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(54) Title: DETONATOR OUTPUT INTERRUPTER FOR DOWNHOLE TOOLS

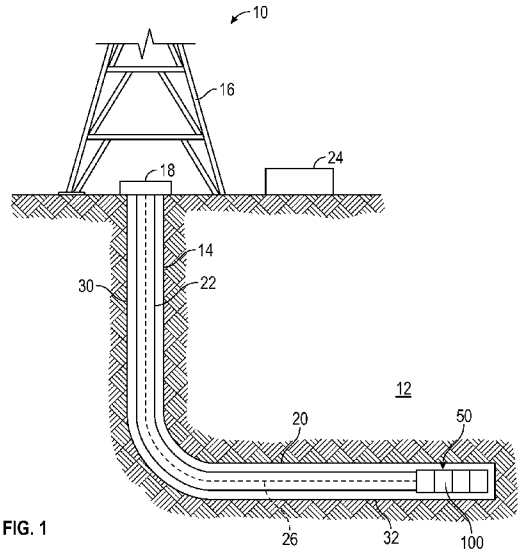

FIG. 1

(57) Abstract: An apparatus for selectively activating a downhole tool by using a Shockwave generated by a detonator assembly may include an outer housing having a bore and an inner housing disposed in the bore of the outer housing. The inner housing may include a chamber having at least one canted surface, an inlet communicating with the chamber and being positioned between the chamber and the detonator assembly, an outlet communicating with the chamber and being positioned between the chamber and the downhole tool, and an energy blocker disposed in the chamber and being freely movable in the chamber as the inner housing changes orientation relative to a vertical datum. The energy blocker axially aligns with the inlet and the outlet when the inner housing is angularly offset less than a specified amount relative to a vertical datum.

WO 2015/157532 A1

TITLE: **DETONATOR OUTPUT INTERRUPTER FOR DOWNHOLE TOOLS**

INVENTOR(S): **DAVIDSON, Mark; ANDRICH, Lyle W.; and VASS, Bradley J.**

TECHNICAL FIELD

[0001] The present disclosure relates to devices and methods for firing one or more downhole tools. More particularly, the present disclosure is in the field of control devices and methods for enhancing the reliability of firing systems used to fire a ballistic downhole tool.

BACKGROUND

[0002] One of the activities associated with the completion of an oil or gas well is the perforation of a well casing. During this procedure, perforations, such as passages or holes, are formed in the casing of the well to enable fluid communication between the wellbore and the hydrocarbon producing formation that is intersected by the well. These perforations are usually made with a perforating gun loaded with shaped charges. The gun is lowered into the wellbore on electric wireline, slickline or coiled tubing, or other means until it is at a desired target depth; *e.g.*, adjacent to a hydrocarbon producing formation. Thereafter, a surface signal actuates a firing head associated with the perforating gun, which then detonates the shaped charges. Projectiles or jets formed by the explosion of the shaped charges penetrate the casing to thereby allow formation fluids to flow from the formation through the perforations and into the production string for flowing to the surface.

[0003] Many oil well tools incorporate a high-order detonation as part of their operation. When these tools are fired prematurely, it can be costly and time consuming to repair the well and re-attempt the desired wellbore operation. The present disclosure relates to methods and devices for preventing premature high-order detonations from initiating operation of oil well tools.

SUMMARY

[0004] In aspects, the present disclosure provides an apparatus for selectively activating a downhole tool by using a shockwave generated by a detonator assembly. The apparatus may include an outer housing having a bore and an inner housing disposed in the bore of the outer housing. The inner housing may include a chamber having at least one canted surface, an inlet communicating with the chamber and being positioned between the chamber and the detonator assembly, an outlet communicating with the chamber and being positioned between the chamber and the downhole tool, and an energy blocker disposed in the chamber and being freely movable in the chamber as the inner housing changes orientation relative to a vertical datum. The energy blocker axially aligns with the inlet and the outlet when the inner housing is angularly offset less than a specified amount relative to a vertical datum.

