit liner material and a second modular unit multiphase blast explosive surrounding said second modular liner material; wherein, said detonator base unit, said first modular unit, and said second modular unit are assembled to produce the explosive jet.

Concept 2. The shaped charge apparatus of Concept 1 wherein said first modular unit liner material is a cylindrical first modular unit liner material.

Concept 3. The shaped charge apparatus of Concepts 1 and 2 wherein said first modular unit liner material is made of copper.

Concept 4. The shaped charge apparatus of Concepts 1, 2 and 3 wherein said first modular unit liner material and said second modular unit liner material are aligned.

Concept 5. The shaped charge apparatus of Concepts 1, 2, 3, and 4 wherein said first modular unit multiphase blast explosive is a mixture of conventional explosive and inert particles.

Concept 6. The shaped charge apparatus of Concepts 1, 2, 3, 4, and 5 wherein said

second modular unit multiphase blast explosive is a mixture of conventional explosive and inert particles.

Concept 7. The shaped charge apparatus of Concepts 1, 2, 3, 4, 5, and 6 further comprising at least one additional modular unit.

Concept 8. The shaped charge apparatus of Concept 7 wherein said additional modular unit liner material is a cylindrical first additional unit liner material.

Concept 9. The shaped charge apparatus of Concept 7 wherein said additional modular unit liner material is made of copper.

Concept 10. The shaped charge apparatus of Concept 7 wherein said detonator base unit liner material, said first modular unit liner material, said second modular unit liner material, and said additional modular unit liner material are aligned.

Concept 11. An apparatus that produces a jet for penetrating the casing of a well, comprising:

a perforator,

a detonator base unit in said perforator, said detonator base unit including a conventional explosive;

a first modular unit in said perforator including a first modular unit liner material and a first modular unit multiphase blast explosive surrounding said first modular liner material;

and

a second modular unit in said perforator including a second modular unit liner material and a second modular unit multiphase blast explosive surrounding said second modular liner material; wherein, said detonator base unit, said first modular unit, and said second modular unit are assembled to produce the explosive jet for penetrating the casing of a well.

Concept 12. The apparatus that produces a jet for penetrating the casing of a well of Concept 11 wherein said first modular unit liner material and said second modular unit liner material are aligned.

Concept 13. The apparatus that produces a jet for penetrating the casing of a well of Concepts 11 and 12 wherein said first modular unit multiphase blast explosive is a mixture of conventional explosive and inert particles.

Concept 14. The apparatus that produces a jet for penetrating the casing of a well of Concepts 11, 12, and 13 further comprising at least one additional modular unit.

Concept 15. A torpedo apparatus that includes a warhead that produces a jet for penetrating a vessel, comprising:

an explosive unit in the warhead,

a detonator base unit in said explosive unit, said detonator base unit including a conventional explosive;

a first modular unit in said explosive unit including a first modular unit liner material and a first modular unit multiphase blast explosive surrounding said first modular liner material;

and

a second modular unit in said explosive unit including a second modular unit liner material and a second modular unit multiphase blast explosive surrounding said second modular liner material; wherein, said detonator base unit, said first modular unit, and said second modular unit are assembled to produce the explosive jet for penetrating the vessel.

Concept 16. The torpedo apparatus of Concept 15 further comprising at least one additional modular unit.

Concept 17. The torpedo apparatus of Concepts 15 and 16 wherein said first modular unit liner material, said second modular unit liner material, and said additional modular unit liner material are aligned.

Concept 18. An apparatus that includes a shell that produces a jet for penetrating armor, comprising:

an explosive unit in the shell,

a detonator base unit in said explosive unit, said detonator base unit including a conventional explosive;

a first modular unit in said explosive unit including a first modular unit liner material and a first modular unit multiphase blast explosive surrounding said first modular liner material;

and

a second modular unit in said explosive unit including a second modular unit liner material and a second modular unit multiphase blast explosive surrounding said second modular liner material; wherein, said detonator base unit, said first modular unit, and said second modular unit are assembled to produce the explosive jet for penetrating the armor.

Concept 19. The apparatus that includes a shell that produces a jet for penetrating armor of Concept 18 further comprising at least one additional modular unit.

Concept 20. The apparatus that includes a shell that produces a jet for penetrating armor of Concepts 18 and 19 wherein said first modular unit liner material and said second modular unit liner material and said additional modular unit liner material are aligned.

