(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 627 092 A1**

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
25.03.2020 Bulletin 2020/13

(51) Int Cl.:
F42B 1/036 *(2006.01)*

(21) Application number: **19208507.4**

(22) Date of filing: **01.04.2016**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **02.04.2015 US 201562142099 P**

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
16774375.6 / 3 278 052

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Remarks:
This application was filed on 12.11.2019 as a divisional application to the application mentioned under INID code 62.

(54) SNAP-ON LINER RETENTION DEVICE

(57) A shaped charge retainer ring for use in containing the liner of a shaped charge and the explosive material. 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.

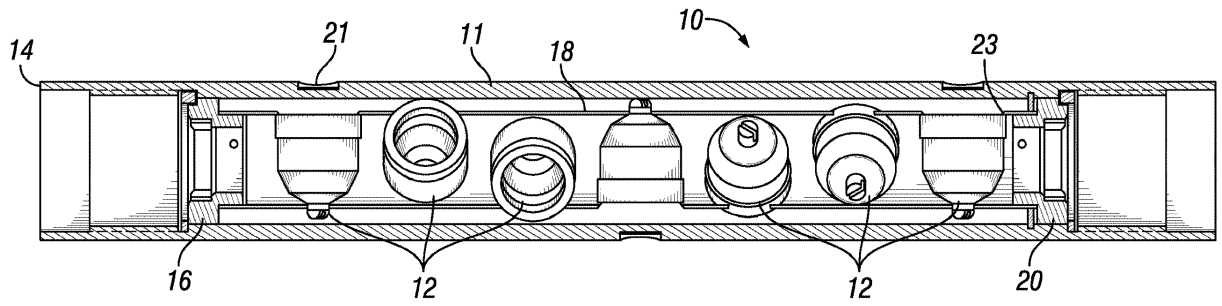

FIG. 1

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Description

RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application No. 62/142,099, filed April 2, 2015.

BACKGROUND OF THE INVENTION

[0002] 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.

[0003] 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.

[0004] 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 a liner in the explosive material. 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.

[0005] 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, 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.

[0006] 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 a liner in the explosive material. 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.

[0007] Within a typical gun tube is a charge holder, which is a tube that is designed to hold the actual shape charges. The charge holder will contain cutouts called charge holes where the shape charges will be placed. A typical shaped charge is carried in a cylindrical perforating gun.

[0008] Typically, the liner is held within the shaped charge case using an adhesive material. Adhesives present issues during the manufacturing process that incur additional costs and have environmental issues. A need exists for a means of cheaply retaining a liner and explosive material within the shaped charge case without using adhesives. Additionally, it is desirable to place an insulating and non-sparking material on the shaped charge cases for a variety of reasons including safety.

SUMMARY OF EXAMPLES OF THE INVENTION

[0009] An example embodiment is a shaped charge apparatus having a shaped charge case with an axis, an inner surface, an outer surface, and a top surface, and at least one circumferential groove on the outer surface. An L-shaped inner retainer ring with an inner radial surface, an outer radial surface, a lower axial surface, and an upper axial surface may be attached to the shaped charge case. The lower axial surface of the inner retainer ring may be adjacent to the top surface of the shaped charge and the outer radial surface maybe adjacent to the inner surface of the shaped charge. Another L-shaped outer retainer ring having an upper axial surface, a lower axial surface, an inner radial surface, and an outer radial surface, may be attached to the top of the L-shaped inner ring. The inner radial surface of the outer retainer ring may include at least one circumferential groove interfaced with the shaped charge outer surface circumferential groove. The shaped charge may include a liner with an inner surface and an outer surface. The liner may be restrained axially by the inner retainer ring and the outer retainer ring. An explosive material may be located between the outer surface of the liner and the inner surface of the shaped charge case.

[0010] A variation of the example embodiment may include the one circumferential groove on the outside surface of the shaped charge case being a plurality of circumferential grooves. At least one circumferential groove on the inner radial surface of the outer retainer ring may be a plurality of circumferential grooves. The inner retainer ring may be composed of plastic. The outer retainer ring may be composed of plastic. The outer retainer ring and the inner retainer ring may be integrally formed into a single retainer ring. The inner retainer ring may be rated to function up to 400 degrees Fahrenheit. The outer retainer ring may be rated to function up to 400 degrees Fahrenheit. The inner retainer ring may have a low electrical conductivity. The outer retainer ring may have a low electrical conductivity. The inner retainer ring may be manufactured using an additive manufacturing process.