[0005] In aspects, the present disclosure provides a method for selectively activating a downhole tool by using a shockwave generated by a detonator assembly. The method employs detonator output interrupters according to the present disclosure along with one or more well tools that are conveyed to a target depth across a wellbore that has vertical and deviated sections.

[0006] It should be understood that examples of the more important features of the disclosure have been summarized rather broadly in order that the detailed description thereof that follows may be better understood, and in order that the contributions to the art may be appreciated. There are, of course, additional features of the disclosure that will be described hereinafter and which will in some cases form the subject of the claims appended thereto.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] For detailed understanding of the present disclosure, references should be made to the following detailed description of the preferred embodiment, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals and wherein:

[0008] **FIG. 1** schematically illustrates an elevation view of a surface facility adapted to perform one or more pre-defined tasks in a wellbore using one or more downhole tools;

[0009] **FIG. 2** illustrates a side sectional view of a detonator output interrupter according to one embodiment of the present disclosure;

[0010] **FIG. 3** illustrates a side sectional view of the **FIG. 2** detonator output interrupter in a horizontal orientation; and

[0011] **FIG. 4** illustrates a side sectional view of the **FIG. 2** detonator output interrupter in an inverted orientation.

DETAILED DESCRIPTION

[0012] The present disclosure relates to devices and methods for providing a detonator output interrupter to selectively initiate operation of one or more downhole tools. The present disclosure is susceptible to embodiments of different forms. There are shown in the drawings, and herein will be described in detail, specific embodiments of the present disclosure with the understanding that the present disclosure is to be considered an exemplification of the principles of the disclosure, and is not intended to limit the disclosure to that illustrated and described herein.

[0013] Referring to **FIG. 1,** there is shown a well construction and/or hydrocarbon recovery facility **10** positioned over a subterranean formation of interest **12**. The facility **10** can include known equipment and structures such as a rig **16**, a wellhead **18**, and cased or uncased pipe/tubing **20**. A work string **22** is suspended within the wellbore **14** from the rig **16**. The work string **22** can include drill pipe, coiled tubing, wire line, slick line, or any other known conveyance means. The work string **22** can include telemetry lines or other signal/power transmission mediums that establish one-way or two-way telemetric communication. A telemetry system may have a surface controller (e.g., a power source) **24** adapted to transmit electrical signals via a cable or signal transmission line **26** disposed in the work string **22**. To perform one or more tasks in the wellbore **14**, the work string **22** may include a downhole tool **50** that is activated by a high-order detonation.

[0014] Conventionally, the downhole tool **50** is conveyed by the work string **22** along the various sections of the wellbore **14** until a desired target depth is reached. The wellbore **14** may have a complex geometry that includes one or more vertical sections **30** and one or more deviated sections **32**. While shown as perfectly vertical and perfectly horizontal, the vertical sections **30** and the deviated sections **32** may vary in actual angular offset from a vertical datum. In some instances, the target depth is in the deviated section **32** of the wellbore **14**. As discussed below, detonator output interrupters according to the present disclosure can prevent premature activation while the downhole tool **50** is being conveyed to the target depth.

[0015] Referring to **FIG. 2**, there is sectionally illustrated one non-limiting embodiment of a detonator output interrupter **100** made in accordance with the present disclosure. The detonator output interrupter **100** can selectively prevent an energetic discharge, such as a shockwave, generated by the detonator assembly **110** from energetically activating a downhole tool **120**. The detonator assembly **110** may include a firing head **112** and an initiator **114**. The downhole tool **50** can be a perforating gun or any other device that uses a high-order detonation and associated shock wave to initiate operation. As shown, the downhole tool **50** may be fired by detonating a bi-directional booster charge **122** that ignites a detonating cord **124**.

[0016] In one embodiment, the detonator output interrupter **100** may include an outer housing **130**, an inner housing **132**, and an energy blocker **134**.

