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(54) Title: HIGH TEMPERATURE, HIGH PRESSURE BACK-OFF SHOT TOOL

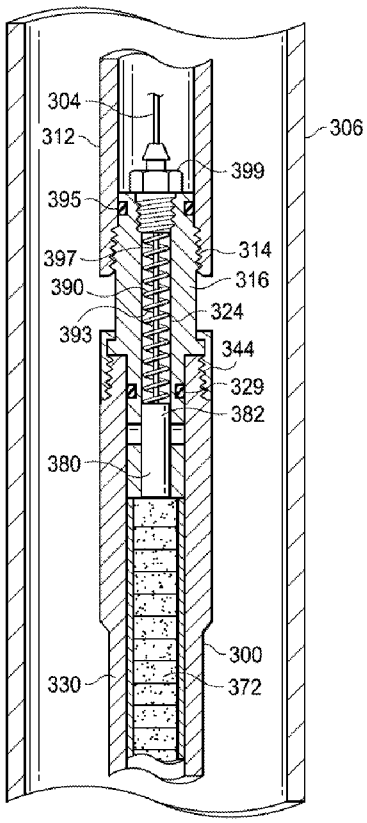


FIG. 3A

(57) Abstract: A back-off shot tool system includes a high-pressure resistant charge housing at least partially containing an explosive material. A booster charge is placed adjacent the explosive material to activate the explosive material upon actuation. The high-pressure resistant charge housing is formed from a material that is able to withstand high temperatures and pressures, such as a ceramic. In addition, the material of the high-pressure resistant charge housing is frangible so that it will fragment into small pieces that can be process or extracted from the well with fluid that is extracted from the region in which the back-off shot tool is deployed.

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HIGH TEMPERATURE, HIGH PRESSURE BACK-OFF SHOT TOOL

Technical Field

The present disclosure relates generally to tooling assemblies for freeing stuck pipe in a wellbore.

Discussion of the Related Art

Wells are drilled at various depths to access and produce oil, gas, minerals, and other naturally-occurring deposits from subterranean geological formations. The drilling of a well is typically accomplished with a drill bit that is rotated within the well to advance the wellbore by removing topsoil, sand, clay, limestone, calcites, dolomites, or other materials to form a wellbore. The drill bit is typically attached to a drill string that may be rotated to drive the drill bit and through which drilling fluid, referred to as "drilling mud" or "mud", may be delivered downhole. The drilling mud is used to cool and lubricate the drill bit and downhole equipment and the circulating drilling mud also transports rock fragments and other cuttings to the surface of the well.

In some cases, drilling of the well may involve deploying a drill string at extreme depths, which may subject the drill-bit and nearby equipment to high temperatures and pressures. Such temperatures and pressures may be in the range of up to, for example, 30 ksi and 500° F, respectively.

In unfortunate circumstances, drilling of the well may also involve complications that result in stoppage of drilling operations. For example, the drill bit may become stuck or otherwise lodged at the base of a wellbore. In such cases, a well operator may deploy a slickline or wireline assembly to free the drill bit or to disconnect the drill string from the drill bit so that it can be removed from the well to allow for the deployment of other tools to either fish the stuck drill bit from the wellbore or to otherwise allow drilling operations to continue along, for example, a deviated path that circumvents the stuck drill bit.

BRIEF DESCRIPTION OF THE DRAWINGS

Illustrative embodiments of the present disclosure are described in detail below with reference to the attached drawing figures, which are incorporated by reference herein and wherein:

FIG. 1A is diagram showing a subsea well in which the drill bit has become stuck, and an example back-off shot tool has been deployed to decouple the drill string from the drill collar in accordance with aspects of the present disclosure;

FIG. 1B is a diagram showing a subterranean well that is analogous in most respects to FIG. 1A, in which the drill bit has become stuck, and an example back-off shot tool has been deployed to assist with the decoupling of the drill string from the drill collar in accordance with aspects of the present disclosure;

FIG. 2 is a diagram showing a wireline tool string that includes an example back-off shot tool in accordance with aspects of the present disclosure;

FIG. 3A is a diagram showing an upper portion of the back-off shot tool of FIG. 2; and

FIG. 3A is a diagram showing a lower portion of the back-off shot tool of FIG. 2.

The illustrated figures are only exemplary and are not intended to assert or imply any limitation with regard to the environment, architecture, design, or process in which different embodiments may be implemented.

DETAILED DESCRIPTION

In the following detailed description of the illustrative embodiments, reference is made to the accompanying drawings that form a part hereof. These embodiments are described in sufficient detail to enable those skilled in the art to practice the disclosed embodiments. It is understood that other embodiments may be utilized and that logical structural, mechanical, electrical, and chemical changes may be made without departing from the spirit or scope of the disclosure. To avoid detail not necessary to enable those skilled in the art to practice the embodiments described herein, the description may omit certain information known to those skilled in the art. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the illustrative embodiments is defined only by the appended claims.

As noted in the above discussion of related art, the drilling of a well generally involves the deployment of a drill bit to remove material from a formation to form a wellbore that reaches a desired depth. In some cases, such as deep water drilling or in the case of drilling very deep subterranean wells, the drill bit and bottom of the wellbore may experience extreme pressures and temperatures, in the range of up to, for example, 30 ksi and 500° F, respectively. In

certain embodiments, pressure may be approximately 20 ksi or greater. In unfortunate circumstances, the drilling of such wells may encounter problems, such as a drill bit becoming stuck or lodged in the formation. In such cases, a well operator may deploy a slickline or wireline tool to free the drill bit or to disconnect the drill string from the drill bit so that it can be fished out of the wellbore or simply drilled around to complete the well. One such tool is a back-off shot tool.

As referenced herein, wireline-delivered tools are tools that are suspended from a wireline that is electrically connected to control systems at the surface of the well, usually for the purposes gathering and conveying data about the formation, wellbore, or fluid in the wellbore. Wireline may also be used to provide control signals to equipment in a wireline tool string. Slickline tools are similarly deployed into a wellbore but may not have an electrical connection to surface equipment. Slickline and wireline tools may be deployed by first removing the drill string and then lowering the wireline and tools to an area of interest within the formation or by lowering the tools within the drill string itself.

As referenced herein, a back-off shot tool is a tool that is deployed proximate, or near, a joint between two tubing segments of a tool string, such as the joint between a drill bit and drill collar to deliver a shot or impact to the joint to loosen threads that comprise the joint and allow the up-hole portion of the drill string to be decoupled from the stuck portion of the drill string and removed from the well. While a drill string is discussed as an exemplary type of tool string that may become stuck in a well and separated using back-off shot tool, it is noted that the back-off shot tool described herein may be equally applicable to other types of tool strings that include threaded tubing segments.

