

WO 2015/050765 A1



SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, **Published:**
GW, KM, ML, MR, NE, SN, TD, TG).

— *with international search report (Art. 21(3))*

PCT PATENT APPLICATION
SUB-CALIBER SHAPED CHARGE PERFORATOR

Cross Reference to Related Application:

This application claims priority to U.S. Non-Provisional Application 14/045,529, filed October 3, 2013, the full disclosure of which is hereby incorporated by reference herein for all purposes.

Field of Invention

The present disclosure relates in general to a device for perforating a wellbore. More specifically, the present invention relates to a liner for a shaped charge having a liner inserted into a case, where a gap exists between the respective outer and inner diameters of the liner and case.

Description of Prior Art

Perforating systems are used for the purpose, among others, of making hydraulic communication passages, called perforations, in wellbores drilled through earth formations so that predetermined zones of the earth formations can be hydraulically connected to the wellbore. Perforations are needed because wellbores are typically lined with a string of casing and cement is generally pumped into the annular space between the wellbore wall and the casing. Reasons for cementing the casing against the wellbore wall includes retaining the casing in the wellbore and hydraulically isolating various earth formations penetrated by the wellbore. Sometimes an inner casing string is included that is circumscribed by the casing. Without the perforations

oil/gas from the formation surrounding the wellbore cannot make its way to production tubing inserted into the wellbore within the casing.

Perforating systems typically include one or more perforating guns connected together in series to form a perforating gun string, which can sometimes surpass a thousand feet of perforating length. The gun strings are usually lowered into a wellbore on a wireline or tubing, where the individual perforating guns are generally coupled together by connector subs. Included with the perforating gun are shaped charges that typically include a housing, a liner, and a quantity of high explosive inserted between the liner and the housing. When the high explosive is detonated, the force of the detonation collapses the liner and ejects it from one end of the charge at very high velocity in a pattern called a jet that perforates the casing and the cement and creates a perforation that extends into the surrounding formation. Each shaped charge is typically attached to a detonation cord that runs axially within each of the guns.

SUMMARY OF THE INVENTION

Provided herein are embodiments for perforating a wellbore. In one example, a shaped charge for use in perforating a wellbore is described that includes a case having an opening, a liner inserted into a space in the case and having an open end and an apex, explosive disposed between the liner and case, a hole in the apex of the liner, and a gap between an outer diameter of the open end of the liner and inner diameter of the opening in the case. The hole can optionally have a diameter that ranges from about 10 % to about 82% of an axial length of the liner. Optionally, an outer diameter of the open end of the liner ranges from about 60% to about 75% of an inner diameter of the opening of the case. In an example, the hole ranges from about 7 % of the liner outer diameter to about 60 % of the liner outer diameter. The shaped charge can be

SUBSTITUTE SHEET (RULE 26)

selectively retained within a gun tube by a coupling that is provided with the case. In an alternate embodiment, the shaped charge is selectively disposed in the wellbore within a perforating string. The shaped charge can further include a slot on an end of the case opposite the opening that selectively receives a detonating cord, and an initiator in a passage formed through the case between the detonating cord and the explosive. A protective covering may optionally be included in the gap and over the explosive.

Also disclosed herein is a shaped charge for use in perforating a wellbore that includes a case having an opening, a liner in the case, explosive between the liner and case, and a gap defined an outer diameter of the open end of the liner and inner diameter of the opening in the case, and having a diameter that ranges from about 60 % to about 75 % of the inner diameter of the opening in the case. A hole may be included in an apex of the liner. In this example, the hole has a diameter that ranges from about 29% to about 82% of a length of the liner. The case can be fitted with a coupling to selectively mount the shaped charge in a perforating string, and the perforating string can be disposed in the wellbore. Further in this example, detonating the explosive causes the liner to form a metal jet that penetrates into a formation adjacent the wellbore to form a perforation.

A method of perforating a wellbore is also provided herein that includes providing a shaped charge made up of a case having an opening, a liner inserted in the opening that comprises an apex, a hole in the apex, and an open end with an outer diameter spaced radially inward from an inner diameter of the opening to define an annular gap, and explosive between the liner and the case. The method further includes installing the shaped charge in a perforating gun, deploying the perforating gun in the wellbore, and detonating the explosive so that a detonation wave is generated that collapses the liner to form a metal jet that penetrates into a

wall of the wellbore and perforates the formation. In an example of the method, the outer diameter of the liner ranges from about 60% to about 75% of the inner diameter of the opening. In another embodiment of the method, the hole ranges from about 15% of the liner outer diameter to about 44% of the liner outer diameter. The perforating gun of the example method can be a part of a perforating string that is deployed on a line, and wherein a detonating signal is transmitted from surface through the line and to perforating gun. Further optionally in the method, the shaped charge is mounted into a gun tube that is inserted in the perforating gun.