The outer retainer ring may be manufactured using an additive manufacturing process.

[0011] Another example embodiment may include a method for making a shaped charge by forming explosive material inside of a shaped charge case, forming a liner over the explosive material, and installing a first retainer ring onto the shaped charge case. The retainer ring may prevent axial movement of the liner and the explosive material within said shaped charge case.

[0012] A variation of the example embodiment may further include installing a second retainer ring to the shaped charged case. The example may include installing the shaped charge in a charge tube. The second retainer ring may prevent axial movement of the first retainer ring. The forming of a liner may result in a substantially frusto-conical shape. The forming of explosive material may result in a substantially frusto-conical shape. The example embodiment may include electrically isolating the shaped charge. It may include manufacturing the first retainer ring. It may include manufacturing the second retainer ring. The manufacturing of the first retainer ring may include an additive manufacturing process. The manufacturing of the second retainer ring may include an additive manufacturing process.

[0013] Another example embodiment may include a shaped charge with a case having an apex end, an open end having a rim, and a cavity extending into case from the open end. It may have a liner fitted into the open end of the case. It may have an electrically insulating ring adapted to fit over the rim of the open end of the case.

[0014] A variation of the example embodiment may include the rim of the open end of the case being substantially circular. It may have a substantially cylindrical inner surface and a substantially cylindrical outer surface and the insulating ring being substantially circular and a substantially cylindrical inner surface and a substantially cylindrical outer surface. The inner surface of the insulating ring may have a smaller diameter than the inner surface of the open end of the case. The outer surface of the rim of the case may have a retention feature. The retention feature may include a raised circumferential ridge, a plurality of raised circumferential ridges, a circumferential groove, or a plurality of circumferential grooves. The inner surface of the rim of the case may have a retention feature that may include a raised circumferential ridge, a plurality of raised circumferential ridges, a circumferential groove or a plurality of circumferential grooves.

[0015] Further variations of the embodiment may include the inner surface of the insulating ring with a retention feature. The retention feature may include a raised circumferential ridge, a plurality of raised circumferential ridges, a circumferential groove, or a plurality of circumferential grooves.

[0016] Further variations of the embodiment may include the outer surface of the insulating ring having a retention feature of a raised circumferential ridge, a plurality of raised circumferential ridges, a circumferential groove, or a plurality of circumferential grooves.

[0017] Further variations of the embodiment disclosed may include the rim of the open end of the case being substantially circular and having a substantially cylindrical inner surface. It may also have a substantially cylindrical outer surface. It may also have the insulating ring having a substantially circular end face, a substantially cylindrical inner wall extending axially from the end face, and a substantially cylindrical outer wall extending axially from the end face. The outer wall of the insulating ring may be adapted to fit outside the outer surface of the rim of the case. The outer wall of the insulating ring may include a retention feature adapted to engage a retention feature on the outer surface of the rim of the case. The inner wall of the insulating ring may be adapted to fit inside the inner surface of the rim of the case. The inner wall of the insulating ring may have a retention feature adapted to engage a retention feature on the inner surface of the rim of the case.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] For a thorough understating of the present invention, 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. Briefly:

FIG. 1 is cross section of an example perforating gun.

FIG. 2 is a cross section view of a shaped charge with an inner retainer ring and an outer retainer ring.

FIG. 3 is a cross section view of a shaped charge with a single retainer ring.

DETAILED DESCRIPTION OF EXAMPLES OF THE INVENTION

[0019] 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.

[0020] Referring to FIG. 1, a typical perforating gun 10 includes a gun body 11 that houses the shaped charges 12. The gun body 11 contains end fittings 16 and 20 which secures the charge tube 18 into place. The charge tube 18 has charge holes 23 that are openings where shaped charges 12 may be placed. 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 requirement. Other design variations

may use ends that are bolted together. In FIG. 1, a 60 degree phase gun is shown where each shaped charge 12 is rotated about the center axis by 60 degrees from one shaped charge to the next. Each shaped charge 12 has a corresponding scallop 21 milled into the gun body 11. Other embodiments of this design are possible including zero degree phase guns, where all the shaped charges are aligned. Other end fittings or connections could be used in lieu of threaded fittings, such as bolted fittings.