In a typical embodiment, the back-off shot tool includes a high-pressure resistant charge housing that encloses an explosive material that is detonated to deliver an impact to the drill string, thereby loosening threads of a threaded joint in the drill string proximate the high-pressure resistant charge housing. A left-hand torque may be simultaneously applied to the drill string. The high-pressure resistant charge housing may be subjected to the extreme temperatures and pressures noted above, and is typically formed from a metal or other high-strength material that is able to withstand the high temperatures and pressures to which the high-pressure resistant charge housing is subjected. Such high-pressure resistant charge housings may become more ductile at high temperatures which, upon detonation of the explosive material, may result in the high-pressure resistant charge housing fragmenting into

large pieces of debris that are difficult to fish from the wellbore and may obstruct future drilling operations or retrieval of the drill bit.

In certain embodiments, a high-pressure resistant charge housing is disclosed that is able to withstand the high temperatures and pressures of a deep well resulting from the increased loads associated with the high-pressure environment. In addition, the high-pressure resistant charge housing may be formed from a material having mechanical properties that are not negatively affected by exposure to high temperatures. Further, the high-pressure resistant charge housing may be at least partially constructed of a reinforced, frangible material that is selected and formed to fragment into very small particles in response to being subjected to detonation of the explosive material or, if not in response to detonation, in response to being contacted by a drill bit that is subsequently deployed into the wellbore.

In an exemplary embodiment, a back-off shot tool system is disclosed that includes a detonator system with a charge and a high-pressure resistant charge housing. The charge may be any type of charge, but in certain embodiments may be a booster charge. In certain embodiments, the charge and/or booster charge may be a shaped charge for directing explosive force primarily in a certain direction. Shaped charges and how to form a shaped charge for a particular purpose are known to one of skill in the art. An explosive material may be disposed within the high-pressure resistant charge housing. The high-pressure resistant charge housing may be formed at least partially from a frangible material, as described in more detail below. In certain embodiments, a shaped charge may be disposed adjacent the high-pressure resistant charge housing and configured to discharge toward the high-pressure resistant charge housing to activate the explosive material. The frangible material may include a ceramic or a ceramic-reinforced sintered metal or glass, or some combination thereof. In an embodiment in which the frangible material is a ceramic, the ceramic may be toughened zirconium oxide or yttria stabilized zirconia. In an embodiment, the explosive material may include a plurality of wafers or pellets that are sized and configured to provide an explosion of the desired magnitude upon detonation. The back-off shot tool system high-pressure resistant charge housing, and related systems and methods are described in more detail with regard to the attached figures.

Referring now to the figures, FIGS. 1A and 1B show an illustrative embodiment of a downhole system 100 in which a back-off shot tool 138 is deployed to back-off a threaded

coupling 170 between a first tubing segment 172 and a second tubing segment 174 of a drill string 120 or other type of tool string or tubing.

The downhole system 100 is deployed in a well 102 having a wellbore 104 that extends from a surface 108 of the well to or through a subterranean geological formation 112. The well 102 is illustrated offshore in FIG. 1A with the system 100 being deployed in a subsea well 119 from a floating platform 121. Alternatively, the system 100 may be deployed in a land-based well (see FIG. 1B) from a land-based platform 122 or rig. The downhole system 100 includes a wireline or slickline assembly 115 attached to a winch 117 to lift and lower a downhole portion of the assembly 115 into the well 102 using a cable 106.

FIGS. 1A-1B each illustrate these possible uses of the system 100. In the embodiment illustrated in FIG. 1A, the well 102 is formed by a drilling process in which a drill bit 116 is turned by a drill string 120 that extends the drill bit 116 from the surface 108 to the bottom of the well 102. The drill string 120 may be made up of one or more connected tubing segments or pipes of varying or similar cross-section. The drill string 120 may refer to the collection of pipes or tubing segments as a single component, or alternatively to the individual pipes or tubes that comprise the string. The term drill string is not meant to be limiting in nature and may refer to any component or components that are capable of transferring energy from the surface of the well to the drill bit. In several embodiments, the drill string 120 may include a central passage disposed longitudinally in the drill string and capable of allowing fluid communication between the surface of the well and downhole locations.

At or near the surface 108 of the well, the drill string 120 may include or be coupled to a kelly 128. The kelly 128 may have a square, hexagonal or octagonal cross-section. The kelly 128 is connected at one end to the remainder of the drill string 120 and at an opposite end to a rotary swivel 132. The kelly 128 passes through a rotary table 136 that is capable of rotating the kelly 128 and thus the remainder of the drill string 120 and drill bit 116. The rotary swivel 132 allows the kelly 128 to rotate without rotational motion being imparted via the rotary swivel 132. A hook, cable 142, traveling block (not shown), and hoist (not shown) are provided to lift or lower the drill bit 116, drill string 120, kelly 128 and rotary swivel 132. The kelly 128 and swivel 132 may be raised or lowered as needed to add additional sections of tubing to the drill string 120 as the drill bit 116 advances, or to remove sections of tubing from the drill string 120 if removal of the drill string 120 and drill bit 116 from the well 102 is desired.

In normal drilling operations, a reservoir (not shown) is positioned at the surface 108 and holds drilling mud for delivery to the well 102. A supply line is fluidly coupled between the reservoir and the inner passage of the drill string 120, and in operation, a pump drives fluid through the supply line and downhole to lubricate the drill bit 116 during drilling and to carry cuttings from the drilling process back to the surface 108. After traveling downhole, the drilling mud returns to the surface 108 by way of an annulus 160 formed between the drill string 120 and the wellbore 104. At the surface 108, the drilling mud is returned to the reservoir through a return line. The drilling mud may be filtered or otherwise processed prior to recirculation through the well 102.

In rare circumstances, the drill bit 116 may become stuck in the wellbore 104, and the well operator may implement procedures to fish the drill bit 116 from the well or disconnect the drill string 120 from the drill bit 116 so that an alternative, deviated wellbore may be drilled to circumvent the stuck drill bit. In such cases, the well operator may first disconnect the tubing segments 172, 174 that couple the drill bit to the drill string 120. The tubing segments 172, 174 may include a first tubing segment 172 and second tubing segment 174, which may be coupled by a threaded joint 170. The threaded joint 170 may be very difficult to unthread from the surface 108. To loosen the threads 170 so that a left-hand or reverse torque may be applied to the drill string 120 to decouple the first tubing segment 172 from the second tubing segment 174, the well operator may deploy a back-off shot tool 138 that impacts the threaded joint 170. In operation, the impact may back-off the threads of the threaded joint 170 so that the portion of the drill string 120 that is up hole of the first tubing segment 172 may be removed from the wellbore 104. Removal of the second tubing segment 174 allows the well operator to continue drilling or two deploy a slickline or wireline tool string to recover the drill bit 116 and first tubing segment 172. In some instances, the back-off shot tool 138 may be deployed lower in the drill string to deliver an impact to separate, for example, the first tubing segment to a drill collar that couples the drill bit 116 to the drill string 120.