BRIEF DESCRIPTION OF DRAWINGS

Some of the features and benefits of the present invention having been stated, others will become apparent as the description proceeds when taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a side sectional view of an example of a shaped charge in accordance with the present invention.

FIG. 2 is a side sectional view of an example of a perforating gun having the shaped charge of Figure 1.

FIG. 3 is a partial side sectional view of a perforating string in a wellbore made up of the perforating gun of Figure 2.

While the invention will be described in connection with the preferred embodiments, it will be understood that it is not intended to limit the invention to that embodiment. On the contrary, it is intended to cover all alternatives, modifications, and equivalents, as may be included within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF INVENTION

The method and system of the present disclosure will now be described more fully hereinafter with reference to the accompanying drawings in which embodiments are shown. The method and system of the present disclosure may be in many different forms and should not be construed as limited to the illustrated embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey its scope to those skilled in the art. Like numbers refer to like elements throughout.

It is to be further understood that the scope of the present disclosure is not limited to the exact details of construction, operation, exact materials, or embodiments shown and described, as modifications and equivalents will be apparent to one skilled in the art. In the drawings and specification, there have been disclosed illustrative embodiments and, although specific terms are employed, they are used in a generic and descriptive sense only and not for the purpose of limitation. Examples exist wherein the term “about” when used in conjunction with a cited value, defines the scope of the cited value to range from a value that is less than the cited value by an amount that is 5% of the cited value, and/or greater than the cited value by an amount that is 5% of the cited value. Ranges may be expressed herein as from about one particular value, and/or to about another particular value. When such a range is expressed, it is to be understood that another embodiment is from the one particular value and/or to the other particular value, along with all combinations within said range.

Shown in side sectional view is one example of a shaped charge 10 that is made up of a shaped charge case 12 and having an opening 13 on one end that opens up into a space within the case 12. A thin walled liner 14 shown inserted into the opening 13 and having an apex A

SUBSTITUTE SHEET (RULE 26)

directed towards a closed end of the space within the case 12. An open end 15 of liner 14, which is opposite apex A, is a plane that is generally parallel with a plane in which the opening 13 is disposed. The liner can be formed from a composition of particles pressed and held together with a ductile or malleable binder. A non-exhaustive list of particle material includes tungsten, molybdenum, depleted uranium, hafnium, copper, bismuth, tantalum, and combinations thereof. A non-exhaustive list of binder materials includes bismuth, zinc, tin, uranium, silver, gold, antimony, cobalt, copper, zinc alloys, tin alloys, nickel, copper, tungsten, palladium, and combinations thereof.

An explosive 16 is shown provided in the space within the case 12 and between an outer surface of the liner 14 and inner surface of space. Examples of explosives include compositions sold under trade designations HMX, HNS, RDX, HNIW, PYX and TNAZ. A hole 18 is shown formed through the liner 14 and proximate apex A. Example holes 18 can have a shape that is curved, circular, elliptical, and alike. A protective covering 20 is shown over the portion of the explosive 16 exposed to hole 18. In the example of Figure 1, the outer diameter of the liner OD_L is shown set radially inward (with respect to axis A_X) from an inner diameter from the case ID_C . The difference in length between the OD_L and ID_C defines a gap G that circumscribes an outer periphery of the liner 14 and adjacent its open end 15. Optionally, a protective covering 22 is laid over the portion of the explosive 16 and at the surface of gap G.

A detonating cord 24 is shown for providing detonation of explosive 16 within case 12 where a booster charge 26 is shown extending through the end of the case 12 and from the closed end of space and to adjacent the detonation cord 24. A slot 25 is formed in the end of the case 12 opposite its opening 13 and provides a place for insertion and retention of the detonation cord 24.

SUBSTITUTE SHEET (RULE 26)

In the example of Figure 1, the offset between the outer diameter of liner OD_L and inner diameter of case ID_C defines what is sometimes referred to as a sub-caliber charge. In this example, the liner outer diameter OD_L can range from about 60% to about 75% of the charge case inner diameter ID_C . Optionally, the diameter of hole 18 can have a value that ranges from about 29% to about 82% of a length L of liner 14. An advantage of the configuration of liner 14 is that more control of the distribution of material of liner 14 into the jet is accomplished.

Shown in Figure 2 is a side sectional view of a plurality of shaped charges 10 disposed within an annular gun tube 27, which is in turn inserted within an annular gun body 28. The shaped charges 10 are oriented so the openings 13 of the cases 12 are oriented in a direction generally radially outward from an axis of the gun tube 27. Further illustrated is the detonation cord 26 extending between adjacent shaped charges 10, so that by forming a detonation wave in one end of the detonation cord 26, the detonation wave can be passed through each of the shaped charges 10 to which the detonating cord 24 is attached. The combination of the shaped charges 10 and gun tube 27 inserted with the perforating gun body 28 forms a perforating gun 29. In one example, a coupling 30 may be provided on an outer surface of a shaped charge 10 (Figure 1) for maintaining the shaped charge 10 within gun tube 27.