[0021] Referring to FIG. 2, an example embodiment is a shaped charge 116 with a shaped charge case 111 having an axis 117, an inner surface 108, an outer surface 118, and a top surface 107. Shaped charge case 111 has circumferential groove 103 on the outer surface 118. An L-shaped inner retainer ring 115 with an inner radial surface 109, an outer radial surface 119, a lower axial surface 120, and an upper axial surface 106 is attached to the top surface 107 of the shaped charge case 111. The lower axial surface 120 is adjacent to the top surface 107 of the shaped charge case 111. The outer radial surface 119 is adjacent to the inner surface 108 of the shaped charge case 111. A L-shaped outer retainer ring 102 having an upper axial surface 122, a lower axial surface 121, an inner radial surface 104, and an outer radial surface 105 engages with the shaped charge case 111. Its inner radial surface 104 includes at least one circumferential groove 123 that is interfaced with the shaped charge outer surface circumferential groove 103. The shaped charge 116 includes a liner 113 with an inner surface 124 and an outer surface 125. The liner 113 is restrained axially by the inner retainer ring 115 and the outer retainer ring 102. An explosive material 112 is located between the outer surface 125 of the liner 113 and the inner surface 108 of the shaped charge case 111. The shaped charge case 111 has an apex end 126.

[0022] Another example embodiment may include the shaped charge case 111 having an axis 117, an inner surface 108, an outer surface 118, and a top surface 107 and at least one circumferential retaining feature 103 for retaining a ring on the outer surface. The retaining feature 103 may be a circumferential groove, a plurality of circumferential grooves, a thread, a buttress thread, a plurality of ridges, a plurality of detents, a lip, or some other retaining means that is well known in the art.

[0023] A variation of the example embodiment may include a plurality of circumferential grooves 103 on the outside surface 118 of the shaped charge case 111. The inner retainer ring 115 may be composed of plastic. The outer retainer ring 102 may be composed of plastic. The inner retainer ring 115 may be rated to function up to 400 degrees Fahrenheit. The outer retainer ring 102 may be rated to function up to 400 degrees Fahrenheit. The inner retainer ring 115 probably has a low electrical conductivity. The outer retainer ring 102 probably has a low electrical conductivity. The inner retainer ring 115 may be manufactured using an additive manufacturing process. The outer retainer ring 102 may be manufactured using an additive manufacturing process.

[0024] Another example embodiment includes a method for making a shaped charge by forming explosive material 112 inside of a shaped charge case 111, forming a liner 113 over the explosive material 112, and installing a first retainer ring 115 onto the shaped charge case 111. The retainer ring 115 prevents axial movement of the liner 113 and the explosive material 112 within said shaped charge case 111.

[0025] A variation of the example embodiment includes installing a second retainer ring 102 to the shaped charged case 111. It could also include installing the shaped charge 116 in a charge tube 18. The second retainer ring 102 may prevent axial movement of the first retainer ring 115. The forming of a liner 113 may result in a substantially frusto-conical shape. The forming explosive material 112 may result in a substantially frusto-conical shape. The example embodiment may further include electrically isolating the shaped charge 116. It may include manufacturing the first retainer ring 115. It may further include manufacturing the second retainer ring 102. The manufacturing of the first retainer ring 115 may include an additive manufacturing process. The manufacturing of the second retainer ring 102 may include an additive manufacturing process.