As shown in FIGS. 1A and 1B, the back-off shot tool 138 may be deployed within the drill string 120 and adjacent the threaded joint 170 using a wireline or slickline assembly 115. An example of such a back-off shot tool 138 is described in more detail with regard to FIGS. 2, 3A, and 3B. The back-off shot tool 138 of FIGS. 2, 3A, and 3B may be sized to have an outer diameter that is less than the inner diameter of the drill string 120, and may be otherwise configured for deployment within the drill string 120. More specifically, the back-off shot tool

138 is adapted for positioning at a threaded joint 170, as shown in FIG. 1, to deliver an impact generated by an explosive charge to the drill string 120. The impact is delivered simultaneously with the application of a left-hand torque to back off the threads of the threaded joint 170 to decouple the second tubing segment 174 from the first tubing segment 172.

In an embodiment, as shown in FIG. 2, the back-off shot tool 138 includes a high-pressure resistant charge housing 202. The selection of material for the high-pressure resistant charge housing 202 may provide the necessary strength to withstand the high pressures and/or temperatures. The selection of material may also provide the required frangible characteristics to the high-pressure resistant charge housing 202. The high-pressure resistant charge housing 202 may withstand high pressures and/or temperatures associated with deep water wells and other types of wells in geological formations that are at a high temperature and/or pressure. Such high temperatures and/or pressures may be, for example, up to 500°F and approximately 30 ksi. In certain embodiments, high temperature may be any temperature over 350°F. In certain embodiments, the pressure may be approximately 20 ksi or greater. The high-pressure resistant charge housing 202 may be made of a rigid or reinforced material that is selected to withstand high temperatures and pressures that are a result of, for example (a) the pressure differential between the inside of the high-pressure resistant charge housing 202, which may be atmospheric pressure or a pressure lower than pressure within the wellbore, and wellbore in which the back-off shot tool 138 is deployed, which could be up to approximately 30 ksi, and (b) changes in material properties resulting from increases in temperature. For example, the high-pressure resistant charge housing 202 may be made from a ceramic or reinforced metal or glass, or hardened steel as described in more detail below. The high-pressure resistant charge housing 202 may be coupled to a firing head module 204 that includes a detonator assembly to ignite explosive material housed within the high-pressure resistant charge housing 202. The detonator assembly may be suitable for use in a high temperature, high-pressure environment. For example, the detonator assembly may employ a deflagration-to-detonation technique utilizing an insensitive pyrotechnic and secondary explosives, wherein a semiconductor bridge (SCB) element similar to those used in automotive airbag systems is used to initiate the deflagration reaction to trigger the detonator assembly.

A shock absorbing subassembly 206 may be coupled to the firing head 204 on the up hole side of the firing head 204 to convey a detonation signal to the firing head 204 and to absorb shock upon actuation of the explosive material. The shock absorbing subassembly 206 prevents the transfer of an impact resulting from such actuation and to prevent the impact from being transmitted to up hole elements of the wireline tool string. In turn, the shock absorbing subassembly 206 may be coupled to a button sub 208 that transmits an actuation signal from a firing pin of a pin connector 210 that is coupled to a wireline 212 to receive a detonation signal from a controller at the surface.

In the embodiment of FIGS. 3A and 3B, a back-off shot tool 300 is suspended within a drill string 306 adjacent a threaded joint 308. A lower portion of a shock absorbing subassembly 312 is coupled to a firing head module 316 at a threaded joint 314. A wireline 304 extends upward to toward the surface. Below the threaded joint 314, the firing head module 316 is substantially cylindrical in shape. A sealed interface which includes a seal such as a threaded joint 344 that includes an O-ring 329 couples the firing head module 316 to a high-pressure resistant charge housing 330.

In an embodiment, the high-pressure resistant charge housing 330 is formed at least partially from a frangible material that is designed to fragment to particulate sizes of less than or equal to about ¼ of an inch in diameter upon detonation of explosive material 372 located at least partially inside the high-pressure resistant charge housing 330. Suitable materials for use in forming the high-pressure resistant charge housing 330 include a variety of ceramics, metals, and glasses that are suitably brittle upon impact yet able to withstand high pressure differentials across the wall of the high-pressure resistant charge housing 330 when the high-pressure resistant charge housing 330 is deployed in a high-pressure environment. For example, the frangible material may be a sintered metal having a plurality of metal particles that are sintered together in a cast to form the high-pressure resistant charge housing 330. In another embodiment, the frangible material may be any suitable ceramic, such as a transformation-toughened zirconium oxide or yttria stabilized zirconia.

As discussed herein, a transformation toughened zirconium oxide (TTZ), is a high toughness ceramic material having a variety of microstructures, including partially stabilized zirconia that includes tetragonal and cubic microstructures, and tetragonal zirconia polycrystal that includes primarily tetragonal microstructures.

As discussed herein, yttria-stabilized zirconia (YSZ) is a ceramic in which the crystal structure of zirconium dioxide is stabilized at room temperature by an addition of yttrium oxide.

In the embodiment of FIGS. 3A and 3B, the high-pressure resistant charge housing 330 is generally cylindrical and includes threads at its upper end to form a threaded joint 344 to couple the firing head module 316. The firing head module 316 includes complementary threads to engage the threads of the high-pressure resistant charge housing 330 at the threaded joint 344 which fastens the firing head module 316 to the high-pressure resistant charge housing 330. The outer diameter of the high-pressure resistant charge housing and other elements of the back-off shot tool 300 may be in the range of 1-11/16 inches to 2-5/8 inches, or any other suitable diameter that allows for the back-off shot tool 300 to be lowered and positioned within a drill string without inducing binding or unwanted friction between the outer surface of the back-off shot tool 300 and the inner surface of the drill string.