Concept 21. A method of making a shaped charge that produces a jet, comprising the steps of:

providing a detonator base unit, a detonator base unit, said detonator base unit including a conventional explosive;

providing a first modular unit including a first modular unit liner material and a first modular unit multiphase blast explosive surrounding said first modular liner material; and

providing a second modular unit including a second modular unit liner material and a second modular unit multiphase blast explosive surrounding said second modular liner material; wherein, said detonator base unit, said first modular unit, and said second modular unit are assembled to produce the explosive jet.

Concept 22. The method of making a shaped charge that produces a jet of Concept 21 wherein said first modular unit multiphase blast explosive is a mixture of conventional explosive and inert particles.

Concept 23. The method of making a shaped charge that produces a jet of Concepts 21 and 22 wherein said second modular unit multiphase blast explosive is a mixture of conventional explosive and inert particles.

Concept 24. The method of making a shaped charge that produces a jet of Concepts 21, 22, and 23 further comprising at least one additional modular unit.

Concept 25. The method of making a shaped charge that produces a jet of Concepts 21, 22, 23, and 24 wherein said first modular unit liner material, said second modular unit liner material, and said additional modular unit liner material are aligned.

THE CLAIMS ARE:

Claim 1. A shaped charge apparatus that produces a jet, comprising:

a detonator base unit, said detonator base unit including a conventional explosive;

a first modular unit including a first modular unit liner material and a first modular unit multiphase blast explosive surrounding said first modular liner material;

and

a second modular unit including a second modular unit liner material and a second modular unit multiphase blast explosive surrounding said second modular liner material; wherein, said detonator base unit, said first modular unit, and said second modular unit are assembled to produce the explosive jet.

Claim 2. The shaped charge apparatus of claim 1 wherein said first modular unit liner material is a cylindrical first modular unit liner material.

Claim 3. The shaped charge apparatus of claim 1 wherein said first modular unit liner material is made of copper.

Claim 4. The shaped charge apparatus of claim 1 wherein said first modular unit liner material and said second modular unit liner material are aligned.

Claim 5. The shaped charge apparatus of claim 1 wherein said first modular unit multiphase blast explosive is a mixture of conventional explosive and inert particles.

Claim 6. The shaped charge apparatus of claim 1 wherein said second modular unit multiphase blast explosive is a mixture of conventional explosive and inert particles.

Claim 7. The shaped charge apparatus of claim 1 further comprising at least one additional modular unit.

Claim 8. The shaped charge apparatus of claim 7 wherein said additional modular unit liner material is a cylindrical first additional unit liner material.

Claim 9. The shaped charge apparatus of claim 7 wherein said additional modular unit liner material is made of copper.

Claim 10. The shaped charge apparatus of claim 7 wherein said detonator base unit liner material, said first modular unit liner material, said second modular unit liner material, and said additional modular unit liner material are aligned.

Claim 11. An apparatus that produces a jet for penetrating the casing of a well, comprising:

a perforator,

a detonator base unit in said perforator, said detonator base unit including a conventional explosive;

a first modular unit in said perforator including a first modular unit liner material and a first modular unit multiphase blast explosive surrounding said first modular liner material;

and

a second modular unit in said perforator including a second modular unit liner material and a second modular unit multiphase blast explosive surrounding said second modular liner material; wherein, said detonator base unit, said first modular unit, and said second modular unit are assembled to produce the explosive jet for penetrating the casing of a well.

Claim 12. The apparatus that produces a jet for penetrating the casing of a well of claim 11 wherein said first modular unit liner material and said second modular unit liner material are aligned.

Claim 13. The apparatus that produces a jet for penetrating the casing of a well of claim 11 wherein said first modular unit multiphase blast explosive is a mixture of conventional explosive and inert particles.

Claim 14. The apparatus that produces a jet for penetrating the casing of a well of claim 11 further comprising at least one additional modular unit.

Claim 15. A torpedo apparatus that includes a warhead that produces a jet for penetrating a vessel, comprising:

an explosive unit in the warhead,

a detonator base unit in said explosive unit, said detonator base unit including a conventional explosive;

a first modular unit in said explosive unit including a first modular unit liner material and a first modular unit multiphase blast explosive surrounding said first modular liner material;

and

a second modular unit in said explosive unit including a second modular unit liner material and a second modular unit multiphase blast explosive surrounding said second modular liner material; wherein, said detonator base unit, said first modular unit, and said second modular unit are assembled to produce the explosive jet for penetrating the vessel.