[0026] The outer retainer ring 102 and the inner retainer ring 115 may be integrally formed into a single retainer ring 215 as shown in FIG. 3. Another example embodiment may include a shaped charge 216 with a case 211 having an apex end 226, an open end 208 having a rim 230, and a cavity extending into case from the open end 208. A liner 213 is fitted into the open end of the case. An electrically insulating ring 215 is fitted over the rim 230 of the open end 208 of the case 211. Explosive material 212 is located between the liner 213 and the charge case 211

[0027] A variation of the example embodiment may include the rim 230 of the open end 208 of the case 211 being substantially circular and having a substantially cylindrical inner surface 214. It have include a substantially cylindrical outer surface 218. The insulating ring 215 may be substantially circular. It may include a substantially cylindrical inner surface 231 and a substantially cylindrical outer surface 232. The inner surface 231 of the insulating ring 215 may have a smaller diameter than the inner surface 214 of the open end 208 of the case 211. The outer surface 218 of the rim 230 of the case 211 may include a retention feature 203 such as a raised circumferential ridge, a plurality of raised circumferential ridges, a circumferential groove, or a plurality of circumferential grooves.

[0028] In other examples the inner surface 214 of the rim of the case may include a retention feature 203 such as a raised circumferential ridge, a plurality of raised circumferential ridges, a circumferential groove, or a plurality of circumferential grooves. Further variations of the embodiment may include the inner surface 231 of the insulating ring 215 having a retention feature. The reten-

tion feature may include a retention feature 203 such as a raised circumferential ridge, a plurality of raised circumferential ridges, a circumferential groove, or a plurality of circumferential grooves.

[0029] Further variations of the embodiment may include the outer surface 232 of the insulating ring 215 has a retention feature 233. The retention feature 233 may include a retention feature 203 such as a raised circumferential ridge, a plurality of raised circumferential ridges, a circumferential groove, or a plurality of circumferential grooves.

[0030] Further variations of the embodiment disclosed may include the rim 230 of the open end 208 of the case 211 being substantially circular. It may have a substantially cylindrical inner surface 214 and a substantially cylindrical outer surface 218. The insulating ring 215 may have a substantially circular end face 202, a substantially cylindrical inner wall 235 extending axially from the end face 202, and a substantially cylindrical outer wall 234 extending axially from the end face 202. The outer wall 234 of the insulating ring 215 may be adapted to fit outside the outer surface of the rim 230 of the case 211. The outer wall 234 of the insulating ring 215 may include a retention feature 233 adapted to engage a retention feature 203 on the outer surface 218 of the rim 230 of the case 211. The inner wall 235 of the insulating ring 215 may be adapted to fit inside the inner surface 214 of the rim 230 of the case 211. Alternatively, the inner wall 235 of the insulating ring 215 may include a retention feature adapted to engage a retention feature on the inner surface of the rim 230 of the case 211.

[0031] In the following, further aspects of the invention are described.

[0032] According to a first aspect, a shaped charge apparatus comprises a shaped charge case with an axis, an inner surface, an outer surface, and a top surface; and at least one circumferential retaining means for retaining a ring on the outer surface.

[0033] According to the first aspect, the at least one retaining means on the outside surface of the shaped charge case is a circumferential groove.

[0034] According to the first aspect, the at least one retaining means is a plurality of circumferential grooves.

[0035] According to the first aspect, the retaining means is a thread.

[0036] According to the first aspect, the thread is a buttress thread.

[0037] According to the first aspect, the retaining means is a plurality of ridges.

[0038] According to the first aspect, retaining means is a plurality of detents.

[0039] According to the first aspect, retaining means is a lip.

[0040] According to a second aspect, a shaped charge retaining system comprises: a shaped charge case with an axis, an inner surface, an outer surface, and a top surface; at least one circumferential groove on the outer surface; a L-shaped inner retainer ring with an inner radial surface, an outer radial surface, a lower axial surface, and an upper axial surface, wherein the lower axial surface is adjacent to the top surface of the shaped charge and the outer radial surface is adjacent to the inner surface of the shaped charge; a L-shaped outer retainer ring having an upper axial surface, a lower axial surface, an inner radial surface, and an outer radial surface, wherein the inner radial surface includes at least one circumferential groove that interfaced with the shaped charge outer surface circumferential groove; a liner with an inner surface and an outer surface, wherein the liner is restrained axially by the inner retainer ring and the outer retainer ring; and an explosive material located between the outer surface of the liner and the inner surface of the shaped charge case.

[0041] According to the second aspect, the at least one circumferential groove on the outside surface of the shaped charge case is a plurality of circumferential grooves.

