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(54) DETONATING CORD RETAINING DEVICE

(57) An apparatus and method for connecting a detonating cord (32) with a shaped charge (12).

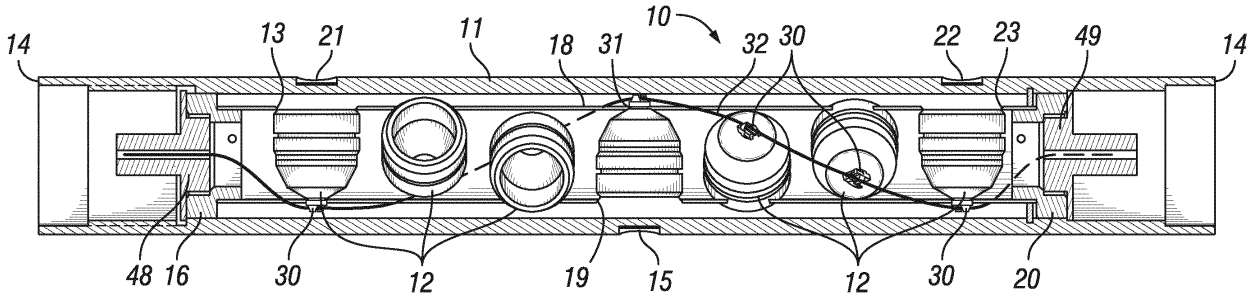

FIG. 1

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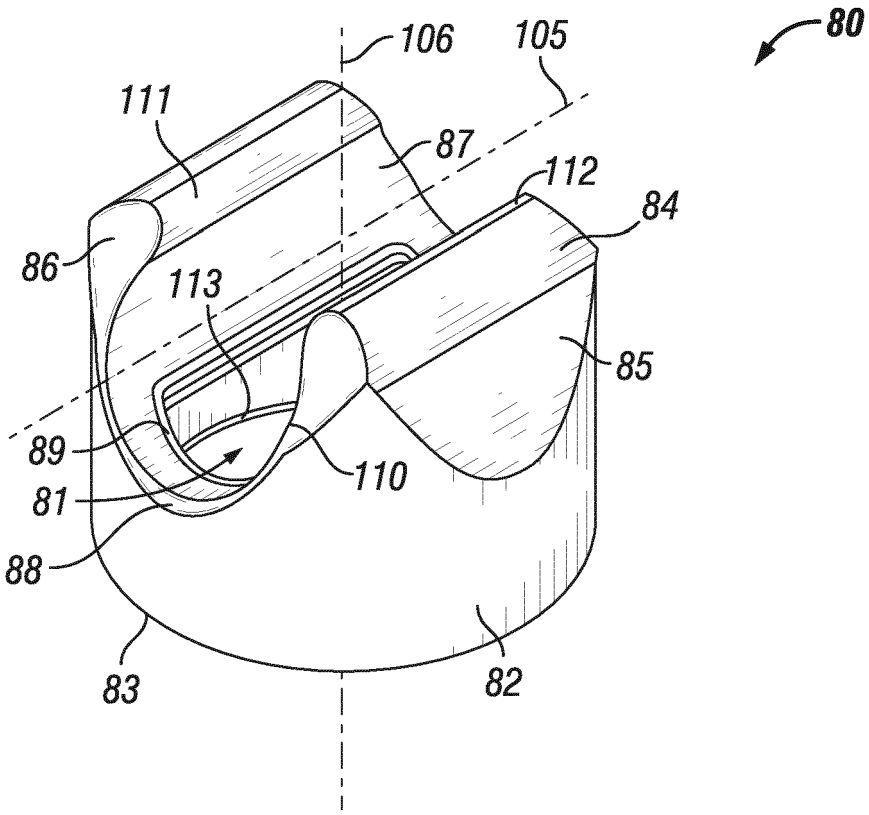

FIG. 7

Description

Related Applications

[0001] This application claims priority to U.S. Provisional Application No. 62/147,340, filed April 14, 2015.

Field

[0002] This disclosure generally relates to perforating guns used in a subterranean environment such as an oil or gas well. More particularly, it relates to fittings and retainers that aligns the detonating cord with a shaped charge installed in a charge tube. The embodiments disclosed have a retainer feature which allows for simplified installation with existing shaped charges and detonating cord.

Background

[0003] Generally, when completing a subterranean well for the production of fluids, minerals, or gases from underground reservoirs, several types of tubulars are placed downhole as part of the drilling, exploration, and completions process. These tubulars can include casing, tubing, pipes, liners, and devices conveyed downhole by tubulars of various types. Each well is unique, so combinations of different tubulars may be lowered into a well for a multitude of purposes.

[0004] A subsurface or subterranean well transits one or more formations. The formation is a body of rock or strata that contains one or more compositions. The formation is treated as a continuous body. Within the formation hydrocarbon deposits may exist. Typically a wellbore will be drilled from a surface location, placing a hole into a formation of interest. Completion equipment will be put into place, including casing, tubing, and other downhole equipment as needed. Perforating the casing and the formation with a perforating gun is a well known method in the art for accessing hydrocarbon deposits within a formation from a wellbore.

[0005] Explosively perforating the formation using a shaped charge is a widely known method for completing an oil well. A shaped charge is a term of art for a device that when detonated generates a focused explosive output. This is achieved in part by the geometry of the explosive in conjunction with an adjacent liner. Generally, a shaped charge includes a metal case that contains an explosive material with a concave shape, which has a thin metal liner on the inner surface. Many materials are used for the liner; some of the more common metals include brass, copper, tungsten, and lead. When the explosive detonates the liner metal is compressed into a super-heated, super pressurized jet that can penetrate metal, concrete, and rock.

[0006] A perforating gun has a gun body. The gun body typically is composed of metal and is cylindrical in shape. Within a typical gun tube is a charge holder or carrier tube, which is a tube that is designed to hold the actual shaped charges. The charge holder will contain cutouts called charge holes where the shaped charges will be placed.

[0007] A shaped charge is typically detonated by a booster or igniter. Shaped charges may be detonated by electrical igniters, pressure activated igniters, or detonating cord. One way to ignite several shaped charges is to connect a common detonating cord that is placed proximate to the igniter of each shaped charge. The detonating cord is comprised of material that explodes upon ignition. The energy of the exploding detonating cord can ignite shaped charges that are properly placed proximate to the detonating cord. Often a series of shaped charges may be daisy chained together using detonating cord.

Summary of Example Embodiments

[0008] In order to detonate a shaped charge in a perforating gun a continuous detonating cord is placed adjacent to each shaped charge. Holding a detonating cord in place is crucial to ensuring that all of the shaped charges detonate when the detonating cord detonates. Otherwise, unexploded ordinance may end up being brought to the surface, causing a serious safety issue. Furthermore, current means of fastening the shaped charge to the detonating cord require multiple cumbersome means.

[0009] An example embodiment may include a shaped charge retainer having an adaptor for holding a shaped charge, a first interface adapted to engage a charge holder, and a second interface adapted to engage a detonating cord. It may include a third interface adapted to engage a shaped charge. The first interface may have an oblong shape for translating into a matching oblong shaped cutout in the charge holder in a first orientation. The rotation of the shaped charge to a second orientation may substantially eliminate at least one degree of freedom of the shaped charge retainer. The shaped charge retainer may prevent disengaging via the inference of the first interface. The second interface may be a clamp for engaging to a detonating cord by rotating it relative to the detonating cord. The second interface may include a plurality of clamps. The second interface may be a u-shaped retainer. The second interface may be a c-shaped retainer. The second interface may include one or more protrusions adapted to restrain a detonating cord. The first interface may have an oblong shape. The first interface may have a non-circular shape. The first interface may be circular in shape. The first interface may be oblong in shape. The first interface may be polygon in shape. The first interface may be threaded. The first interface may be integrally formed to the charge holder. The third interface may be adapted to snap onto the end of a shaped charge. The third interface may be adapted to thread onto the end of a shaped charge. The third interface may be adapted to mechanically fasten to a shaped charge.