Claim 16. The torpedo apparatus of claim 15 further comprising at least one additional modular unit.

Claim 17. The torpedo apparatus of claim 16 wherein said first modular unit liner material, said second modular unit liner material, and said additional modular unit liner material are aligned.

Claim 18. An apparatus that includes a shell that produces a jet for penetrating armor, comprising:

an explosive unit in the shell,

a detonator base unit in said explosive unit, said detonator base unit including a conventional explosive;

a first modular unit in said explosive unit including a first modular unit liner material and a first modular unit multiphase blast explosive surrounding said first modular liner material;

and

a second modular unit in said explosive unit including a second modular unit liner material and a second modular unit multiphase blast explosive surrounding said second modular liner material; wherein, said detonator base unit, said first modular unit, and said second modular unit are assembled to produce the explosive jet for penetrating the armor.

Claim 19. The apparatus that includes a shell that produces a jet for penetrating armor of claim 18 further comprising at least one additional modular unit.

Claim 20. The apparatus that includes a shell that produces a jet for penetrating armor of claim 19 wherein said first modular unit liner material and said second modular unit liner material and said additional modular unit liner material are aligned.

Claim 21. A method of making a shaped charge that produces a jet, comprising the steps of:

providing a detonator base unit, a detonator base unit, said detonator base unit including a conventional explosive;

providing a first modular unit including a first modular unit liner material and a first modular unit multiphase blast explosive surrounding said first modular liner material; and

providing a second modular unit including a second modular unit liner material and a second modular unit multiphase blast explosive surrounding said second modular liner material; wherein, said detonator base unit, said first modular unit, and said second modular unit are assembled to produce the explosive jet.

Claim 22. The method of making a shaped charge that produces a jet of claim 21 wherein said first modular unit multiphase blast explosive is a mixture of conventional explosive and inert particles.

Claim 23. The method of making a shaped charge that produces a jet of claim 21 wherein said second modular unit multiphase blast explosive is a mixture of conventional explosive and inert particles.

Claim 24. The method of making a shaped charge that produces a jet of claim 21 further comprising at least one additional modular unit.

Claim 25. The method of making a shaped charge that produces a jet of claim 24 wherein said first modular unit liner material, said second modular unit liner material, and said additional modular unit liner material are aligned.