[0042] According to the second aspect, the at least one circumferential groove on the inner radial surface of the outer retainer ring is a plurality of circumferential grooves.

[0043] According to the second aspect, the inner retainer ring is composed of plastic.

[0044] According to the second aspect, the outer retainer ring is composed of plastic.

[0045] According to the second aspect, the outer retainer ring and the inner retainer ring are integrally formed into a single retainer ring.

[0046] According to the second aspect, the inner retainer ring is rated to function up to 400 degrees Fahrenheit.

[0047] According to the second aspect, the outer retainer ring is rated to function up to 400 degrees Fahrenheit.

[0048] According to the second aspect, the inner retainer ring has a low electrical conductivity.

[0049] According to the second aspect, the outer retainer ring has a low electrical conductivity.

[0050] According to the second aspect, the inner retainer ring is manufactured using an additive manufacturing process.

[0051] According to the second aspect, the outer retainer ring is manufactured using an additive manufacturing process.

[0052] According to a third aspect, a method for making a shaped charge comprises: forming explosive material inside of a shaped charge case; forming a liner over the explosive material; and installing a first retainer ring onto the shaped charge case, wherein the retainer ring prevents axial movement of the liner and the explosive material within said shaped charge case.

[0053] The method according to the third aspect, further comprising installing a second retainer ring to the shaped charged case.

[0054] The method according to the third aspect, further comprising installing the shaped charge in a charge tube.

[0055] The method according to the third aspect, wherein the second retainer ring prevents axial movement of the first retainer ring.

[0056] The method according to the third aspect, wherein the forming a liner results in a substantially frusto-conical shape.

[0057] The method according to the third aspect, wherein the forming explosive material results in a substantially frusto-conical shape.

[0058] The method according to the third aspect, further comprising electrically isolating the shaped charge.

[0059] The method according to the third aspect, further comprising manufacturing the first retainer ring.

[0060] The method according to the third aspect, further comprising manufacturing the second retainer ring.

[0061] The method according to the third aspect, wherein the manufacturing of the first retainer ring includes additive manufacturing.

[0062] The method according to the third aspect, wherein the manufacturing of the second retainer ring includes additive manufacturing.

[0063] According to a fourth aspect, shaped charge comprises: a case having an apex end, an open end having a rim, and a cavity extending into case from the open end; a liner fitted into the open end of the case; an electrically insulating ring adapted to fit over the rim of the open end of the case.

[0064] According to the fourth aspect, the rim of the open end of the case is substantially circular and comprises a substantially cylindrical inner surface and a substantially cylindrical outer surface; and the insulating ring is substantially circular and comprises a substantially cylindrical inner surface and a substantially cylindrical outer surface.

[0065] According to the fourth aspect, the inner surface of the insulating ring has a smaller diameter than the inner surface of the open end of the case.

[0066] According to the fourth aspect, the outer surface of the rim of the case comprises a retention feature.

[0067] According to the fourth aspect, the retention feature comprises a raised circumferential ridge.

[0068] According to the fourth aspect, the retention feature comprises a plurality of raised circumferential ridges.

[0069] According to the fourth aspect, the retention feature comprises a circumferential groove.

[0070] According to the fourth aspect, the retention feature comprises a plurality of circumferential grooves.

[0071] According to the fourth aspect, the inner surface of the rim of the case comprises a retention feature.

[0072] According to the fourth aspect, the retention feature comprises a raised circumferential ridge.

[0073] According to the fourth aspect, the retention feature comprises a plurality of raised circumferential ridges.

[0074] According to the fourth aspect, the retention feature comprises a circumferential groove.

[0075] According to the fourth aspect, the retention feature comprises a plurality of circumferential grooves.

[0076] According to the fourth aspect, the inner surface of the insulating ring comprises a retention feature.

[0077] According to the fourth aspect, the retention feature comprises a raised circumferential ridge.

[0078] According to the fourth aspect, the retention feature comprises a plurality of raised circumferential ridges.

[0079] According to the fourth aspect, the retention feature comprises a circumferential groove.

[0080] According to the fourth aspect, the retention feature comprises a plurality of circumferential grooves.