The back-off shot tool 300 also includes a plug 360 inserted into an opening 334 at the lower end of the high-pressure resistant charge housing 330. The plug 360 may be coupled to the high-pressure resistant charge housing 330 by, for example, an engaging pin 362 that protrudes through a hole 364 in the plug 360 and corresponding holes 366 and 368 at the lower end of the high-pressure resistant charge housing 330. The plug 360 is generally formed from the same material as the high-pressure resistant charge housing 330 or a similar material having suitable properties that are also selected to fragment upon actuation of explosive material 372 enclosed at least partially within the high-pressure resistant charge housing 330. The plug 360 may be glued, epoxied, sintered, welded or otherwise bonded to the high-pressure resistant charge housing 330 to ensure a fluid seal between the interior of the high-pressure resistant charge housing 330 and the wellbore when the back-off shot tool 300 is deployed.

The high-pressure resistant charge housing 330 includes a cavity 336, which may be a generally cylindrical cavity 336 that at least partially contains an explosive material 372. The explosive material 372 may be in the form of wafers or pellets that can be incrementally added or removed to control the magnitude of the impact generated by detonation of the explosive material 372. The effective density of the explosive material 372 may also be varied by adding spacers either between the explosive material or between the explosive material 372 and the interior wall of the cavity 336.

The explosive material 372 may be formed from any suitable explosive compound. For example, the explosive material may be T4 Atomic Demolition Munitions, commonly referred to as ("Research Department Explosive") RDX or octogen, known as Her Majesty's eXplosive ("HMX"), or another explosive suitable for use in a high temperature or high-pressure environment.

The firing head module 316 is coupled to the high-pressure resistant charge housing 330 such that coupling the firing head module 316 to the high-pressure resistant charge housing 330 results in an electrically actuated booster charge 380 being inserted into the housing 330 to contact the explosive material 372. An upper portion 382 of the booster charge 380 protrudes through a bore 324 in the firing head module 316, and the booster charge 380 is biased against explosive material 372 by a biasing spring 390 (such as a coil spring) that extends from a firing head module connector 399 to the booster charge 380. A firing wire 397, which may be, for example, Primacord, extends from the booster charge 380 and through the center of the biasing spring 390 to couple the firing head module connector 399 to the booster charge 380. The firing head module connector 399 includes an annular groove around its periphery for housing a seal 395, such as an O-ring to provide a fluid-tight seal between up-hole elements of the backup tool 300 and the firing head module 316. The firing head module connector 399 is electrically insulated from the external surface of the firing head module connector 399 and the firing head module 316. To ground the booster charge 380, a ground wire 393 winds along the biasing spring 390 from the booster charge 380 to couple with an electrical ground.

In operation, prior to assembly, the back-off shot tool 300 may be transported to a well in which a back-off shot is needed to decouple a threaded coupling of a drill string or similar tubing. The back-off shot tool 300 may be transported without booster charge 380 or explosive materials 372, which may be assembled with the high-pressure resistant charge housing 380 and firing head module 316 on site.

In an embodiment, the booster charge 380 is placed in the firing head module 316 such that the spring 390 biases the booster charge 380 against the explosive charge 372 and the booster charge 380 is coupled to the firing head module connector 399 with the firing wire 397 and ground wire 393 to receive an actuation signal from a surface controller. The firing head module 316 is then threaded into the high-pressure resistant charge housing 330, and the firing head module connector 399 is coupled to the firing head module 316.

The back-off shot tool 300 is then deployed to the desired location within the drill string 306. To deliver the desired back-off impact, force, such as left-hand torque, is applied to the drill string 306 from the surface and the back-off shot tool 300 is actuated via the wireline 304. This actuation causes the explosive material 372 to explode, delivering an impact to the threaded joint 308. The impact should help to decouple the threaded joint 308 so that the upper portion of the drill string 306 may be retrieved to the surface. The explosion of the explosive material 372 causes the high-pressure resistant charge housing 330 to shatter or fragment into relatively small materials that may be removed from the well with drilling fluid or other fluid that is extracted from the well without impeding fluid flow.

From the above description, it is apparent that a novel and unobvious back-off shot tool has been invented. Of course, certain modifications, additions and deletions to the preferred embodiments as disclosed herein may be made without departing from the spirit and scope of the claimed embodiments.

The illustrative systems, methods, and devices described herein may also be described by the following examples:

Example One. A back-off shot housing includes a high-pressure resistant charge housing and an explosive material disposed at least partially therein. The high-pressure resistant charge housing comprises a frangible material.

Example Two. A back-off shot housing includes a high-pressure resistant charge housing and an explosive material disposed at least partially therein. The high-pressure resistant charge housing comprises a frangible material, which is a sintered metal.

Example Three. A back-off shot housing includes a high-pressure resistant charge housing and an explosive material disposed at least partially therein. The high-pressure resistant charge housing comprises a frangible material. The frangible material comprises a glass.

Example Four. A back-off shot housing includes a high-pressure resistant charge housing and an explosive material disposed at least partially therein. The high-pressure resistant charge housing comprises a frangible material. The frangible material comprises a ceramic.

Example Five. A back-off shot housing includes a high-pressure resistant charge housing and an explosive material disposed at least partially therein. The high-pressure resistant charge housing comprises a frangible material. The frangible material comprises a ceramic, which is a transformation-toughened zirconium oxide.

Example Six. A back-off shot housing includes a high-pressure resistant charge housing and an explosive material disposed at least partially therein. The high-pressure resistant charge housing comprises a frangible material. The frangible material comprises a ceramic, which is an yttria stabilized zirconia.

Example Seven. A back-off shot housing includes a high-pressure resistant charge housing and an explosive material disposed at least partially therein. The high-pressure resistant charge housing comprises a frangible material and the explosive material comprises a plurality of wafers.

Example Eight. A back-off shot housing includes a high-pressure resistant charge housing and an explosive material disposed at least partially therein. The high-pressure resistant charge housing comprises a frangible material and the explosive material comprises a plurality of pellets.

Example Nine. A back-off shot tool system includes a firing head module having a booster charge and a high-pressure resistant charge housing having an explosive material disposed at least partially therein. The high-pressure resistant charge housing includes a frangible material and the booster charge is disposed adjacent the high-pressure resistant charge housing and configured to discharge toward the high-pressure resistant charge housing, thereby activating the explosive material.

Example Ten. A back-off shot tool system includes a firing head module having a booster charge and a high-pressure resistant charge housing having an explosive material disposed at least partially therein. The high-pressure resistant charge housing includes a frangible material and the booster charge is disposed adjacent the high-pressure resistant charge housing and configured to discharge toward the high-pressure resistant charge housing, thereby activating the explosive material. In this exemplary embodiment, the frangible material comprises a sintered metal.