[0017] The outer housing **130** may be formed as a cylindrical structure that acts as a bulkhead and an enclosure for the internal components of the detonator assembly **110** and the detonator output interrupter **100**. In one embodiment, the outer housing has a first end **140** that connects via threads **142** to an adjacent tool **144** and a second end **146** that connects via threads **148** to the downhole tool **50**. The outer housing also has a bore **150** in which the firing head **112**, the initiator **114** and the inner housing **132** are serially disposed. In other embodiments, these components may be disposed in separate enclosures. For example, the firing head **112** and the initiator **114** may be positioned in a separate sub.

[0018] In one arrangement, the inner housing **132** may also be a cylindrical structure that is configured to retain the energy blocker **134** and to channel the

shockwave generated by the detonator assembly **110** to the downhole tool **50**. The inner housing may include an inlet **152** and an outlet **154** that communicate with a chamber **156**. The inlet **152** and the outlet **154** are axially aligned with one another and may be concentric within the inner housing **132** as shown or may be offset from the central axis of the inner housing **132**.

[0019] The chamber **156** includes opposing surfaces **158** that are substantially transverse to the vertical datum **102** and a cylindrical inner surface that is substantially parallel to the vertical datum **102**. By substantially, it is meant within 30 degrees. The inlet **152** has one end proximate to the initiator **114** and another end terminating at a first surface of the opposing surfaces **158.** The outlet **154** has one end proximate to the downhole tool **50** and another end terminating at a second surface of the opposing surfaces **158.** The surfaces are generally canted such that they slope toward the inlet **152** or the outlet **154**. That is, the surfaces **158** may be sloped to position an apex at the inlet **152** or the outlet **154**. For example, the surfaces **158** may have a conical shape that positions the cone apex at the inlet **152** or the outlet **154**. Generally concave shapes may also be used. The shape and amount of slope of the surfaces **158** can control the amount of deviation needed to shift the energy blocker **134**. The opposing surfaces **158** are shown as similarly shaped, but they may also be dissimilarly shaped. That is, the surfaces **158** may be canted the same way, canted different ways, or one may have no cant.

[0020] The energy blocker **134** deflects, absorbs, or otherwise interrupts an energy train generated by the detonator assembly **110** from initiating the downhole tool **50**. The energy blocker **134** is disposed in the chamber **156** and can selectively obstruct the axial path along which a shockwave generated by the initiator **114** traveling to the booster charge **122**. The energy blocker **134** may be formed of steel, metal, ceramics, plastics, composites, or any other material that deflects and / or breaks up the shockwave such that the energy is dissipated into the inner housing **132**. In one arrangement, the detonator output interrupter **100** blocks the shock wave when the detonator output interrupter **100** is in the vertical position (*e.g.*, aligned with the vertical datum **102**). The energy blocker **134** shifts to a position that does not impede the travel of the shockwave after the tool **100** is oriented at or past a selected

deviation. In one embodiment, the energy blocker **134** may be a spherical body such as a ball. In the vertical orientation shown in **Fig. 2**, the energy blocker **134** gravitates to and rests over the outlet **154** because the surface **158** is canted.

[0021] In one non-limiting embodiment, the energy blocker **134** may be a metal ball (e.g., a steel ball bearing) that is "freely movable" in the chamber **156**. By "freely moveable," it is meant that the energy blocker **134** is not connected to any other structure and can freely move due to gravity as the detonator output interrupter changes orientation. A ball shape allows the energy blocker **134** to roll due to gravity. However, other shapes may also be used (e.g. disk shapes). Also, actions other than rolling may be used (e.g., sliding, pivoting, rotating, etc.). Thus, the energy blocker **134** may use any configuration that is responsive to gravity and can move out of contact with the inlet **152** or the outlet **154** when the downhole tool **100** is in the appropriate orientation. The shape and weight of the energy blocker **134**, as well as the dimensions and shape of the chamber **152**, can also control how much deviation will be needed to shift the energy blocker **134**.