[0010] Another example embodiment is a detonating

cord retainer having a bottom portion adapted to interface with the bottom of shaped charge. Generally the shaped charge end will have a lip or other relevant feature that can be secured to. The bottom portion of the retainer will have a corresponding flange or other snapping mechanism that can fit over the lip of the shaped charge. Once the retainer is attached to the shaped charge, the shaped charge can be installed in a charge tube. The charge tube is a device adapted to contain the shaped charges in a perforating gun. The charge tube will generally have a large hole for fitting the shaped charge through and a smaller hole, radially opposite the large hole, for the retainer to fit through. The retainer in this example can have a unique shape that will match with a similar unique shaped cutout in the charge tube. After the retainer is fitted through the unique shaped hole, it can be rotated, in this case 45 degrees, such that the retainer is in interference with the charge tube and cannot be disengaged. Further, there can be locking features on the retainer that engage additional cutouts on the charge tube to prevent the retainer from rotating once locked.

[0011] The first part is the installation of the retainer onto the shaped charge and then installing the combination into a charge tube. The second portion of the device disclosed is a detonating cord restraining mechanism located on the top of the retainer. In this example, the restraining mechanism includes two arches shaped to allow detonating cord to fall into place when the retainer is in the unlocked position. When the retainer is rotated as described above to lock into the charge tube, the orientation of the two arches changes with respect to the detonating cord such that the detonating cord is locked into place in the retainer.

[0012] A variation of the examples disclosed may include a charge tube having a charge hole cutout adapted to fit a shaped charge within the charge tube, a shaped charge retaining cutout, and a first locking cutout. The first locking cutout is located adjacent to the shaped charge retaining cutout.

[0013] Examples may also have the shaped charge retaining cutouts adapted to fit a shaped charge retaining fitting. The shaped charge retaining cutout may be located 180 degrees opposite of the charge hole cutout. Examples may include a plurality of charge hole cutouts in a variety of orientations with respect to each other, sometimes referred to as phase angle. A plurality of shaped charge retaining cutouts would go along with a plurality of charge hole cutouts. The retaining cutouts would include one or more locking cutouts located nearby each retaining cutout. The shaped charge retaining cutouts may have an irregular shape such that only one orientation of a retaining fitting would fit through the retaining cutout. One possible shape for the retaining cutout is an irregular hexagonal shape. The locking cutouts may have circular, rectangular, or irregular shapes. Some embodiments would include at least two locking cutouts for each retaining cutout, located on two different sides of each retaining cutout. The first locking cutout and the shaped charge retaining cutout are oriented such that a shaped charge retainer rotates in order to lock into place.

[0014] Another example embodiment includes a shaped charge retainer having a base portion with an opening adapted to attach to a shaped charge, a body portion adapted to accept a detonating cord, and a detonating cord retainer portion. The base portion has a flange adapted to engage a shaped charge. The base portion has a cutout adapted to allow the base portion to snap onto a shaped charge. The body portion may further comprise a first rectangular portion and a second rectangular portion substantially parallel to the first rectangular portion. The first rectangular portion may be longer than the second rectangular portion. The detonating cord retainer portion further may include a first detonating cord retainer. The detonating cord retainer portion may include a second detonating cord retainer. The first rectangular portion may include a fillet. The second rectangular portion may contain a fillet. The first detonating cord retainer may contain an arch. The second detonating cord retainer may contain an arch. The first detonating cord retainer and the second detonating cord retainer may be are adapted to accept a detonating cord at a first angle with respect to an axis formed by the substantially parallel first rectangular portion and the second rectangular portion. The apparatus may be adapted to substantially restrain the detonating cord when rotated a second angle.

[0015] Another example embodiment may include a method for securing a detonating cord to a shaped charge having installing a retainer fitting onto the end of a shaped charge, installing the shaped charge into a charge tube, installing a detonating cord onto the retainer fitting, and rotating the retainer fitting a predetermined number of degrees. The method may include locking the retainer fitting onto the charge tube. The retainer fitting may be rotated approximately 45 degrees. The retainer fitting may be snapped onto place on the shaped charge. The shaped charge may be locked into place on the charge tube.

[0016] Another example embodiment may include a perforating gun having a charge tube, a plurality of shaped charges, in which each shaped charge has a retainer fitting, the shaped charge retainer fitting further having a base portion with an opening adapted to attach to a shaped charge, a first rectangular portion and a second rectangular portion, in which the first rectangular portion is substantially parallel to the second rectangular portion, a first detonating cord retainer and a second detonating cord retainer, and a locking mechanism. The base portion may have a flange adapted to engage a shaped charge. The base portion may have a cutout adapted to allow the base portion to snap onto a shaped charge. The first rectangular portion could be longer than the second rectangular portion. The first rectangular portion may contain a fillet. The second rectangular portion may contain a fillet. The first detonating cord retainer may contain an arch. The second detonating cord retainer may contain an arch. The first detonating cord retainer and the

second detonating cord retainer may be adapted to accept a detonating cord at a first angle with respect to an axis formed by the substantially parallel first rectangular portion and the second rectangular portion. The apparatus may be adapted to substantially restrain the detonating cord when rotated a second angle.

[0017] Another example embodiment may include a perforating gun system having a means for containing a plurality of shaped charges, a charge tube, a means for locating a detonating cord proximate to a shaped charge, and a rotational means for securing the detonating cord to the shaped charge. The means for containing a plurality of shaped charges may include a charge tube. The means for locating a detonating cord proximate to a shaped charge may include a retainer fitting. The rotational means for securing the detonating cord to the shaped charge may comprise a base portion with an opening adapted to attach to a shaped charge, a body portion adapted to accept a detonating cord, and a detonating cord retainer portion.

[0018] The embodiment disclosed above may be further modified such that the base portion may have a flange adapted to engage a shaped charge. The base portion may have a cutout adapted to allow the base portion to snap onto a shaped charge. The body portion may further comprise a first rectangular portion and a second rectangular portion substantially parallel to the first rectangular portion. The first rectangular portion may be longer than the second rectangular portion. The detonating cord retainer portion may further comprise a first detonating cord retainer. The detonating cord retainer portion may further comprise a second detonating cord retainer. The first rectangular portion may contain a fillet. The second rectangular portion may contain a fillet. The first detonating cord retainer may contain an arch. The second detonating cord retainer may contain an arch. The first detonating cord retainer and the second detonating cord retainer may be adapted to accept a detonating cord at a first angle with respect to an axis formed by the substantially parallel first rectangular portion and the second rectangular portion. The apparatus may be adapted to substantially restrain the detonating cord when rotated a second angle.

[0019] An example embodiment may include an apparatus for use in a perforating gun having a charge tube having a first end, a second end, an internal cavity, and a center axis. The charge tube has at least one charge cutout. The circular cutout has an axis that is perpendicular to the axis of the charge tube. A retainer cutout corresponds to each substantially circular cutout. The retainer cutout is located one hundred eighty degrees on the charge tube from the charge cutout. At least one adjacent locking cutout corresponds each retainer cutout. The embodiment may include a second adjacent cutout for each retainer cutout. Further, the at least charge cutout is may be a plurality of charge cutouts located along the length of the charge tube. Each retainer cutout may have a shape adapted to only fit a retainer in a predetermined orientation. The charge tube may be adapted to fit a shaped charge device with a retainer fitting for each charge cutout and corresponding retainer cutout.