Example Eleven. A back-off shot tool system includes a firing head module having a booster charge and a high-pressure resistant charge housing having an explosive material disposed at least partially therein. The high-pressure resistant charge housing includes a frangible material and the booster charge is disposed adjacent the high-pressure resistant charge housing and configured to discharge toward the high-pressure resistant charge housing, thereby activating the explosive material. In this exemplary embodiment, the frangible material comprises a glass.

Example Twelve. A back-off shot tool system includes a firing head module having a booster charge and a high-pressure resistant charge housing having an explosive material disposed at least partially therein. The high-pressure resistant charge housing includes a frangible material and the booster charge is disposed adjacent the high-pressure resistant charge housing and configured to discharge toward the high-pressure resistant charge housing, thereby activating the explosive material. In this exemplary embodiment, the frangible material comprises a ceramic.

Example Thirteen. A back-off shot tool system includes a firing head module having a booster charge and a high-pressure resistant charge housing having an explosive material disposed at least partially therein. The high-pressure resistant charge housing includes a frangible material and the booster charge is disposed adjacent the high-pressure resistant charge housing and configured to discharge toward the high-pressure resistant charge housing, thereby activating the explosive material. In this exemplary embodiment, the frangible material comprises a ceramic and the ceramic is a transformation-toughened zirconium oxide.

Example Fourteen. A back-off shot tool system includes a firing head module having a booster charge and a high-pressure resistant charge housing having an explosive material disposed at least partially therein. The high-pressure resistant charge housing includes a frangible material and the booster charge is disposed adjacent the high-pressure resistant charge housing and configured to discharge toward the high-pressure resistant charge housing, thereby activating the explosive material. In this exemplary embodiment, the frangible material comprises a ceramic and the ceramic is an yttria stabilized zirconia.

Example Fifteen. A back-off shot tool system includes a firing head assembly having a booster charge and a high-pressure resistant charge housing having an explosive material

disposed at least partially therein. The high-pressure resistant charge housing includes a frangible material and the booster charge is disposed adjacent the high-pressure resistant charge housing and configured to discharge toward the high-pressure resistant charge housing, thereby activating the explosive material. In this exemplary embodiment, the explosive material comprises a plurality of wafers.

Example Sixteen. A back-off shot tool system includes a firing head assembly having a booster charge and a high-pressure resistant charge housing having an explosive material disposed at least partially therein. The high-pressure resistant charge housing includes a frangible material and the booster charge is disposed adjacent the high-pressure resistant charge housing and configured to discharge toward the high-pressure resistant charge housing, thereby activating the explosive material. In this exemplary embodiment, the explosive material comprises a plurality of pellets.

Example Seventeen. A method of backing off a tooling joint in a wellbore includes placing a high-pressure resistant charge housing proximate the tooling joint, wherein an explosive material is disposed at least partially within the housing and wherein the housing comprises a frangible material. The method further includes actuating a booster charge disposed adjacent the high-pressure resistant charge housing and configured to discharge toward the high-pressure resistant charge housing, thereby activating the explosive material. The method also includes applying a left-hand torque to the threaded joint.

Example Eighteen. A method of backing off a tooling joint in a wellbore includes placing a high-pressure resistant charge housing proximate the tooling joint, wherein an explosive material is disposed at least partially within the housing and wherein the housing comprises a frangible material that includes a sintered metal. The method further includes actuating a booster charge disposed adjacent the high-pressure resistant charge housing and configured to discharge toward the high-pressure resistant charge housing, thereby activating the explosive material. The method also includes applying a left-hand torque to the threaded joint.

Example Nineteen. A method of backing off a tooling joint in a wellbore includes placing a high-pressure resistant charge housing proximate the tooling joint, wherein an explosive material is disposed at least partially within the housing and wherein the housing comprises a frangible material that includes a glass. The method further includes

actuating a booster charge disposed adjacent the high-pressure resistant charge housing and configured to discharge toward the high-pressure resistant charge housing, thereby activating the explosive material. The method also includes applying a left-hand torque to the threaded joint.

Example Twenty. A method of backing off a tooling joint in a wellbore includes placing a high-pressure resistant charge housing proximate the tooling joint, wherein an explosive material is disposed at least partially within the housing and wherein the housing comprises a frangible material that includes a ceramic metal. The method further includes actuating a booster charge disposed adjacent the high-pressure resistant charge housing and configured to discharge toward the high-pressure resistant charge housing, thereby activating the explosive material. The method also includes applying a left-hand torque to the threaded joint.

Example Twenty-one. A method of backing off a tooling joint in a wellbore includes placing a high-pressure resistant charge housing proximate the tooling joint, wherein an explosive material is disposed at least partially within the housing and wherein the housing comprises a frangible material that includes a transformation-toughened zirconium oxide. The method further includes actuating a booster charge disposed adjacent the high-pressure resistant charge housing and configured to discharge toward the high-pressure resistant charge housing, thereby activating the explosive material. The method also includes applying a left-hand torque to the threaded joint.

Example Twenty-two. A method of backing off a tooling joint in a wellbore includes placing a high-pressure resistant charge housing proximate the tooling joint, wherein an explosive material is disposed at least partially within the housing and wherein the housing comprises a frangible material that includes yttria stabilized zirconia. The method further includes actuating a booster charge disposed adjacent the high-pressure resistant charge housing and configured to discharge toward the high-pressure resistant charge housing, thereby activating the explosive material. The method also includes applying a left-hand torque to the threaded joint.

Example Twenty-three. A method of backing off a tooling joint in a wellbore includes placing a high-pressure resistant charge housing proximate the tooling joint, wherein an explosive material is disposed at least partially within the housing and wherein the

housing comprises a frangible material. The method further includes actuating a booster charge disposed adjacent the high-pressure resistant charge housing and configured to discharge toward the high-pressure resistant charge housing, thereby activating the explosive material. The explosive material includes a plurality of wafers. The method also includes applying a left-hand torque to the threaded joint.

Example Twenty-four. A method of backing off a tooling joint in a wellbore includes placing a high-pressure resistant charge housing proximate the tooling joint, wherein an explosive material is disposed at least partially within the housing and wherein the housing comprises a frangible material. The method further includes actuating a booster charge disposed adjacent the high-pressure resistant charge housing and configured to discharge toward the high-pressure resistant charge housing, thereby activating the explosive material. The explosive material includes a plurality of pellets. The method also includes applying a left-hand torque to the threaded joint.

It should be apparent from the foregoing that systems, methods, and devices having significant advantages over the state of the art have been provided. While the disclosure is shown in only a few of its forms, it is not limited to only these embodiments but is susceptible to various changes and modifications without departing from the spirit thereof.