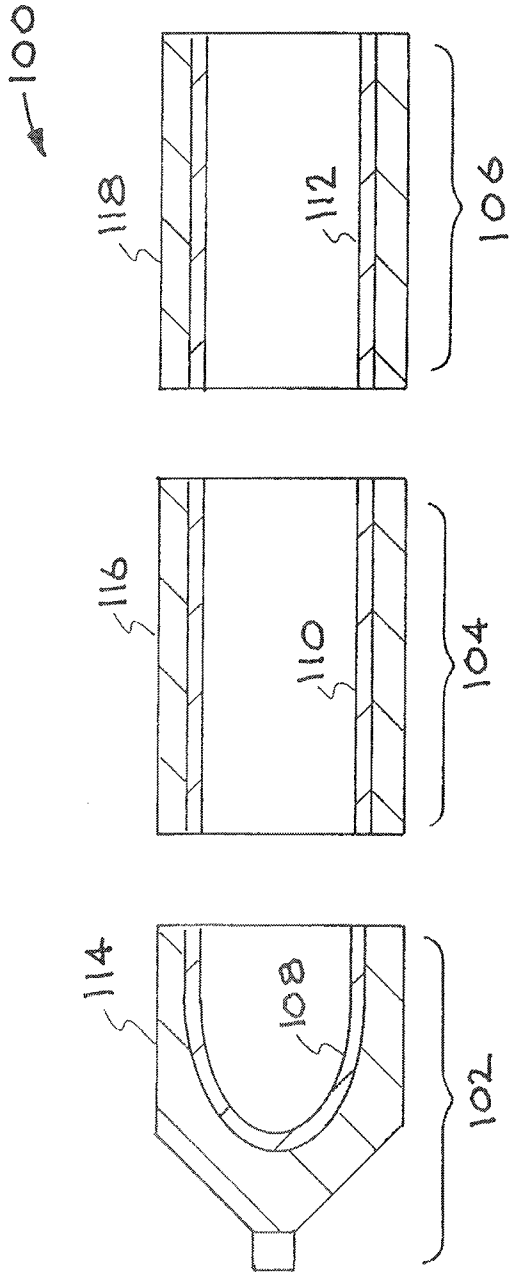


FIG. 1

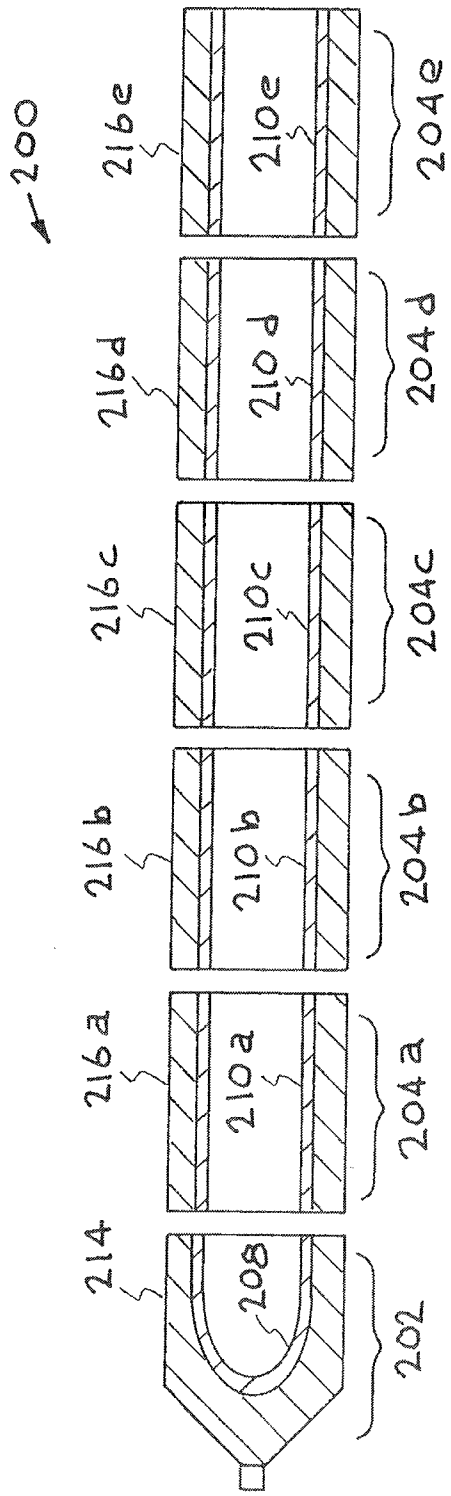

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204e
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202