[0020] Another example embodiment may include a shaped charge retainer having a base portion with an opening adapted to attach to a shaped charge, a body portion with a detonating cord cutout adapted to hold a detonating cord, and a first retainer portion attached to the body portion adapted to retain the detonating cord inside the detonating cord cutout. The embodiment may include the base portion having an adaptor configured to snap onto the end of a shaped charge. The embodiment may include the base portion having a cutout adapted to allow the base portion to flex. The body portion may further comprise a second retainer portion adapted to retain the denotation cord inside the detonating cord cutout. The first retainer portion, the second retainer portion, and the detonating cord cutout may combine to form a u-shaped detonating cord retainer. The first retainer portion and the second retainer portion may both be integral with the body portion. The first retainer portion may contain an arch. The second retainer portion may contain an arch. The base portion may include a thru slot. The embodiment may be adapted to substantially restrain a detonating cord from sideways movement.

[0021] Another example embodiment may include a shaped charge detonating cord retention system having a charge tube with a first axis and at least one charge hole having a second axis perpendicular to the first axis and at least one shaped charge retaining cutout coaxial with the second axis. The shaped charge retaining cutout is adapted to fit a detonating cord retainer in any angular orientation relative to the second axis.

[0022] Variations of the example embodiment may include it having a plurality of charge hole cutouts and a corresponding plurality of shaped charge retaining cutouts. Each charge hole cutout and corresponding shaped charge retaining cutout may have a corresponding common axis perpendicular to the first axis. Each corresponding common axis may be parallel to each other or have a phase angle relative to the next adjacent common axis. The detonating cord retainer may be adapted to interface with the apex end of a shaped charge case.

[0023] The detonating cord retainer may have a base having a bottom end and a top end. A bore extends into the base from the bottom end. An aperture in the top end of the base is adapted to allow detonation communication from the top end of the base into the bore. It also may have a first retention arm having an inner face extending substantially orthogonally from the top side of the base. It may have a second retention arm having an inner face extending substantially orthogonally from the top side of the base. The inner face of the first retention arm is substantially parallel to and facing the inner face of the second retention arm. The inner face of the first retention arm has a retention nub distal from the base extending toward the second retention arm. The first retention arm and second retention arm are adapted to retain a deto-

nating cord in proximity to the aperture. The inner face of the second retention arm has a retention nub distal from the base extending toward the first retention arm. The example may have a circumferential ridge in the bore adapted to engage a corresponding groove in a shaped charge case. In the alternative, it may have a circumferential groove in the bore adapted to engage a corresponding ridge in a shaped charge case. The aperture may extend from the top end of the body to the bore. The bore may extend through a portion of the top end of the body to form the aperture.

[0024] Another example embodiment includes a detonating cord retainer having a first portion with a thru-hole having a first axis, a second portion located above the first portion, a truncated cone located above and coaxially aligned with the first portion and the second portion. It may further have a thru channel with a second axis perpendicular to the first axis. The first portion may be a cylindrical shape located coaxial with the first axis. The second portion may be a cylindrical shape located coaxial with the first axis. The retainer may be composed of plastic. The first cylindrical portion may be adapted to snap over an apex end of a shaped charge case. The first cylindrical portion may be composed of two cylindrical halves. The truncated cone portion may have a u-shaped interface adapted to snap around a detonating cord. The shaped charge retainer may be adapted to rotate in 360 degrees about the apex end of the shaped charge case. The second portion may have a thru-slot along a first plane perpendicular to the first axis.

[0025] Another example embodiment includes a shaped charge retention system having a shaped charge case with an apex end and an explosive discharge end. It further has a charge tube with a center axis. A first plurality of circular cutouts in the charge tube are adapted for interfacing with a shaped charge case apex end. A second plurality of circular cutouts in the charge tube are located 180 degrees opposite of the first plurality of cutouts about the charge tube axis. The embodiment includes a detonating cord. A substantially cylindrical retainer with a channel adapted to accept a detonating cord is included. The shaped charge case is located within the charge tube such that the apex end is coupled to a first circular cutout with the cylindrical retainer and the explosive discharge end is located adjacent to a second circular cutout.

[0026] A variation of the example may include the cylindrical retainer being composed of plastic. The cylindrical retainer may pivot about the shaped charge apex in 360 degrees. The cylindrical retainer may further be coupled to the detonating cord. A plurality of shaped charges may be included. A plurality of cylindrical retainers may be included. The channel may have a u-shaped cutout.

[0027] Another example embodiment includes a shaped charge retainer having a first portion, a first end having a truncated cone shape, a bottom end, with a slotted thru-hole passing through the first portion from the first end to the second end. It further includes a counter-bore in the bottom end having an axis. It further includes a second portion located above the first portion. A truncated cone is located above the first portion. The truncated cone has a channel with a second axis perpendicular to the first axis. The retainer may be composed of plastic. The first portion may be adapted to snap over an apex end of a shaped charge case. The channel of the truncated cone portion may be a u-shaped interface adapted to snap around a detonating cord. The shaped charge retainer may be adapted to rotate in 360 degrees about the apex end of the shaped charge case. The bottom end may be circular, the first portion may be cylindrical, or the second portion may be cylindrical. The first portion, second portion, and truncated cone are coaxial. The first cylindrical portion may be composed of two cylindrical halves. The second portion may have a thru-slot along a first plane perpendicular to the axis.

[0028] The example may further include a shaped charge with a case, the case having an explosive end and an apex end adapted to interface with the shaped charge retainer. The apex end is located within the counter bore in the bottom end. The shaped charge case may be connected to the shaped charge retainer via the apex and counter bore interface. It may include a shoulder located on the bottom end. A charge tube may be captured between the shoulder and a shaped charge case.

Description of the Drawings:

[0029] For a thorough understanding of the present disclosure, reference is made to the following detailed description of the preferred embodiments, taken in conjunction with the accompanying drawings in which reference numbers designate like or similar elements throughout the several figures of the drawing. Briefly:

FIG. 1 is a side cross sectioned view of a perforating gun.

FIG. 2 is a side cross sectioned view of a shaped charge that may be used in a perforating gun with a retainer fitting attached.

FIG. 3A is a detailed view of a retainer fitting.

FIG. 3B is a top view of a retainer fitting with a detonating cord in the unlocked position.

FIG. 3C is a top view of a retainer fitting with a detonating cord in the locked position.

FIG. 3D is a side view of a retainer fitting.

FIG. 3E is a bottom view of a retainer fitting.

FIG. 4 is a side view of a charge tube adapted for use with an example embodiment.

FIG. 5A is a perspective view of a detonating cord retainer.

FIG. 5B is a cross-section view of a detonating cord retainer.

FIG. 6 is a cross-section side view of a detonating cord retainer attached to a shaped charge case.

FIG. 7 is a perspective view of a detonating cord retainer.

FIG. 8 is a side view of a charge tube adapted for use with an example embodiment.

Detailed Description of Examples of the Embodiments:

[0030] In the following description, certain terms have been used for brevity, clarity, and examples. No unnecessary limitations are to be implied therefrom and such terms are used for descriptive purposes only and are intended to be broadly construed. The different apparatus, systems and method steps described herein may be used alone or in combination with other apparatus, systems and method steps. It is to be expected that various equivalents, alternatives, and modifications are possible within the scope of the appended claims.