[0022] Referring to **Fig. 3**, the detonator output interrupter **100** is shown in a horizontal orientation; *i.e.*, the vertical datum **102** (**Fig. 2**) is transverse to gravity. Because of gravity, the energy blocker **134** has fallen to a region of the chamber **156** that is radially offset from the inlet **152** and the outlet **154**. Thus, a shockwave from the initiator **114** travels unimpeded through the chamber **156** to the booster charge **122**. It should be noted that a deviated orientation other than a horizontal would also move the energy blocker **134** away in this particular embodiment.

[0023] In **Fig. 4**, the detonator output interrupter **100** is shown in an inverted position; *i.e.*, vertically flipped from the orientation shown in **Fig. 2**. In this vertical orientation, the energy blocker **134** gravitates to and rests over the inlet **152** because the surface **158** is canted; *i.e.*, sloped. However, the function of the energy blocker **134** remains generally the same in that the shockwave from the initiator **114** is blocked from passing through to the booster charge **122**.

[0024] One illustrative use of the detonator output interrupter **100** will be discussed in connection with **Figs. 1 - 3**. For clarity, the detonator output interrupter **100** will be discussed with reference to perforating guns. It should be

appreciated, however, that the detonator output interrupter **100** is not limited to such use.

[0025] In one mode of use, the detonator output interrupter **100** is incorporated into the tool **50**. The downhole tool **50** may be any device that is intended to be activated by using by a high-order detonation from the detonator assembly **110**. The signal for firing the detonator assembly **110** may be a pressure change, an impact, a time delay, an electrical signal, or any other suitable actuating methodology. When a signal is received, the firing head **112** impacts the initiator **114.** Upon impact, the initiator **114** undergoes a high-order detonation that causes a shock wave to enter the inlet **152**. Whether or not the shockwave passes successfully through to the booster charge **122** depends on the orientation of the detonator output interrupter **100**.

[0026] Initially, the downhole tool **50** may be conveyed along the vertical section **30** of the wellbore **14**. In this section, the orientation of the detonator output interrupter **100** may be less than the selected minimum value for a deviation. Therefore, if the detonator assembly **110** inadvertently generates a shock wave, then the energy blocker **134** may be in physical contact with one of the opposing surfaces **158** and axially aligned with the inlet **152** and the outlet **154**. Thus the energy blocker **134** acts as an energy barrier and / or energy absorber for this inadvertent shock wave. Thus, the downhole tool **50** is not prematurely initiated.

[0027] After the downhole tool **50** has reached the target depth at the deviated section **32** of the wellbore, the orientation of the detonator output interrupter **100** may be at or greater than the selected minimum value for a deviation. The selected value for the deviation may be a 15 degree, 30 degree, 45 degree, 60 degree, 75 degree, a 90 degree, or another intervening value. Therefore, the gravity radially shifts the energy blocker **134** out of alignment with the inlet **152** and the outlet **154**. Thus, for instance, the energy blocker **134** may be radially displaced from the inlet **152** and the outlet **154** and resting on the opposing surface **158** and / or the cylindrical inner surface. Now, a shockwave generated by the detonator assembly **110** can travel axially unimpeded through the chamber **156**, exits at the outlet **154**, and ignite the booster charge **122**. The booster charge **122** detonates the detonating cord **124** or other device, which then initiates operation of the downhole tool **50**.

[0028] As used above, a high-order detonation is a detonation that produces high amplitude pressure waves (e.g., shock waves) and thermal energy. Likewise, a high-order explosive is an explosive formulated to generate a high-order detonation when detonated. In firing head assemblies, a high-order detonation occurs when a firing pin percussively impacts and detonates a detonator that includes a high-order explosive. The primary and secondary explosive bodies, as well as the activator, may use one or more high-explosives. Illustrative high-explosives include, but are not limited, to RDX (Hexogen,Cyclotrimethylenetrinltramine), HMX (Octagon, Cyclotetramethylenetetranitramine), HNS, and PYX.