FIG. 2

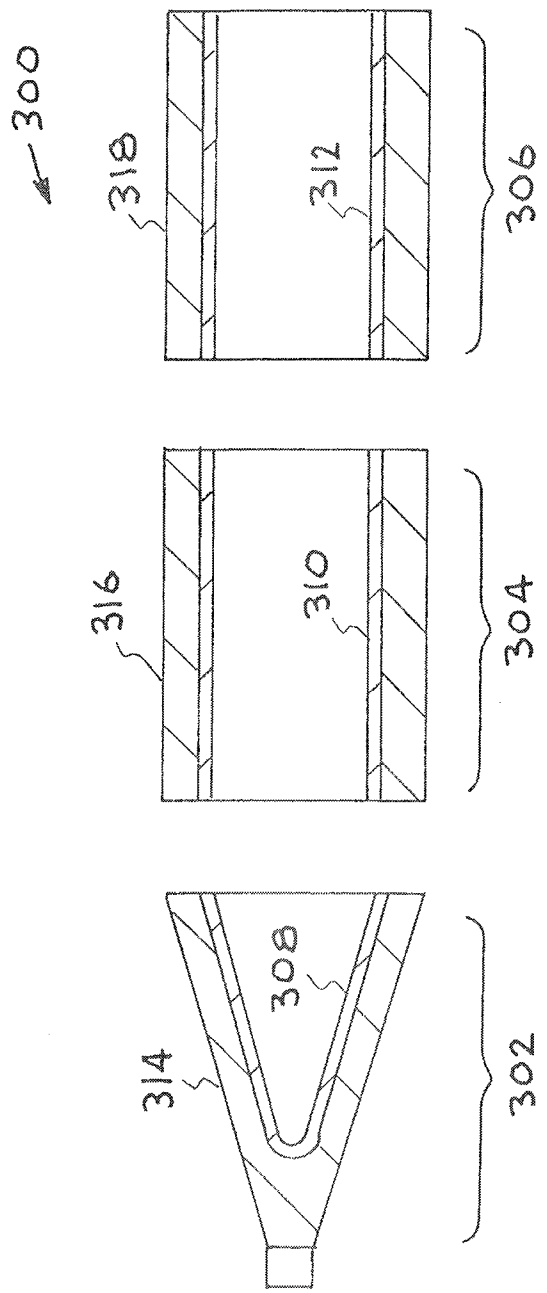


FIG. 3

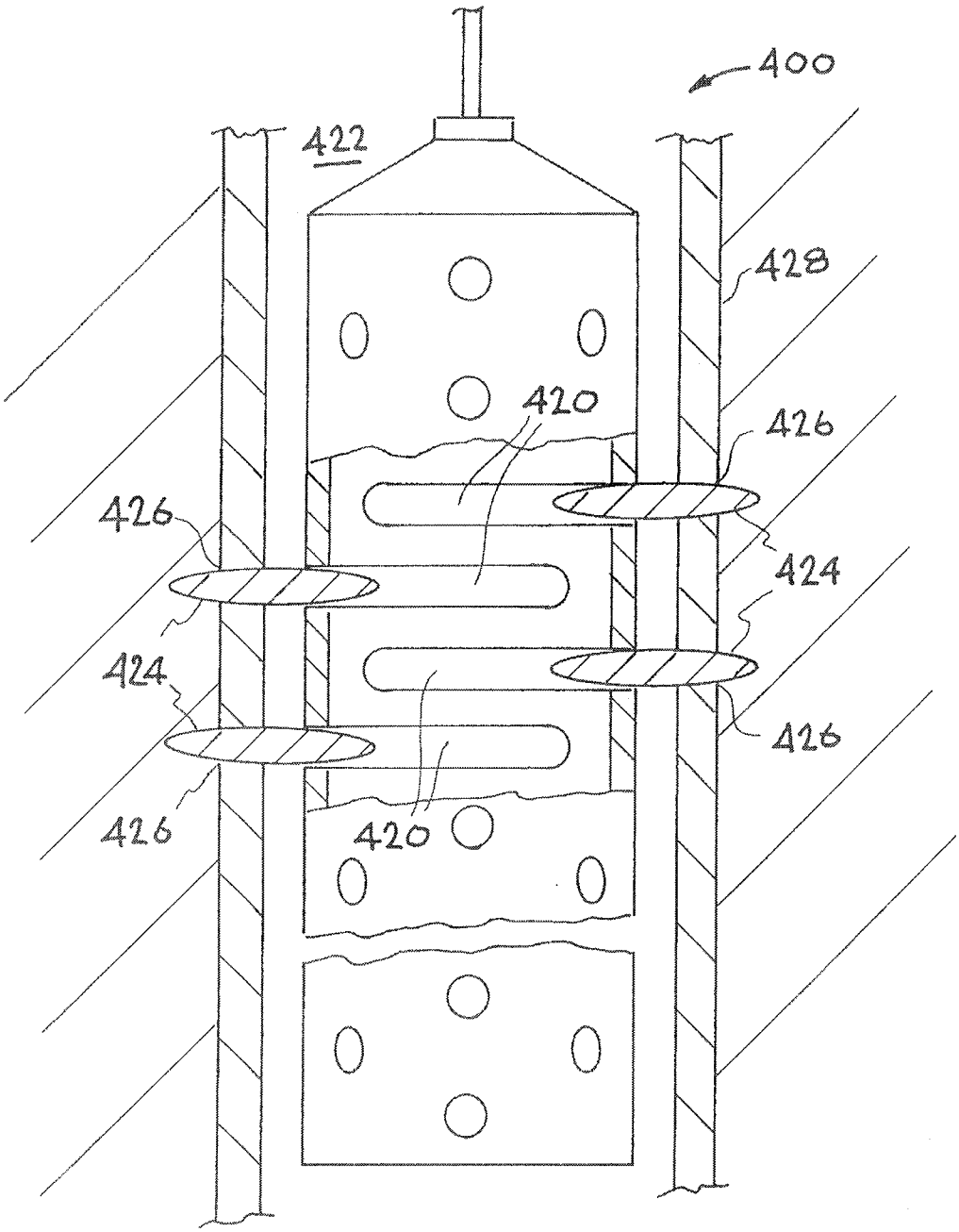


FIG. 4A

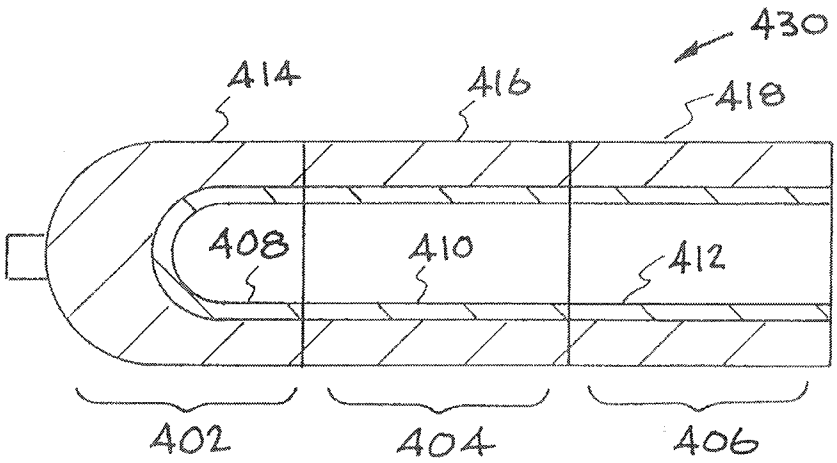