[0031] Referring to an example shown in FIG. 1, a typical perforating gun 10 comprises a gun body 11 that houses the shaped charges 12. The gun body 11 contains end fittings 16 and 20 which secure the charge holder 18 into place. The charge holder 18 in this example is a charge tube and has charge holes 13, 19, and 23 that are openings where shaped charges 12 may be placed. The charge holder 18 has retainer cutouts 31 that are adapted to fit a retainer fitting 30 in a predetermined orientation. Scallops 15, 21, and 22 provide a flat surface on the gun body 11 for the explosive charge to penetrate through. The gun body 11 has threaded ends 14 that allow it to be connected to a series of perforating guns 10 or to other downhole equipment depending on the job requirements. In this example, the retainer fitting 30 is separate from the charge holder 18, however in another variation of the embodiment, the retainer fitting 30 may be integral to the charge holder 18. Each shaped charge 12 has an associated retainer fitting 30 that secures each shaped charge 12 to the charge holder 18 and the detonating cord 32. The detonating cord 32 runs the majority of the length of the gun body 11 beginning at end cap 48 and ending at end cap 49. The detonating cord 32 wraps around the charge holder 18 as shown to accommodate the different orientations of the shaped charges 12. In this embodiment, the shaped charges 12 have an orientation that is rotated 60 degrees about the center axis of the gun body 11 from one shaped charge to the next. Other orientations may have zero angle, where all of the shaped charges 12 are lined up. Other orientations may have different angles between each shaped charge 12. This example using a 60 degree phase is illustrative and not intended to be limiting in this regard.

[0032] Referring to an example shown in FIG. 2, the shaped charges 12 includes a shaped charge case 28 that holds the energetic material 26 and the liner 27. The shaped charge case 28 typically is composed of a high strength metal, such as alloy steel. The liner 27 is usually composed of a powdered metal that is either pressed or stamped into place. The metals used in liner 27 may include brass, copper, tungsten, and lead. The retainer fitting 30 is secured to the apex end 46 of the shaped charge case 28 by snapping into place over a flange on apex end 46. The entire assembly 40 includes shaped charge 12 combined with retainer fitting 30. Alternatively, the retainer fitting 30 could be threaded onto the shaped charge case 28, secured with adhesive, snapped around the full length of the charge case, or formed integrally with the charge case. The fitting 30 could also be secured to the charge case 18 using set screws, roll pins, or any other mechanical attachment mechanisms. Alternatively, shaped charge case 28 could be integrally formed to retainer fitting 30. This would result in a single component, thus reducing cost and complexity.

[0033] Referring to an example shown in FIG. 3A, this is a detail drawing of the retainer fitting 30. The retainer fitting has a first detonating cord retainer 33 and a second detonating cord retainer 34. The retainer fitting 30 has a circular opening 35. The retainer fitting 30 has two rectangular base portions 36 and 37. Base portion 36 is longer than base portion 37. Base portion 36 is parallel to base portion 37.

[0034] The adaptor 39 has a base slot 44, in this example it is perpendicular to the rectangular base portions 36 and 37. The base slot 44 allows some flexibility in the adaptor 39. In this example the adaptor 39 is composed of a plastic material that may deform without yielding. The base slot 44 aids in helping the adaptor 39 yield. This added flexibility allows the adaptor 39 to snap over the apex end 46 of a shaped charge case 28 of FIG. 2.

[0035] In FIG. 3B the retainer fitting 30 has detonating cord retainers 33 and 34. Retainer 34 has an edge 42 that is angled 45 degrees with respect to the parallel axis of rectangular base portions 36 and 37. Retainer 33 has an edge 43 that is also angled 45 degrees with respect to the parallel axis of rectangular base portions 36 and 37. Edge 42 and edge 43 are parallel to each other, forming slot 40. Slot 40 is wide enough to fit detonating cord 51 as depicted in Fig. 3B. Each of the rectangular base portions 36 and 37 contain fillets 38 that are adapted to accommodate the radius of a detonating cord 51.

[0036] In at least one example, detonating cord retainers 33 and 34 are shaped as arches as viewed from the side in FIG. 3D. The adaptor 39 has an internal flange 47 designed to assist in attaching the retainer fitting 30 to the shaped charge case 28 apex end 46. The procedure for securing the detonating cord 51 is to first place it into slot 40 as shown in FIG 3B. Then, rotating the retainer fitting 30 45 degrees detonating cord retainers 33 and 34 force the detonating cord 51 against the fillets 38 as shown in FIG. 3C.

[0037] FIG. 3B shows the detonating cord 51 as it is initially placed in the retainer fitting 30. FIG. 3C depicts the detonating cord 51 as it sits in the retainer fitting 30 after the retainer fitting 30 has been rotated and locked into place on the charge holder 18. As seen in FIG. 3E the retainer fitting 30 has an adaptor 39 which allows for the retainer fitting 30 to snap into place on the apex end 46 of the shaped charge case 28 upon installation.

[0038] Referring to FIG. 4, the charge holder 18 has

the retainer cutout 31 and lock cutouts 54. Installation may include snapping a retainer fitting 30 on each shaped charge 12. The assembled shaped charge 12 with associated retainer fitting 30 is then placed through the charge hole 23 of the charge holder 18 until the retainer fitting 30 exits through the retainer cutout 31. The retainer fitting 30 has a lock block 45 shown in FIG. 3A. The charge holder 18 has a lock cutout 54 associated with each retainer cutout 31. The retainer fitting 30 can be rotated until slot 40 is aligned with the detonating cord 51 as shown in FIG. 3B. The detonating cord 51 is then placed into slot 40. Then the retainer fitting is rotated, or twisted, until the lock block 45 engages the lock cutout 54. Once twisted, the detonating cord 51 and retainer fitting 30 will look as depicted in FIG. 3C. As can be seen in FIG. 4, the retainer cutout 31 is shaped uniquely such that a retainer fitting 30 can only fit into the charge holder 18 in one specific angular orientation. Once the retainer fitting 30 is rotated to a second angular orientation it will interfere with the shape of the retainer cutout 31, preventing the retainer fitting 30 from being able to disengage unless it is rotated back to the original angular orientation.

[0039] The retainer fitting 30 has a lock block 45 that is adapted to fit into the lock cutout 54 on the charge holder 18 as shown in FIG. 4. The lock block 45 is engaged by twisting the retainer fitting until it reaches the desired orientation whereby the lock block 45 and lock cutout 54 are aligned. Engagement of the lock block 45 with lock cutout 54 will keep the retainer fitting 30 from rotating further. Alternatively, the lock block 45 may be eliminated or replaced by other mechanical or friction fit means, such as angling or texturing the undersides of the adaptor 39 as shown in FIG. 3A. Another alternative to the embodiments disclosed may include using the adaptor base 39 and combining it with the u-shaped upper portion 75 from the detonating cord retainer 50. The adaptor base may also have different oblong shapes, including oval shapes, triangular, or other polygons, to allow the adaptor base 39 to lock into the charge holder 18 when rotated.

[0040] As can be seen from the shape of the retainer cutout 31, it can only accommodate the retainer fitting 30 in a specific orientation. Once the retainer fitting 30 has cleared the retainer cutout 31, it will be oriented to lay the detonating cord 51 along slot 42, as shown in FIG. 3B. Then the shaped charge 12 and retainer fitting 30 assembly 40 is rotated, at least in this example, approximately 45 degrees. Rotating the assembly 40 causes the detonating cord 51 located with the slot 42 to be locked into place against the fillets 38 and the cord retainers 33 and 34, as shown in FIG. 3C. The arch design of retainers 33 and 34 force the detonating cord 51 against the fillets 38 upon alignment. Further, once rotated 45 degrees, the retainer fitting is locked into the charge holder 18 by the lock block 45 plugging into the lock cutout 54. The retainer fitting 30 can be composed of materials common in the industry, including metal and plastics. The retainer fitting 30 can be manufactured using injection molding techniques, casting, rapid prototyping, machining techniques, or other common manufacturing techniques known in the art.