[0029] As used above, "selective" means that activation of the downhole tool can occur only when the downhole tool is at a selected orientation relative to a vertical datum **102**. The selected orientation can be a range (e.g., at least thirty degrees offset from the vertical datum). As used above, the terms "activation" and "initiation" are used synonymously. As used above, a shockwave is a high amplitude pressure pulse. In some conventions, an orientation less than forty five degrees from vertical is considered a vertical or substantially vertical and an orientation of forty five degrees or greater from vertical is considered deviated or substantially. As used above, a vertical datum is a datum that is substantially parallel with the direction of gravitational pull (*e.g.*, plus or minus ten degrees).

[0030] In other embodiments, the detonator output interrupter **100** may be used to block other energy transfer systems. For example, the detonator output interrupter **100** could be used with an igniter and propellant system. In such an embodiment, a flame output from the igniter will be interrupted.

[0031] The foregoing description is directed to particular embodiments of the present disclosure for the purpose of illustration and explanation. It will be apparent, however, to one skilled in the art that many modifications and changes to the embodiment set forth above are possible without departing from the scope of the disclosure. It is intended that the following claims be interpreted to embrace all such modifications and changes.

CLAIMS

What is claimed is:

1. An apparatus for selectively activating a downhole tool in a wellbore by using a shockwave generated by a detonator assembly, comprising:

- an outer housing having a bore;

- an inner housing disposed in the bore of the outer housing, the inner housing including:

- a chamber having at least one canted surface;

- an inlet communicating with the chamber, the inlet positioned between the chamber and the detonator assembly,

- an outlet communicating with the chamber, the outlet positioned between the chamber and the downhole tool; and

- an energy blocker disposed in the chamber, the energy blocker being freely movable in the chamber as the inner housing changes orientation relative to a vertical datum, the energy blocker axially aligning with the inlet and the outlet when the inner housing is angularly offset less than a specified amount relative to the vertical datum.

2. The apparatus of claim 1, wherein the energy blocker is a spherical body.

3. The apparatus of claim 1, wherein the outer housing and the inner housing are cylindrical and the at least one surface has a conical shape.

4. The apparatus of claim 1, wherein the at least one canted surface is canted toward one of: (i) the inlet, and (ii) the outlet.

5. The apparatus of claim 1, wherein the chamber includes opposing surfaces that are substantially transverse to the vertical datum, wherein the at least one canted surface is formed on one of the opposing surfaces.

6. The apparatus of claim 1, wherein the chamber includes canted opposing surfaces that are substantially transverse to the vertical datum.

7. The apparatus of claim 1, wherein the energy blocker is formed of at least one of: (i) steel, (ii) metal, (iii) ceramic, (iv) plastic, and (iv) a composite.

8. An apparatus for use in a wellbore, comprising:
   - a detonator assembly having a firing head and an initiator, the detonator assembly being configured to generate a shock wave when activated;
   - detonator output interrupter connectable with the detonator assembly, the detonator output interrupter having:
     - an outer housing having a bore;
     - an inner housing disposed in the bore of the outer housing, the inner housing including:
       - a chamber having a first and a second opposing surface, each opposing surface being substantially transverse to a vertical datum, wherein at least one of the first and the second opposing surfaces is canted;
       - an inlet communicating with the chamber, the inlet positioned between the chamber and the detonator assembly and having an end terminating at the first opposing surface,
       - an outlet communicating with the chamber and having an end terminating at the second opposing face, and
       - an energy blocker disposed in the chamber, the energy blocker being freely movable in the chamber as the inner housing changes orientation relative to a vertical datum, the energy blocker blocking the generated shock wave by axially aligning with the inlet and the outlet when the inner housing is angularly offset less than a specified amount relative to the vertical datum; and

- a downhole tool connectable with the detonator output interrupter, the downhole tool being activated by a generated shock wave that is not blocked by the energy blocker.

9. The apparatus of claim 8, wherein: the energy blocker is a spherical body, the outer housing and the inner housing are cylindrical, and a conical shape defines at least one of the (i) first opposing surface, and (ii) the second opposing.