FIG. 4B

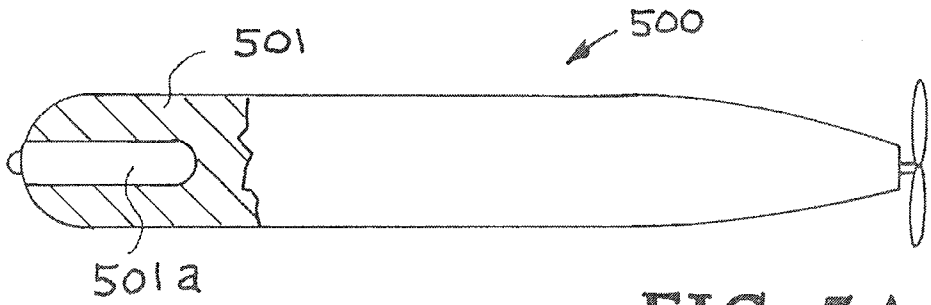


FIG. 5A

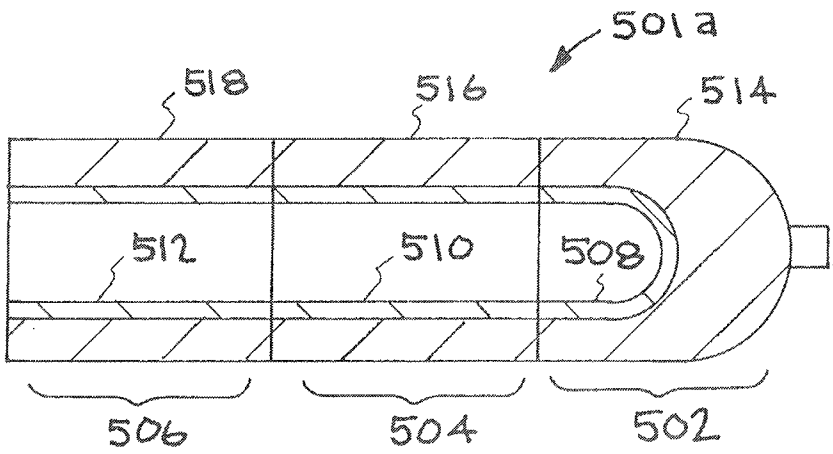


FIG. 5B