[0041] Other alternatives to the embodiments disclosed include using a single base portion instead of the separate base portions 36 and 37. Alternatively, the base portion may have a different oblong shape such as an oval, triangle, or other polygon. Another alternative may have the retainers 33 and 34 contact and secure to one and the other through a fastening mechanism, allowing for a more secure connection between the retainer fitting and the detonation cord. Another variation may include using a circular base, with retainers that connect to one another, securing the detonation cord, and then using a circular adaptor such that the fitting could turn freely with respect to the charge case. This design would allow for optimal wiring of the detonation cord. Once the detonation cord is in its final orientation, a set screw, resilient tabs, or other retaining device could be used to secure the fitting to the case or to the shaped charge in order to prevent movement. In the embodiments disclosed above, two lock blocks 45 and two lock cutouts 54 are disclosed, however more or fewer of either item could be used to secure the retainer fitting to the charge tube. The fitting could be threaded onto the charge case, secured with adhesive, snapped around the full length of the charge case, or formed integrally with the charge case. The fitting could also be secured to the charge case using set screws, roll pins, or any other mechanical attachment mechanisms. Further, charge cases in the examples herein are shown as cylindrical devices with cutouts, however other configurations are possible for holding shaped charges in a perforating gun. For example, a charge strip can be used in which a long strip of metal containing holes for the retainer to engage with is used to hold a linear series of shaped charges in a perforating gun. Other examples may include cylinders with one a single cutout for the retainer and no cutout for the shaped charge. Another example may include a perforating gun that does not use a cylindrical charge holder to contain the shaped charges. Another example may include a charge holder that is integral to the perforating gun.

[0042] Another example embodiment is depicted in FIG. 5A and FIG. 5B. This detonating cord retainer 70 has a base 71 with a through hole 74, a middle portion 72 with a through slot 73, and a upper portion 75 that is shaped as a truncated conical with a u-shaped channel 76 that is sized to snap onto a detonating cord. The detonating cord retainer 70 has a first axis 102 aligning the base 71, middle portion 72, and upper portion 75. The u-shaped channel 76 also has an axis 101 that is perpendicular to the axis 102. The base 71 snaps onto the end of a shaped charge with the edge of the u-shaped channel 76 adapted to snap over a lip. The detonating cord retainer 70 can be secured to the shaped charge, but still rotate to its desired orientation in order to snap to a detonating cord. The u-shaped channel 76 is designed to securely snap onto a detonating cord and restrict the

movement of the detonating cord. In this embodiment the detonating cord could explode through the thin material 77 between the u-shaped channel 76 and the thru slot 73, whereby the explosion would travel down the thru hole 74 and into the back of a shaped charge.

[0043] The thru slot 73 is perpendicular to axis 102. A clip may be placed through the thru slot 73 and adapted to engage a retainer cutout 93 as shown in FIG. 8, thus securing the detonating cord retainer 70 to a charge tube 90. Furthermore, detonating cord retainer 70 has a base 71 that has a shoulder 121 capable of engaging the charge tube 90 in such a way as to restrain the movement of the shaped charge along the axis 108, but allowing rotation about the axis 108. In the alternative, a thru hole or thru aperture could be located at 77 to facilitate explosive communication between the detonating cord and the shaped charge.

[0044] An alternative to the u-shaped channel 76 is a c-shaped cutout in which the channel 76 is rotated 90 degrees such that the detonating cord is accepted from the side rather than the top as shown. The shoulder 78 allows the retainer 70 to snap onto the apex end 60 of a shaped charge, as shown in FIG. 6.

[0045] In FIG. 6 the shaped charge case 58 is attached to the detonating cord retainer 50. The shaped charge case 58 is machined with an apex end 60. The apex end 60 has a lip 59. The detonating cord retainer 50 snaps over the lip 59. Alternatively, the detonating cord retainer 50 could be threaded onto the shaped charge case 58, secured with adhesive, snapped around the full length of the shaped charge case 58, or formed integrally with the shaped charge case 58. The detonating cord retainer 50 could also be secured to the shaped charge case 58 using set screws, roll pins, or any other mechanical fasteners. The detonating cord 61 is snapped into the u-shaped cutout 56. In this example the detonating cord retainer 50 can freely rotate when attached to the shaped charge case 58, however a set screw or other fastening device could be used to prevent rotation if desired. When the detonating cord 61 detonates the explosion will puncture through the thin material 57 and enter thru hole 64 of the shaped charge case 58. The explosion will then interact with the explosive material 62 causing it to explode. The detonation of explosive material 62 will then transform liner 63 into a plasma jet capable of puncturing out of the perforating gun. The thin material 57 may be solid, it could also have a thru hole, perforations, a window or other aid that facilitates the explosion traveling from the detonating cord 61 to the explosive material 62. Furthermore, in this embodiment the u-shaped cutout 56 is depicted as having a gap between the two retaining ends 65, however the gap could be narrower such that the retaining ends 65 touch each other either before or after the detonating cord 61 is put into place. The detonating cord retainer 50 may be constructed of plastic using for instance an injection molding process or a rapid prototyping process. The detonating cord retainer 50 in this embodiment restricts the ability of the detonating cord 61 to move sideways, but it may allow the detonating cord 61 to move through the detonating cord retainer 50 and allows for rotation of the detonating cord 61 with respect to the shaped charge case 58.

[0046] Another example embodiment of a detonating cord retainer 80 is shown in FIG. 7. It is adapted to interface with the apex end of a shaped charge case. Detonating cord retainer 80 includes a base 82 having a bottom end 83 and a top end 88. A bore 81 extends into the base 82 from the bottom end 83. An aperture 89 in the top end 88 of the base 82 is adapted to allow detonation communication from the top end 88 of the base 82 into the bore 81. A first retention arm 86 having an inner face 87 extends substantially orthogonally from the top end 88 of the base 82. A second retention arm 84 has an inner face 110 extending substantially orthogonally from the top end 88 of the base 82. The inner face 87 of the first retention arm 86 is substantially parallel to and facing the inner face 110 of the second retention arm 84.

[0047] The inner face 87 of the first retention arm 86 has a retention nub 111 distal from the base extending toward the second retention arm 84. The first retention arm 86 and second retention arm 84 are adapted to retain a detonating cord in proximity to the aperture 89. The inner face 110 of the second retention arm 84 has a retention nub 112 distal from the base extending toward the first retention arm 86. A circumferential ridge 113 is located in the bore 81 adapted to engage a corresponding groove in a shaped charge case. The circumferential ridge 113 may also be a circumferential groove adapted to engage a corresponding ridge in a shaped charge case. The aperture 89 extends from the top end 88 of the body 82 to the bore 81. The bore 81 may extend through a portion of the top end 88 of the body 82 to form the aperture 89.

[0048] Another example embodiment may include a charge detonating cord retention system having a charge tube 90 as shown in FIG. 8 with a first axis 107. One or more charge holes 92, each having a second axis 108 perpendicular to the first axis 107, are located along the charge tube 90. Each charge hole 92 has a corresponding shaped charge retaining cutout 91 coaxial with the second axis 108. Each shaped charge retaining cutout 91 is adapted to fit a detonating cord retainer in any angular orientation relative to the second axis 108. Each second axis 108 may be parallel to each other or offset by a certain number of degrees about the first axis 107 called a phase angle. For example, in FIG. 8 the phase angle is 60 degrees.