10. The apparatus of claim 8, wherein at least one of: (i) the first opposing surface is canted to the inlet, and (ii) the second opposing surface is canted toward the outlet.

11. The apparatus of claim 8, wherein the first opposing surface is canted to the inlet and the second opposing surface is canted toward the outlet.

12. The apparatus of claim 8, wherein the energy blocker is formed of at least one of: (i) steel, (ii) metal, (iii) ceramic, (iv) plastic, and (iv) a composite.

13. The apparatus of claim 8, wherein the downhole tool includes a bi-directional booster charge and a detonating cord.

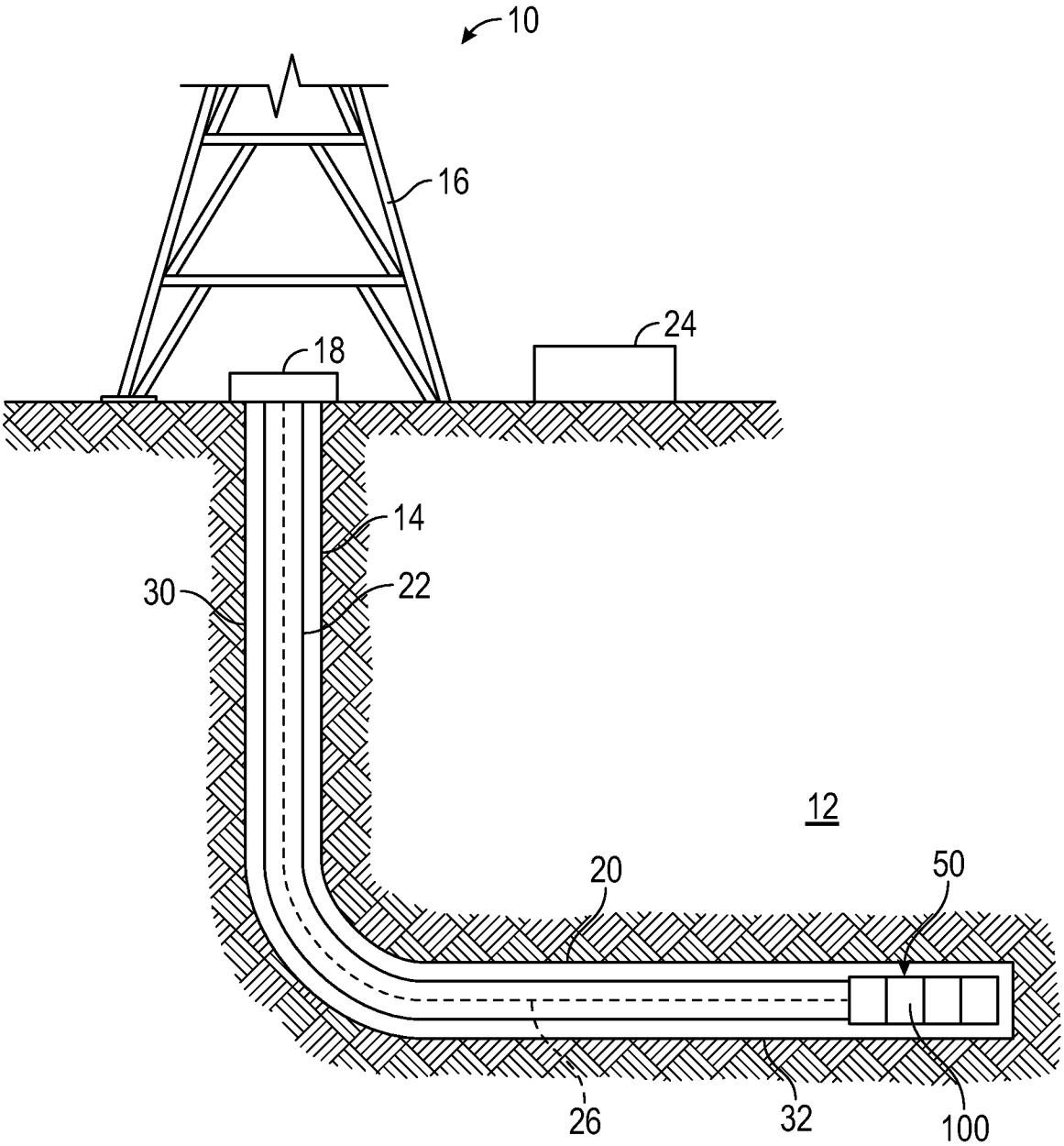

FIG. 1

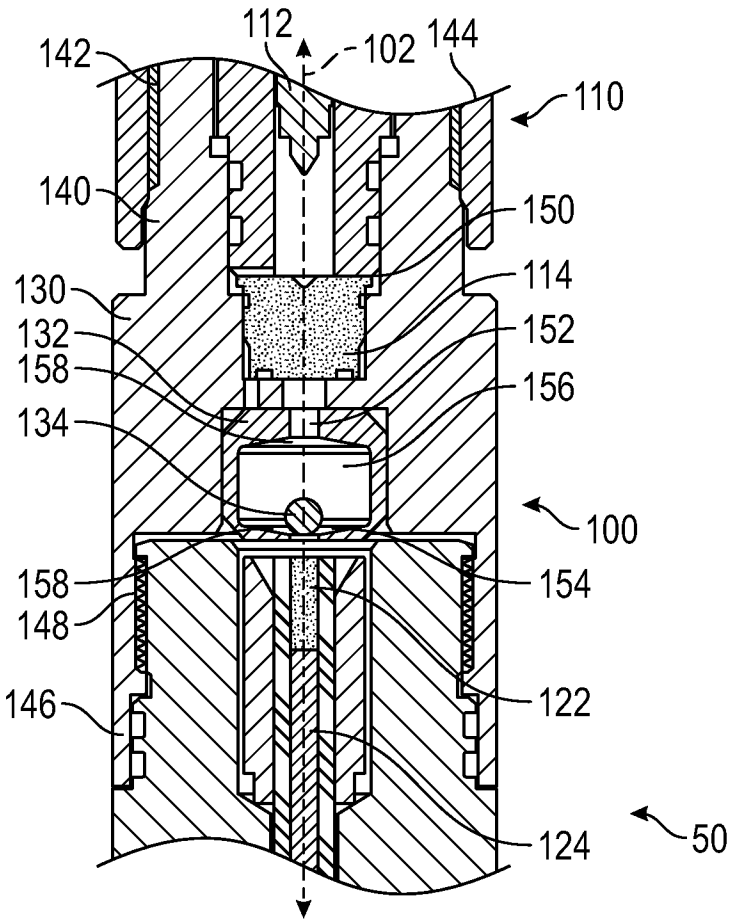
112
102
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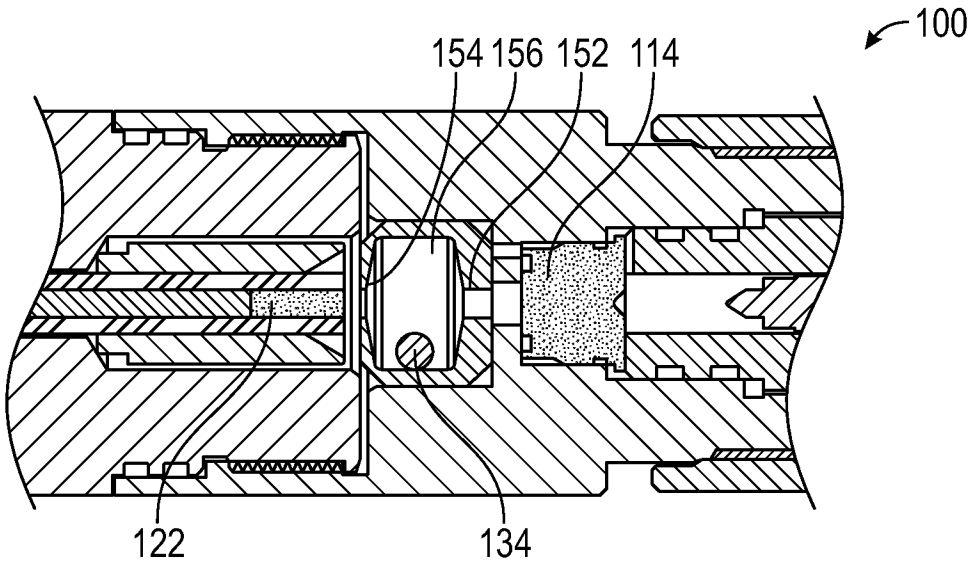
FIG. 2