[0081] According to the fourth aspect, the outer surface of the insulating ring comprises a retention feature.

[0082] According to the fourth aspect, the retention feature comprises a raised circumferential ridge.

[0083] According to the fourth aspect, the retention feature comprises a plurality of raised circumferential ridges.

[0084] According to the fourth aspect, the retention feature comprises a circumferential groove.

[0085] According to the fourth aspect, the retention feature comprises a plurality of circumferential grooves.

[0086] According to the fourth aspect, the rim of the open end of the case is substantially circular and comprises a substantially cylindrical inner surface and a substantially cylindrical outer surface; and the insulating ring comprises a substantially circular end face, a substantially cylindrical inner wall extending axially from the end face, and a substantially cylindrical outer wall extending axially from the end face.

[0087] According to the fourth aspect, the outer wall of the insulating ring is adapted to fit outside the outer surface of the rim of the case.

[0088] According to the fourth aspect, the outer wall of the insulating ring comprises a retention feature adapted to engage a retention feature on the outer surface of the rim of the case.

[0089] According to the fourth aspect, the inner wall of the insulating ring is adapted to fit inside the inner surface of the rim of the case.

[0090] According to the fourth aspect, the inner wall of the insulating ring comprises a retention feature adapted to engage a retention feature on the inner surface of the rim of the case.

[0091] Although the invention has been described in terms of particular embodiments which are set forth in detail, it should be understood that this is by illustration only and that the invention is 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. Accordingly, modifications of the invention are contemplated which may be made without departing from the scope of the claimed invention.

Claims

1. A shaped charge (116; 216), comprising:

a case (111; 211) having an apex end (126; 226),

an open end (208) having a rim (230), and a cavity extending into case from the open end;
a liner (113; 213) fitted into the open end (208) of the case (111; 211);
an explosive material (112; 212) located between the liner (113; 213) and the charge case (111; 211); and
an electrically insulating ring (102, 115; 215) adapted to fit over the rim (230) of the open end (208) of the case (111; 211) and axially restraining the liner (113; 213).

2. The shaped charge (116; 216) of claim 1, wherein:

the rim (230) of the open end (208) of the case (111; 211) is substantially circular and comprises a substantially cylindrical inner surface (108; 214) and a substantially cylindrical outer surface (118; 218); and
the insulating ring (102, 115; 215) is substantially circular and comprises a substantially cylindrical inner surface (231) and a substantially cylindrical outer surface (232).

3. The shaped charge (116; 216) of claim 2, wherein the inner surface (214) of the insulating ring (215) has a smaller diameter than the inner surface (214) of the open end (208) of the case (211).

4. The shaped charge (116; 216) of claim 2, wherein the outer surface (118; 218) or the inner surface (214) of the rim (230) of the case (111; 211) comprises a retention feature (103; 203).

5. The shaped charge (116; 216) of claim 4, wherein the retention feature (103; 203) comprises a raised circumferential ridge, a plurality of raised circumferential ridges, a circumferential groove or a plurality of circumferential grooves.

6. The shaped charge (116; 216) of claim 2, wherein the inner surface (231) or the outer surface (232) of the insulating ring (102, 115; 215) comprises a retention feature (103; 203).

7. The shaped charge (116; 216) of claim 6, wherein the retention feature (103; 203) comprises a raised circumferential ridge, a plurality of raised circumferential ridges, a circumferential groove or a plurality of circumferential grooves.

8. The shaped charge (216) of claim 1, wherein:

the rim (230) of the open end (208) of the case (211) is substantially circular and comprises a substantially cylindrical inner surface (214) and a substantially cylindrical outer surface (218); and
the insulating ring (215) comprises a substantially circular end face (202), a substantially cylindrical inner wall extending (235) axially from the end face (202), and a substantially cylindrical outer wall (234) extending axially from the end face (202).

9. The shaped charge (216) of claim 8, wherein the outer wall (234) of the insulating ring (215) is adapted to fit outside the outer surface (218) of the rim (230) of the case (211).