[0049] Although the embodiments have been described in terms of particular examples which are set forth in detail, it should be understood that this is by illustration only and that the embodiments are not necessarily limited thereto. Alternative embodiments and operating techniques will become apparent to those of ordinary skill in the art in view of the present disclosure.

Claims

1. A detonating cord retainer (80) comprising:

   a base (82) having a bottom end (83) and a top end (88);
   a bore (81) extending into the base (82) from the bottom end (83);
   an aperture (89) in the top end (88) of the base (82) adapted to allow detonation communication from the top end (88) of the base (82) into the bore (81);
   a first retention arm (86) having an inner face (87) extending substantially orthogonally from the top side (88) of the base (82);
   a second retention arm (84) having an inner face (110) extending substantially orthogonally from the top side (88) of the base (82).

2. The detonating cord retainer (80) of claim 1, wherein the inner face (87) of the first retention arm (86) is substantially parallel to and facing the inner face (110) of the second retention arm (84).

3. The detonating cord retainer (80) of claim 1 or 2, wherein the inner face (87) of the first retention arm (86), in particular an end, which is distal from the base (82), of the inner face (87) of the first retention arm (86), has a retention nub (111) distal from the base (82) extending toward the second retention arm (84); and
   the first retention arm (86) and second retention arm (84) are adapted to retain a detonating cord in proximity to the aperture (89).

4. The detonating cord retainer (80) of claim 3, wherein the inner face (110) of the second retention arm (84), in particular an end, which is distal from the base (82), of the inner face (110) of the second retention arm (84), has a retention nub (112) distal from the base (82) extending toward the first retention arm (86).

5. The detonating cord retainer (80) of any one of claims 1 to 4, further comprising a circumferential ridge (113) in the bore (81) adapted to engage a corresponding groove in a shaped charge case.

6. The detonating cord retainer (80) of any one of claims 1 to 4, further comprising a circumferential groove in the bore adapted to engage a corresponding ridge in a shaped charge case.

7. The detonating cord retainer of any one of claims 1 to 6, wherein the aperture (89) extends from the top end (88) of the body (82) to the bore (81).

8. The detonating cord retainer of any one of claims 1 to 7, wherein the bore (81) extends through a portion of the top end (88) of the body (82) to form the aperture (89).

9. A shaped charge comprising:

   a case with an apex end and an explosive end and an axis;
   a substantially conical liner located within and coaxially with the case;
   an explosive material located between the liner and the case;
   a detonating cord retainer (80) according to any one of claims 1 to 8, said detonating cord retainer being adapted to interface with the apex end of the case.

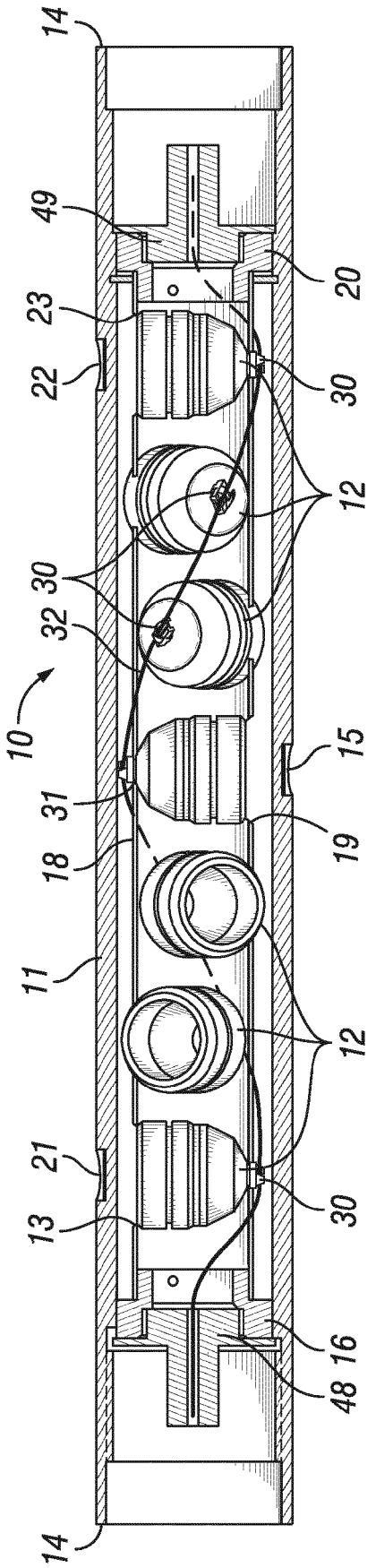
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FIG. 1

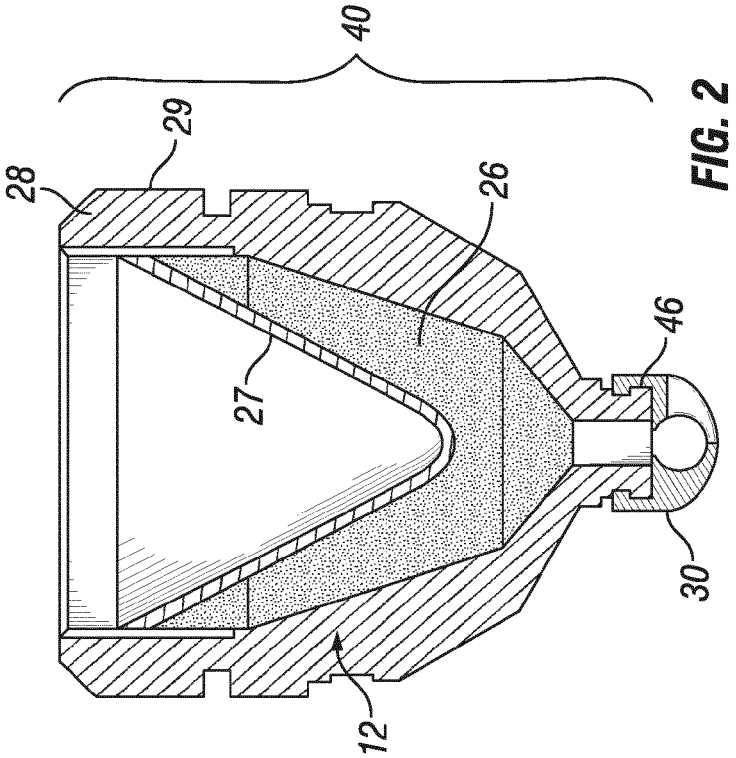
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FIG. 2