100
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134

FIG. 3

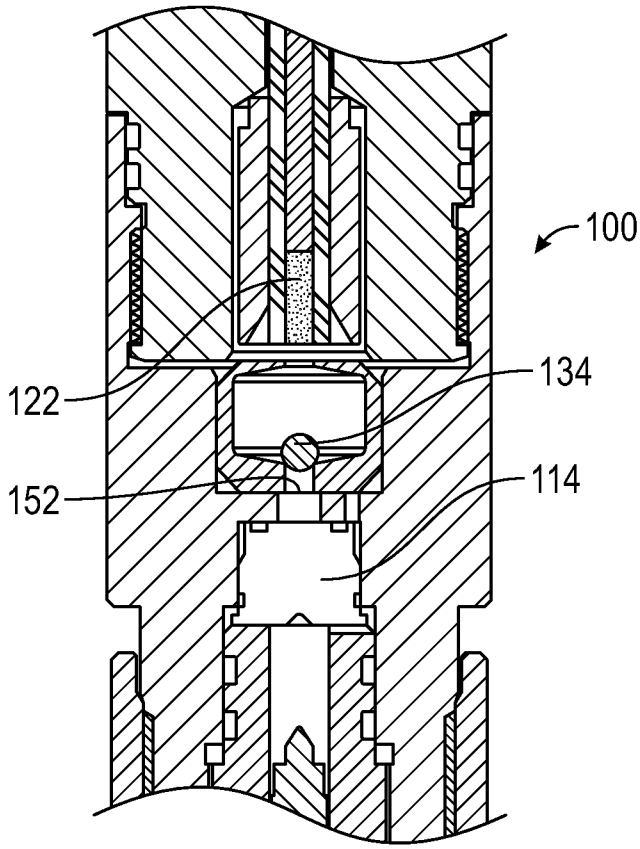

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/025144

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F42D 5/045 (2015.01)
CPC - F42D 5/045 (2015.05)
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)
IPC(8) - E21B 43/1185; F42D 1/02, 1/04, 1/08, 1/22, 5/04, 5/045 (2015.01)
CPC - E21B 43/1185; F42D 1/02, 1/043, 1/08, 1/22, 5/04, 5/045 (2015.05)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC - 102/314; 166/55, 57, 63, 297, 298, 299, 302; 175/4.54, 4.56, 321 (keyword delimited)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Orbit, Google Patents, Google Scholar.
Search terms used: wellbore, drill, downhole, detonator, energy, shock, wave, obstruct, block, absorb, interrupter, ball, axial, vertical, housing, igniter, freely, movable, angle, offset

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,346,014 A (ROSS) 13 September 1994 (13.09.1994) entire document	1-4, 7
Y	US 8,210,250 B2 (FERGUSON et al) 03 July 2012 (03.07.2012) entire document	1-4, 7
A	US 5,165,489 A (LANGSTON) 24 November 1992 (24.11.1992) entire document	1-13
A	US 2011/0284243 A1 (FRAZIER) 24 November 2011 (24.11.2011) entire document	1-13
A	US 7,363,967 B2 (BURRIS II et al) 29 April 2008 (29.04.2008) entire document	1-13

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

* 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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"P" document published prior to the international filing date but later than the priority date claimed
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"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
11 June 2015	01 JUL 2015
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (July 2009)