10. The shaped charge (216) of claim 8, wherein the outer wall (234) of the insulating ring (215) comprises a retention feature (203) adapted to engage a retention feature on the outer surface (218) of the rim (230) of the case (211) or the inner wall (235) of the insulating ring (215) comprises a retention feature (203) adapted to engage a retention feature on the inner surface (214) of the rim (230) of the case (211).

11. The shaped charge (216) of claim 8, wherein the inner wall (235) of the insulating ring (215) is adapted to fit inside the inner surface (214) of the rim (230) of the case (211).

12. The shaped charge (116) of claim 4, wherein the electrically insulating ring (215) is formed of a separate inner retainer ring (115) and outer retainer ring (102);
wherein the inner retainer ring (115) is L-shaped, attached to a top surface (107) of the shaped charge case (111) and with an inner radial surface (109), an outer radial surface (119), a lower axial surface (120), and an upper axial surface (106), wherein the lower axial surface (120) is adjacent to the top surface (107) of the shaped charge case (111) and the outer radial surface (119) is adjacent to the inner surface (108) of the shaped charge case (111); and
wherein the outer retainer ring (102) is L-shaped, engaging with the shaped charge case (111) and having an upper axial surface (122), a lower axial surface (121), an inner radial surface (104), and an outer radial surface (105), wherein the inner radial surface (104) includes at least one circumferential retention feature that is interfaced with the shaped charge case (111) outer surface (118) circumferential retention feature (103).

13. A method for making a shaped charge (116; 216) according to one of the previous claims, the method comprising:

forming explosive material (112; 212) inside of a shaped charge case (111; 211);
forming a liner (113; 213) over the explosive material (112; 212); and
installing an electrically insulating ring (102, 115;

215) onto the shaped charge case (111; 211), wherein the electrically insulating ring (102, 115; 215) prevents axial movement of the liner (113; 213) and the explosive material (112; 212) within said shaped charge case (111; 211).

14. The method of Claim 13, wherein forming the liner (113; 213) and/or forming the explosive material (112; 212) results in a substantially frusto-conical shape.

15. The method of Claim 13, wherein manufacturing of the electrically insulating ring (102, 115; 215) includes additive manufacturing.