As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprise" and/or "comprising," when used in this specification and/or the claims, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The corresponding structures, materials, acts, and equivalents of all means or step plus function elements in the claims below are intended to include any structure, material, or act for performing the function in combination with other claimed elements as specifically claimed. The description has been presented for purposes of illustration and description but is not intended to be exhaustive or limited to the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the disclosure. The embodiment was chosen and described to explain the principles of the disclosure and the practical application and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular

use contemplated. The scope of the claims is intended to broadly cover the disclosed embodiments and any such modification.

CLAIMS

1. A back-off shot housing comprising:
   a high-pressure resistant charge housing that defines an internal cavity and is at least partially composed of a frangible material; and
   an explosive material at least partially within the internal cavity.

2. The back-off shot housing of claim 1, wherein the frangible material comprises a sintered metal.

3. The back-off shot housing of claim 1, wherein the frangible material comprises a glass.

4. The back-off shot housing of claim 1, wherein the frangible material comprises a ceramic.

5. The back-off shot housing of claim 4, wherein the ceramic comprises transformation-toughened zirconium oxide.

6. The back-off shot housing of claim 4, wherein the ceramic comprises yttria stabilized zirconia.

7. The back-off shot housing of claim 1, wherein the explosive material comprises a plurality of wafers.

8. The back-off shot housing of claim 1, wherein the explosive material comprises a plurality of pellets.

9. A back-off shot tool system comprising:
   a high-pressure resistant charge housing comprising an explosive material disposed at least partially therein, the high-pressure resistant charge housing comprising a frangible material; and
   a firing head module comprising a booster charge, wherein the booster charge is biased against the explosive material.

10. The back-off shot tool system of claim 9, wherein the frangible material comprises a sintered metal.

11. The back-off shot tool system of claim 9, wherein the frangible material comprises a glass.

12. The back-off shot tool system of claim 9, wherein the frangible material comprises a ceramic.

13. The back-off shot tool system of claim 12, wherein the ceramic comprises transformation-toughened zirconium oxide.

14. The back-off shot tool system of claim 12, wherein the ceramic comprises yttria stabilized zirconia.

15. The back-off shot tool system of claim 9, wherein the explosive material comprises a plurality of wafers.

16. The back-off shot tool system of claim 9, wherein the explosive material comprises a plurality of pellets.

17. A method of backing off a threaded joint in a wellbore, the method comprising:
placing a high-pressure resistant charge housing at least partially composed of a frangible material and at least partially containing an explosive material proximate the threaded joint;
detonating the explosive material; and
applying a left-hand torque to said threaded joint.

18. The method of claim 17, wherein the frangible material comprises a sintered metal.

19. The method of claim 17, wherein the frangible material comprises a ceramic, and wherein the ceramic comprises transformation-toughened zirconium oxide.

20. The method of claim 17, wherein the frangible material comprises a ceramic, and wherein the ceramic comprises yttria stabilized zirconia.