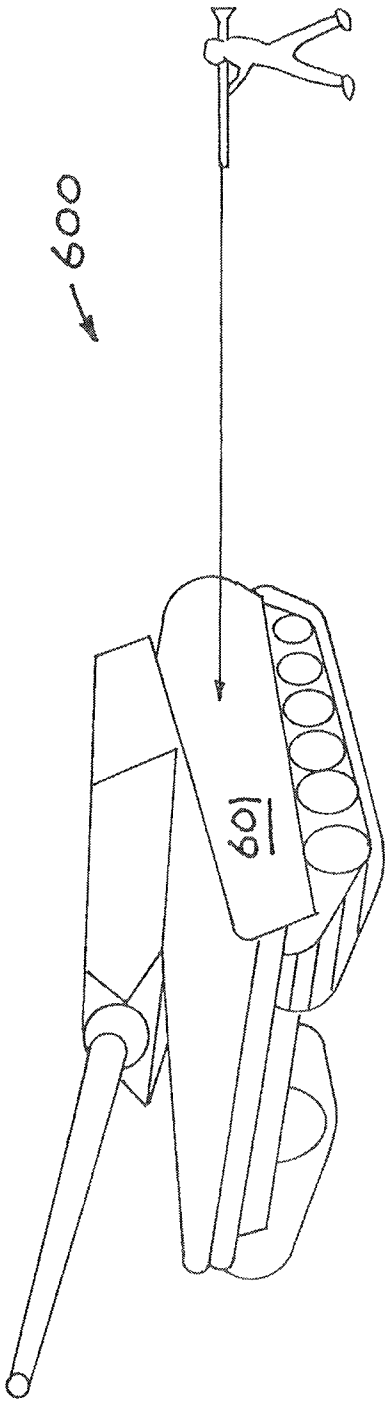


FIG. 6A

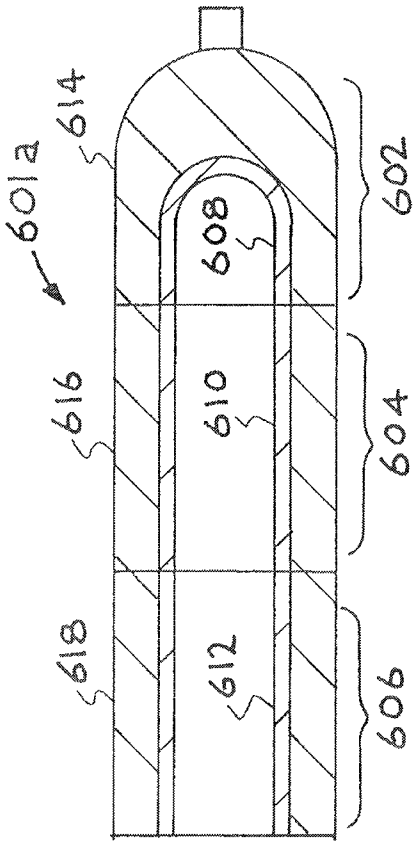


FIG. 6B

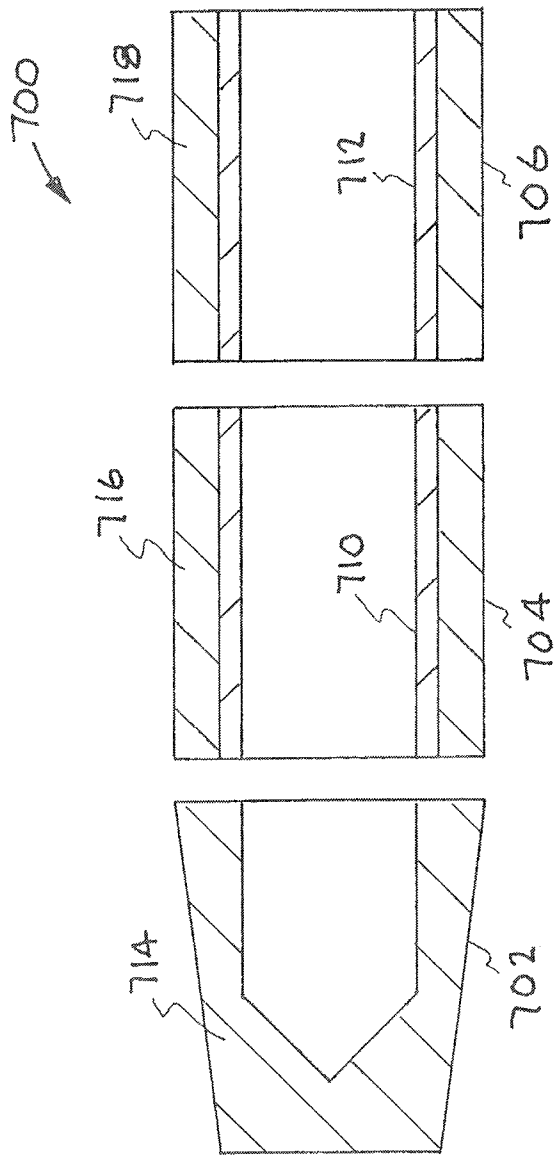


FIG. 7