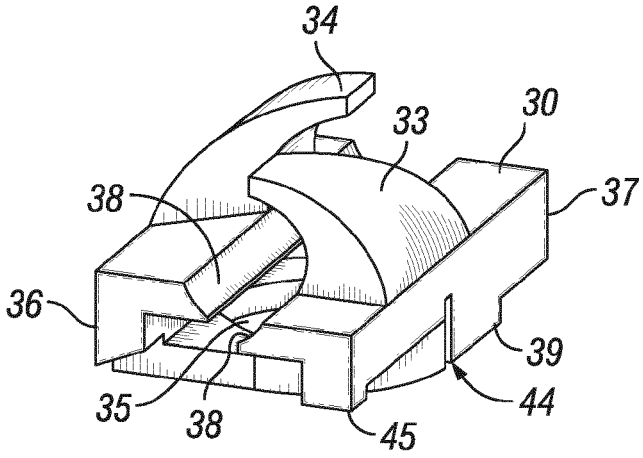

FIG. 3A

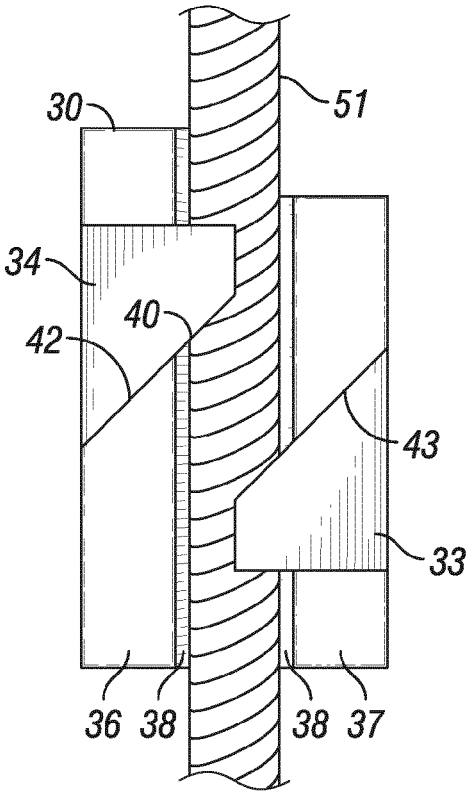

FIG. 3C

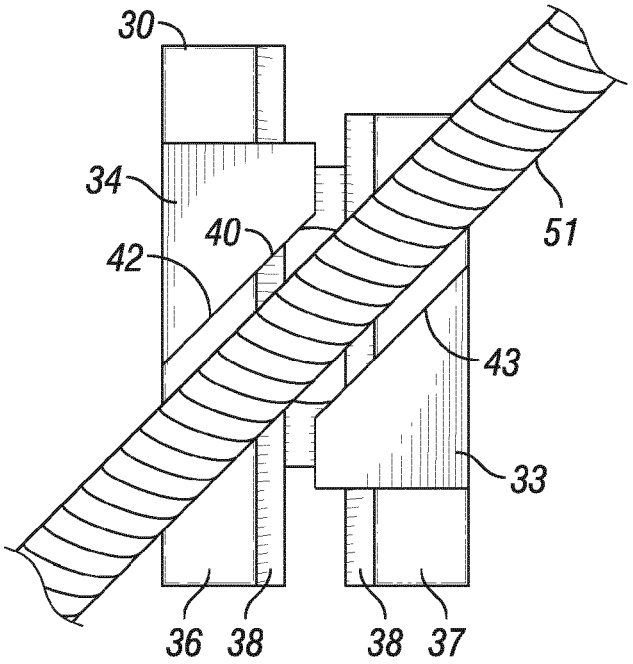

FIG. 3B

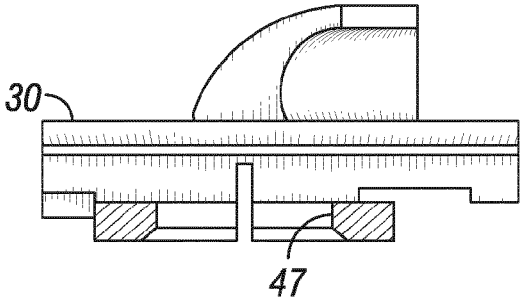

FIG. 3D

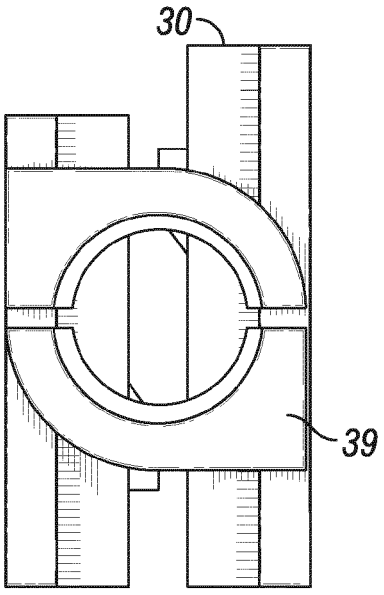

FIG. 3E

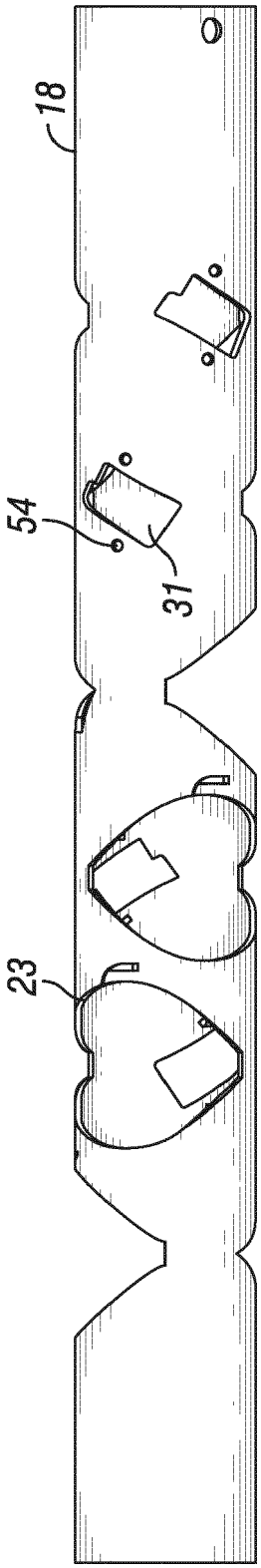

FIG. 4

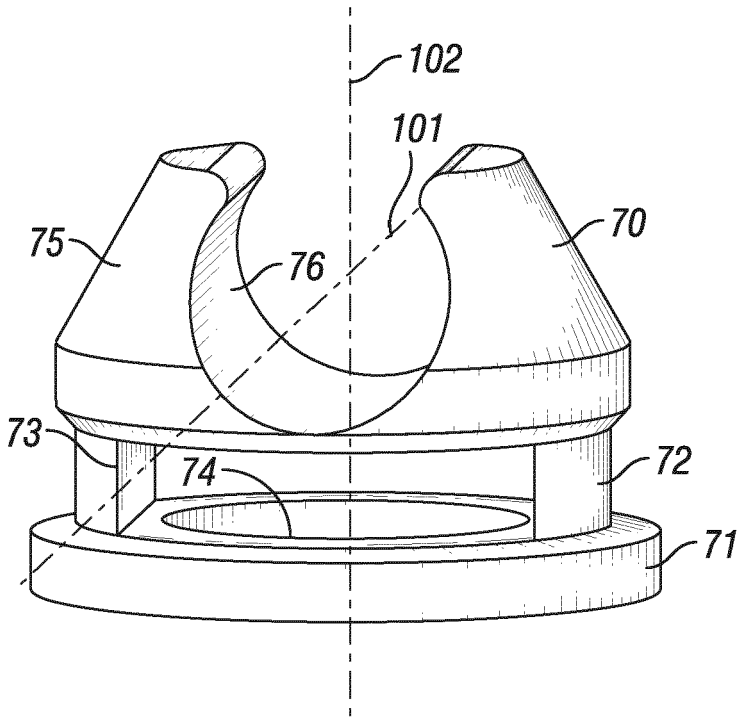

FIG. 5A

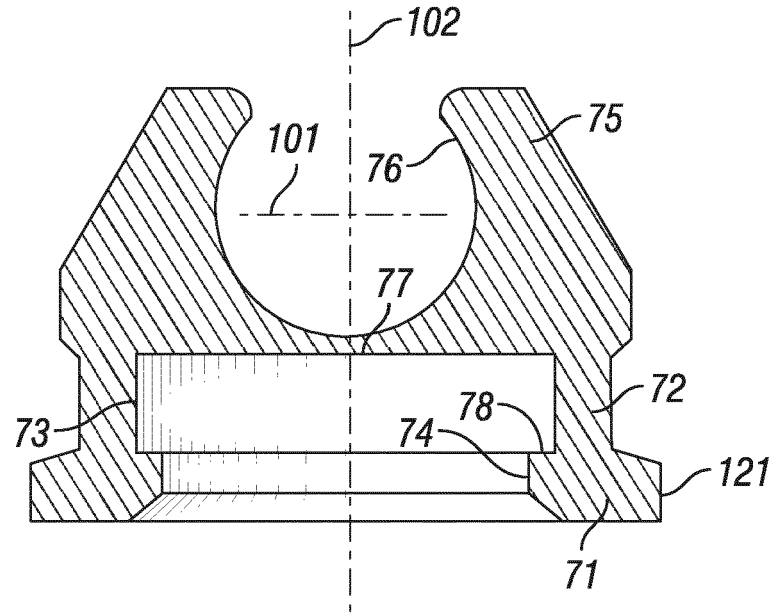

FIG. 5B

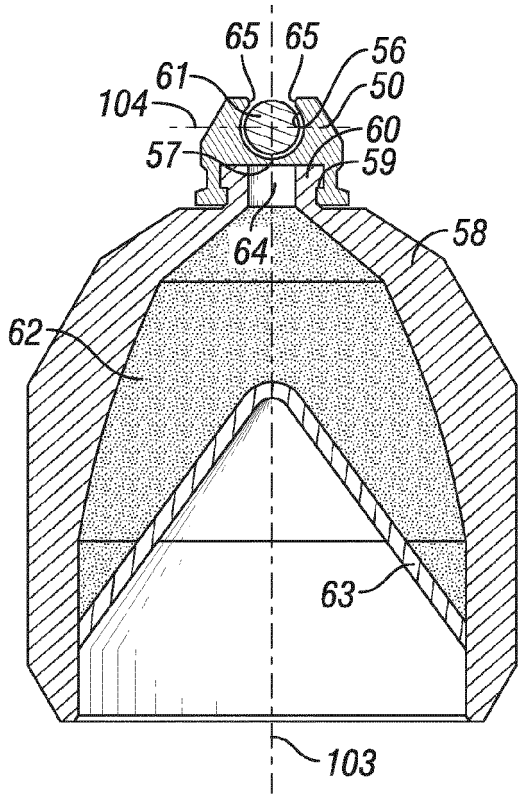
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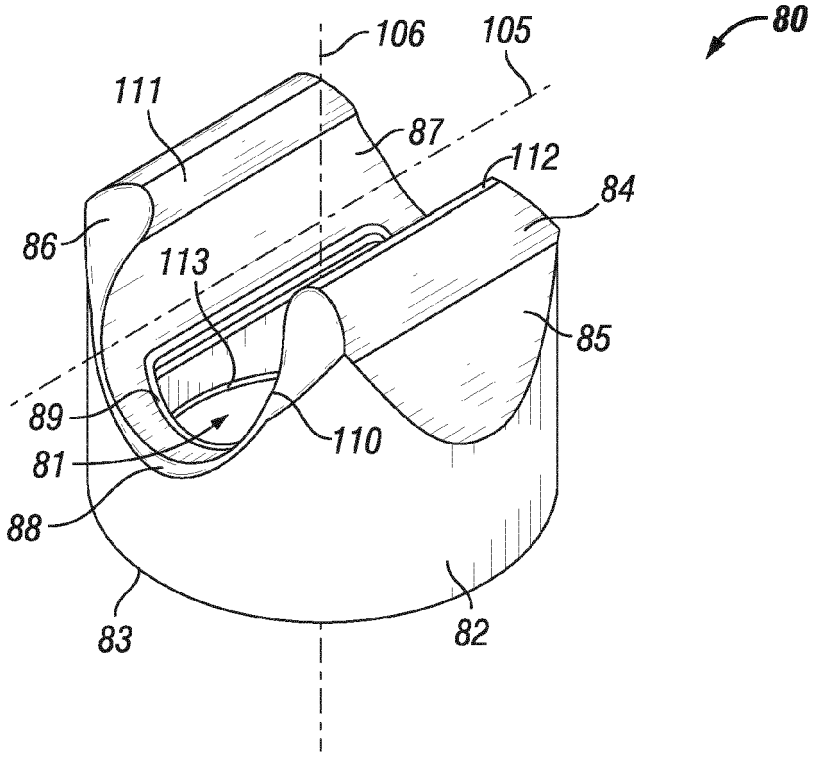
FIG. 6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82

FIG. 7

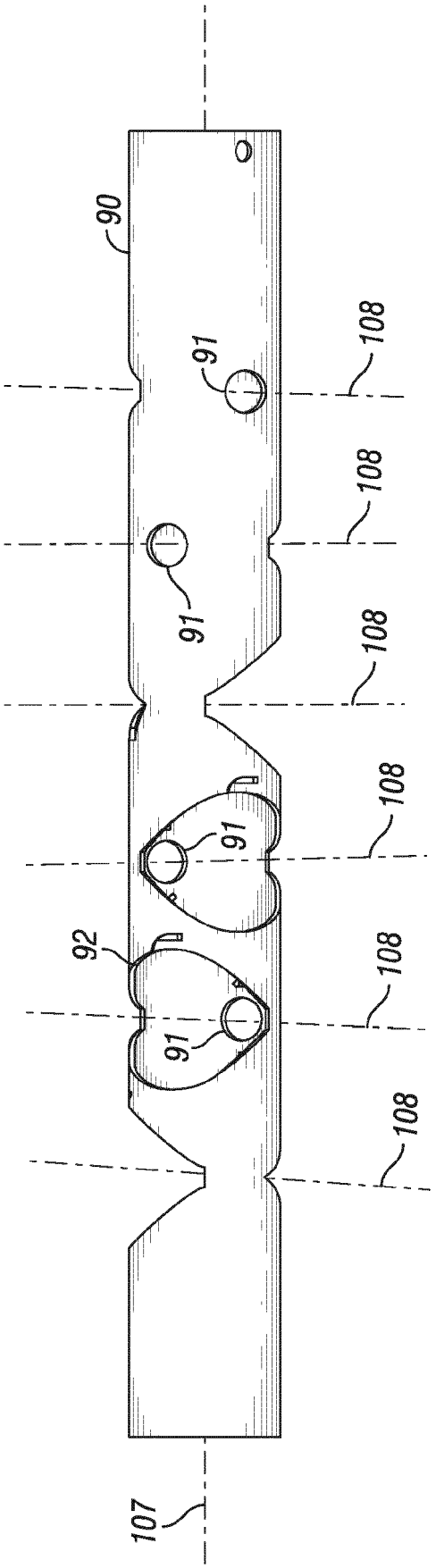

FIG. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 18 18 0100

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X,P	WO 2015/179698 A2 (HUNTING TITAN INC [US]; COLLINS WILLIAM R [US]; MCDONALD DEBRA C [US];) 26 November 2015 (2015-11-26) * page 12, line 7 - page 14, line 8; figures 5A-B, 6 *	1-9	INV. E21B43/117 E21B43/1185 F42D1/04
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E21B
F42D
F42B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	1 October 2018	Hennion, Dmitri

CATEGORY OF CITED DOCUMENTS

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01-10-2018

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