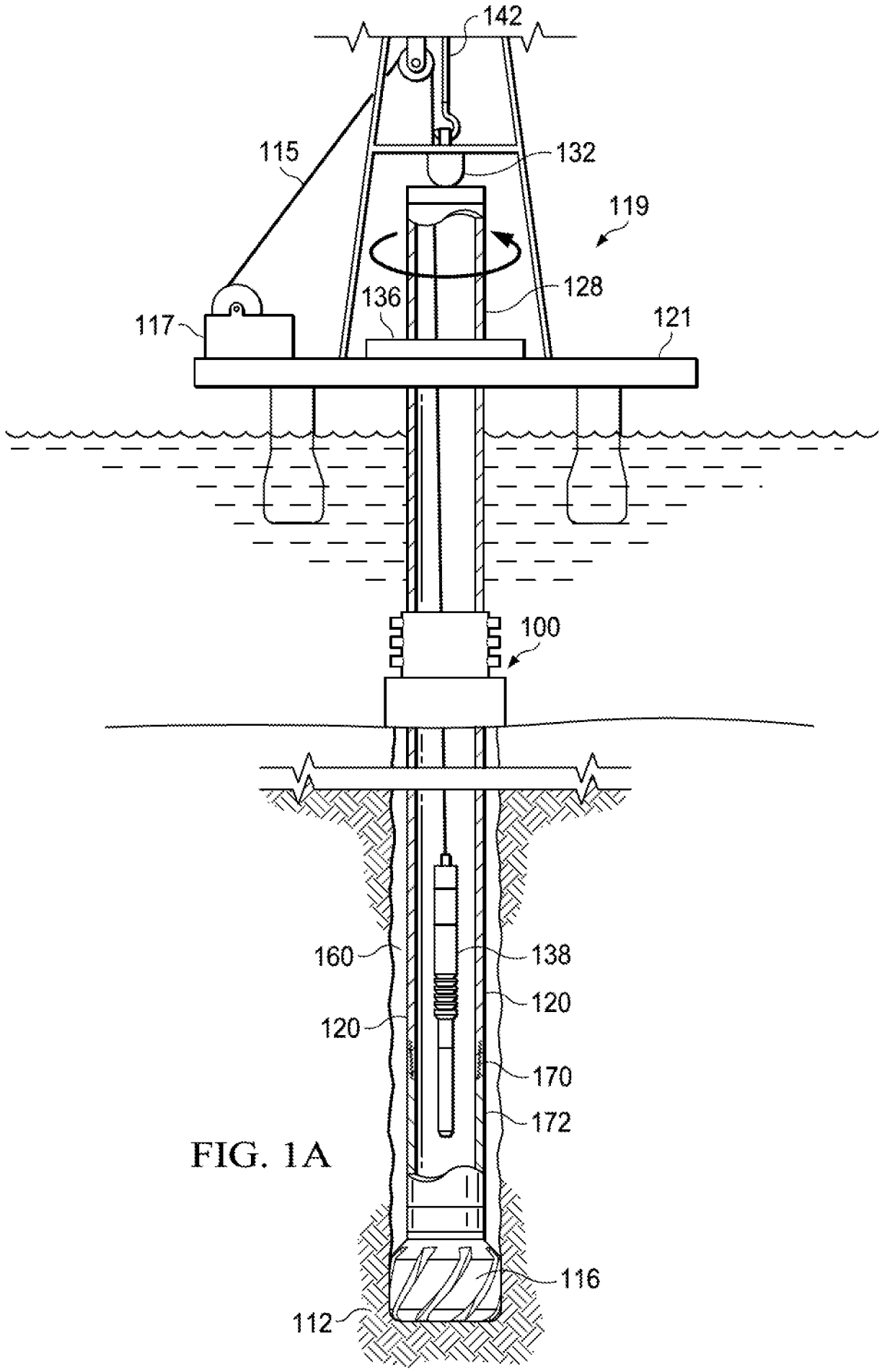

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FIG. 1A

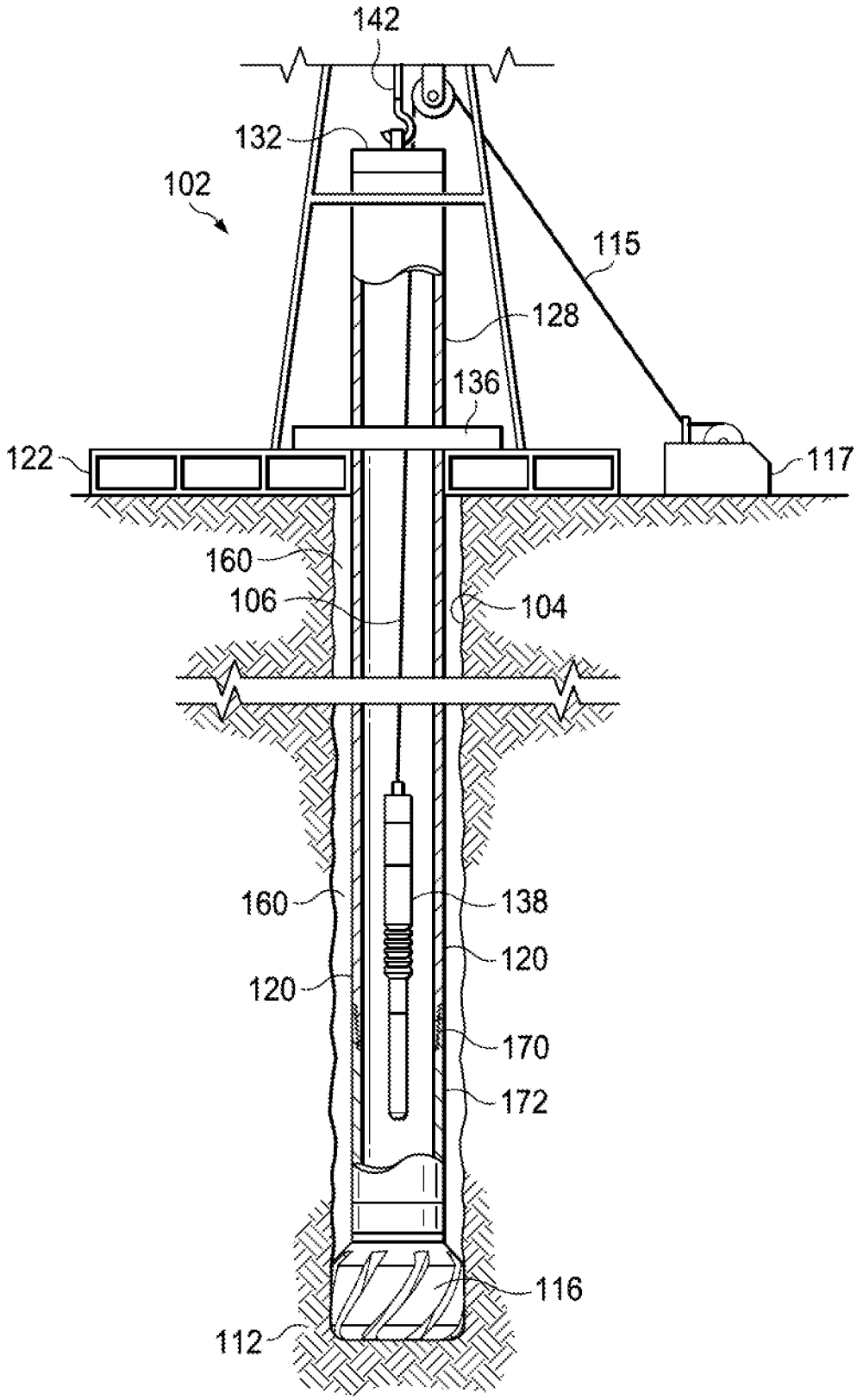

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FIG. 1B

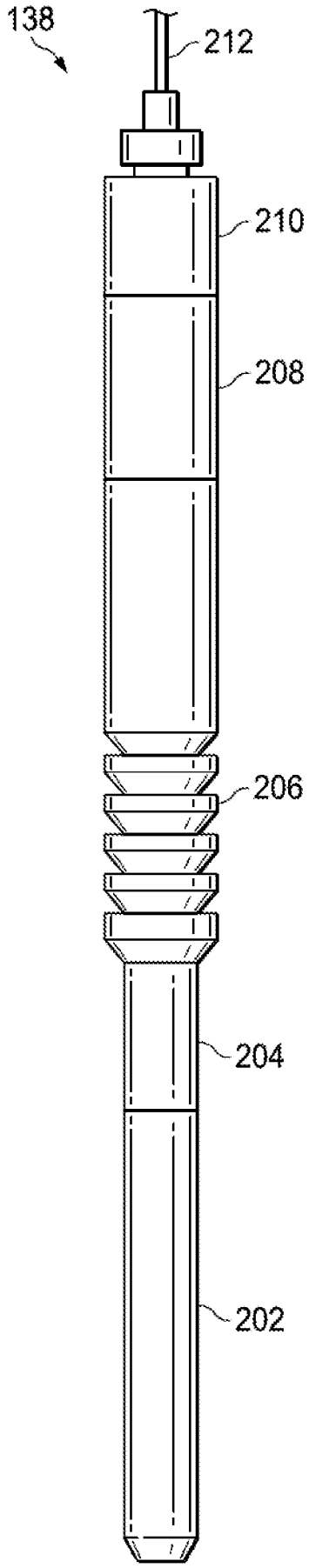


FIG. 2

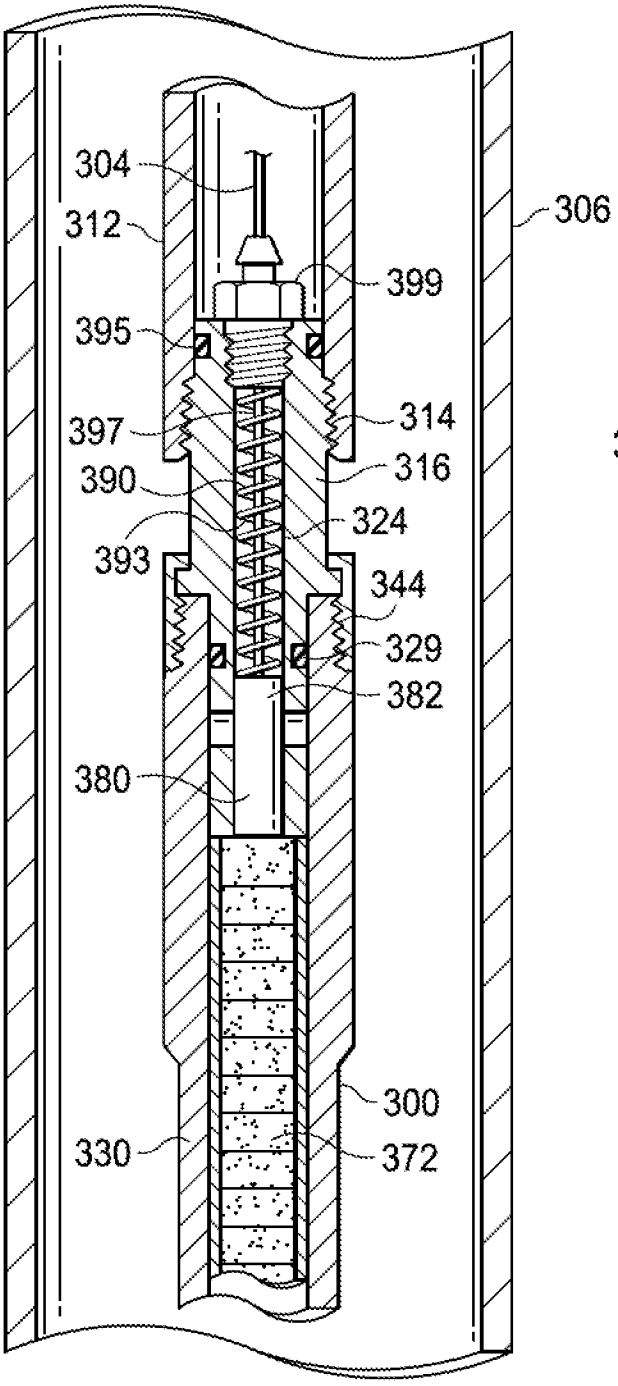

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FIG. 3A

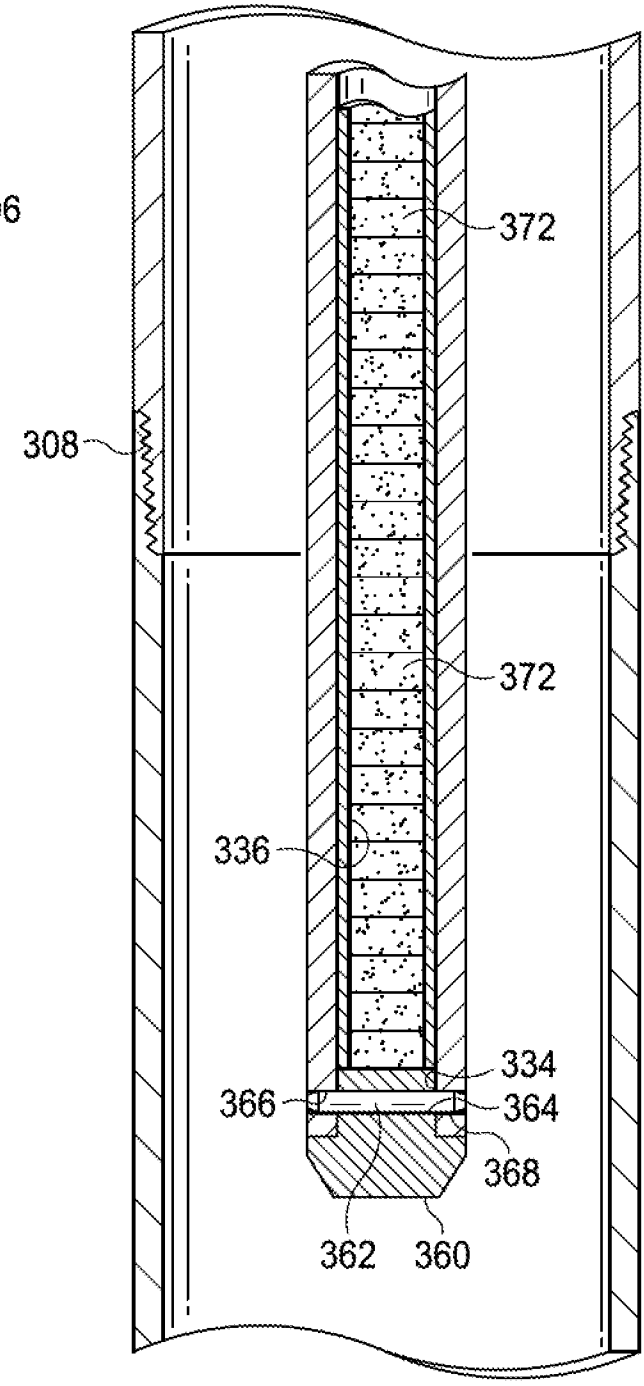

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FIG. 3B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/046159

A. CLASSIFICATION OF SUBJECT MATTER

E21B 43/11(2006.01)i, E21B 43/116(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E21B 43/11; F42B 1/036; E21B 43/00; E21B 31/00; F42B 3/08; E21B 19/00; E21B 23/00; F42B 3/182; E21B 29/02; E21B 43/116

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: back-off, cutter, perforation, explosive, pallet, wafer, frangible, and booster

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4537255 A (REGALBUTO et al.) 27 August 1985 See column 2, line 26 - column 3, line 50, column 5, line 12 - column 6, line 17, and figure 1A.	1,3,7-9,11,15-17
Y		2,4-6,10,12-14 ,18-20
Y	EP 1367354 A1 (HALLIBURTON ENERGY SERVICES, INC.) 03 December 2003 See paragraphs [0014],[0031]-[0033] and figure 2.	2,10,18
Y	US 5129322 A (CHRISTOPHER et al.) 14 July 1992 See column 2, line 42 - column 3, line 44 and figure 1.	4-6,12-14,19-20
A	US 2010-0319929 A1 (BOLZE, VICTOR MATTHEW) 23 December 2010 See paragraphs [0038],[0039] and figure 5.	1-20
A	US 2013-0092378 A1 (MHASKAR et al.) 18 April 2013 See paragraph [0023] and figure 5.	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 April 2015 (10.04.2015)	**10 April 2015 (10.04.2015)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/046159

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		WO 2010-148316 A2	23/12/2010
		WO 2010-148316 A3	21/04/2011
US 2013-0092378 A1	18/04/2013	US 8851191 B2	07/10/2014