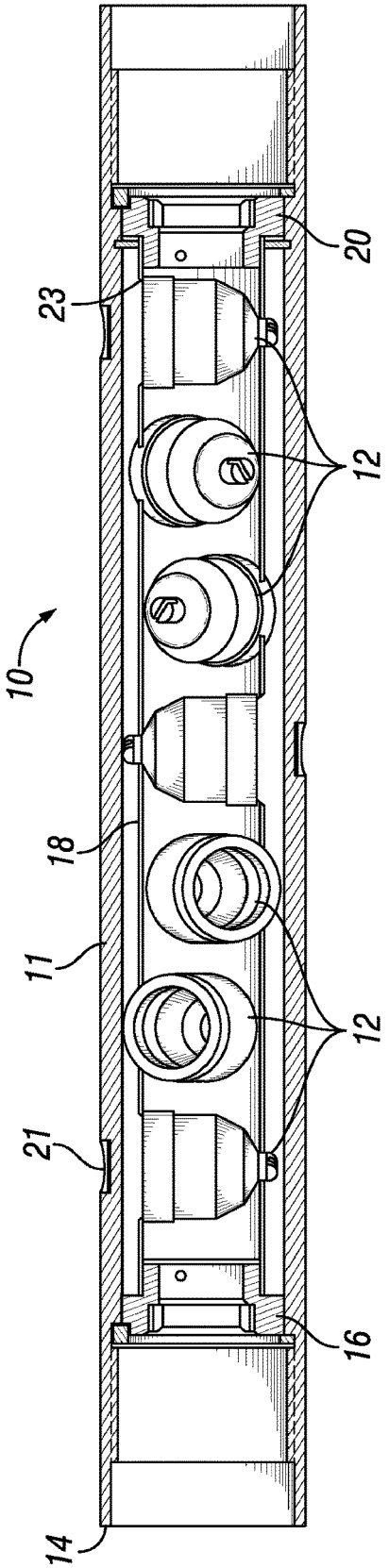

FIG. 1

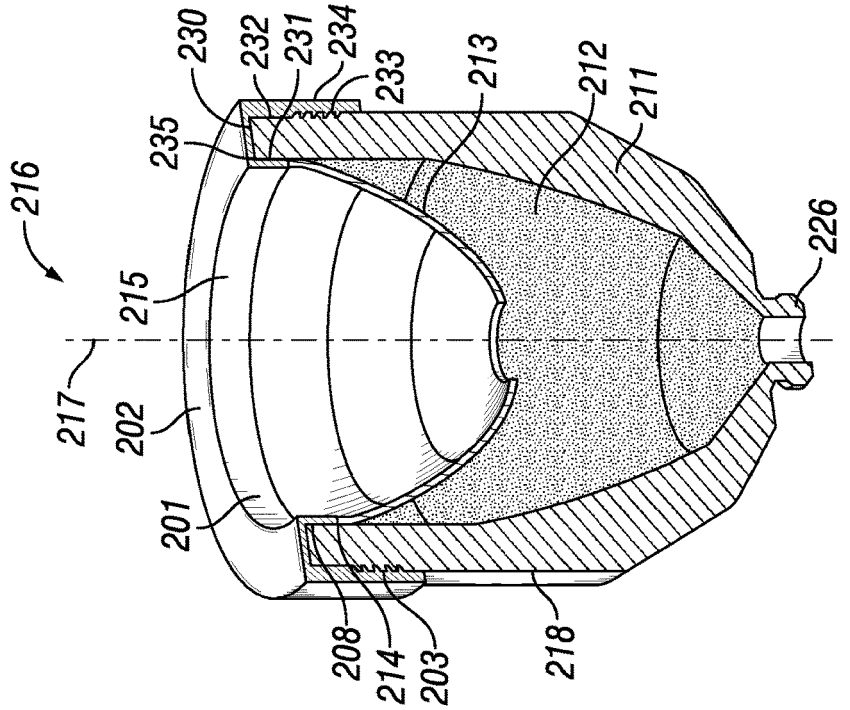
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FIG. 3

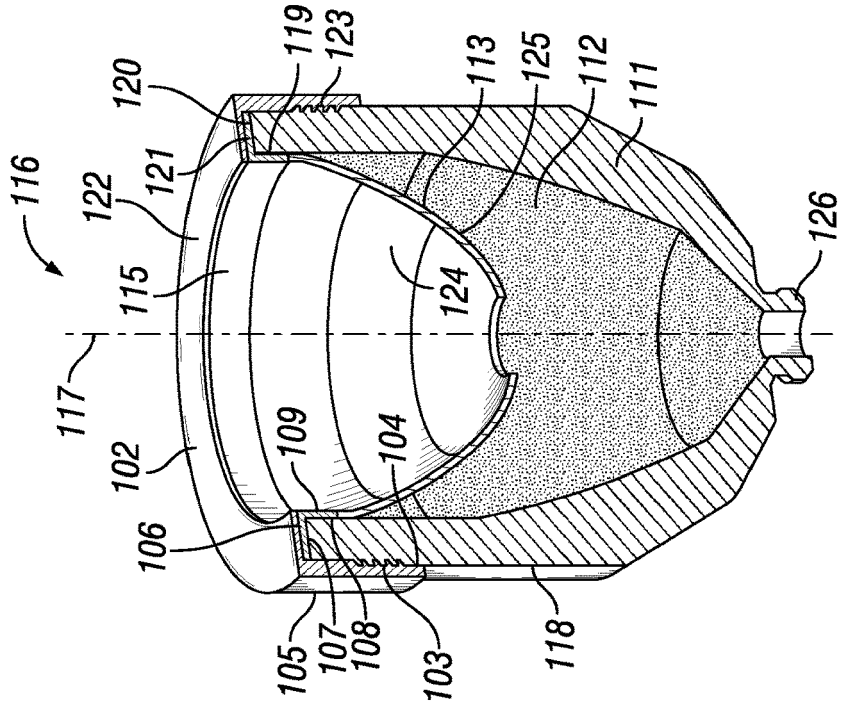
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FIG. 2

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EUROPEAN SEARCH REPORT

Application Number
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	31 January 2020	Giesen, Maarten

CATEGORY OF CITED DOCUMENTS

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