Referring now to Figure 3, a stack of perforating guns 29 is shown coupled together to form a perforating string 31 which is inserted within a wellbore 32. Operation of detonation of the shaped charges 10 within the perforating string 29 can be controlled within a surface truck 34 on surface. In this example, signals generated within the surface truck 34 are sent via a line 36, from which the perforating string 29 is deployed within the wellbore 32. Example embodiments of the line 36 include wireline, slick line, coiled tubing, and cable. In the example of Figure 3, the line 36 is extended through a wellhead assembly 38 shown mounted at the mouth of the

wellbore 32. By sending a signal from surface truck to wire line 36, detonating charges and detonating waves may be initiated in the perforating cord 24 (Figure 2) for initiating detonation of explosive within the shaped charges 10 and that form metal jets 39 that project into a formation 40 adjacent wellbore 32. By initiating and forming the metal jets 39 and directing them into formation 40, perforations 42 are formed within formation 40 and for allowing fluid flow from formation 40 into wellbore 32.

The present invention described herein, therefore, is well adapted to carry out the objects and attain the ends and advantages mentioned, as well as others inherent therein. While a presently preferred embodiment of the invention has been given for purposes of disclosure, numerous changes exist in the details of procedures for accomplishing the desired results. These and other similar modifications will readily suggest themselves to those skilled in the art, and are intended to be encompassed within the spirit of the present invention disclosed herein and the scope of the appended claims.

CLAIMS

What is claimed is.

1. A shaped charge for use in perforating a wellbore comprising:
 - a case having an opening;
 - a liner inserted into a space in the case and having an open end and an apex;
 - explosive disposed between the liner and case;
 - a hole in the apex of the liner; and
 - a gap between an outer diameter of the open end of the liner and inner diameter of the opening in the case.
2. The shaped charge of claim 1, wherein the hole has a diameter that ranges from about 10 % to about 82% of an axial length of the liner.
3. The shaped charge of claim 1, wherein an outer diameter of the open end of the liner ranges from about 60% to about 75% of an inner diameter of the opening of the case.
4. The shaped charge of claim 1, wherein the hole ranges from about 7 % of the liner outer diameter to about 60 % of the liner outer diameter.
5. The shaped charge of claim 1, wherein the shaped charge is selectively retained within a gun tube by a coupling that is provided with the case.
6. The shaped charge of claim 1, wherein the shaped charge is selectively disposed in the wellbore within a perforating string.

SUBSTITUTE SHEET (RULE 26)

7. The shaped charge of claim 1, further comprising a slot on an end of the case opposite the opening that selectively receives a detonating cord, and an initiator in a passage formed through the case between the detonating cord and the explosive.
8. The shaped charge of claim 1, further comprising a protective covering in the gap and over the explosive.
9. A shaped charge for use in perforating a wellbore comprising:
 - a case having an opening;
 - a liner in the case;
 - explosive between the liner and case; and
 - a gap defined by an outer diameter of the open end of the liner and inner diameter of the opening in the case, and having a liner diameter that ranges from about 60 % to about 75 % of the inner diameter of the opening in the case.
10. The shaped charge of claim 9, further comprising a hole in an apex of the liner.
11. The shaped charge of claim 10, wherein the hole has a diameter that ranges from about 29% to about 82% of a length of the liner.
12. The shaped charge of claim 9, wherein the case is fitted with a coupling to selectively mount the shaped charge in a perforating string, and wherein the perforating string is disposed in the wellbore, and wherein detonating the explosive causes the liner to form a metal jet that penetrates into a formation adjacent the wellbore to form a perforation.
13. A method of perforating a wellbore comprising:

- a. providing a shaped charge that comprises a case having an opening, a liner inserted in the opening that comprises an apex, a hole in the apex, and an open end with an outer diameter spaced radially inward from an inner diameter of the opening to define an annular gap, and explosive between the liner and the case;
 - b. installing the shaped charge in a perforating gun;
 - c. deploying the perforating gun in the wellbore; and
 - d. detonating the explosive so that a detonation wave is generated that collapses the liner to form a metal jet that penetrates into a wall of the wellbore and perforates the formation.
14. The method of claim 13, wherein the outer diameter of the liner ranges from about 60% to about 75% of the inner diameter of the opening.
15. The method of claim 13, wherein the hole ranges from about 15% of the liner outer diameter to about 44% of the liner outer diameter.
16. The method of claim 13, wherein the perforating gun is part of a perforating string that is deployed on a line, and wherein a detonating signal is transmitted from surface through the line and to perforating gun.
17. The method of claim 13, wherein the shaped charge is mounted into a gun tube that is inserted in the perforating gun.

1/3

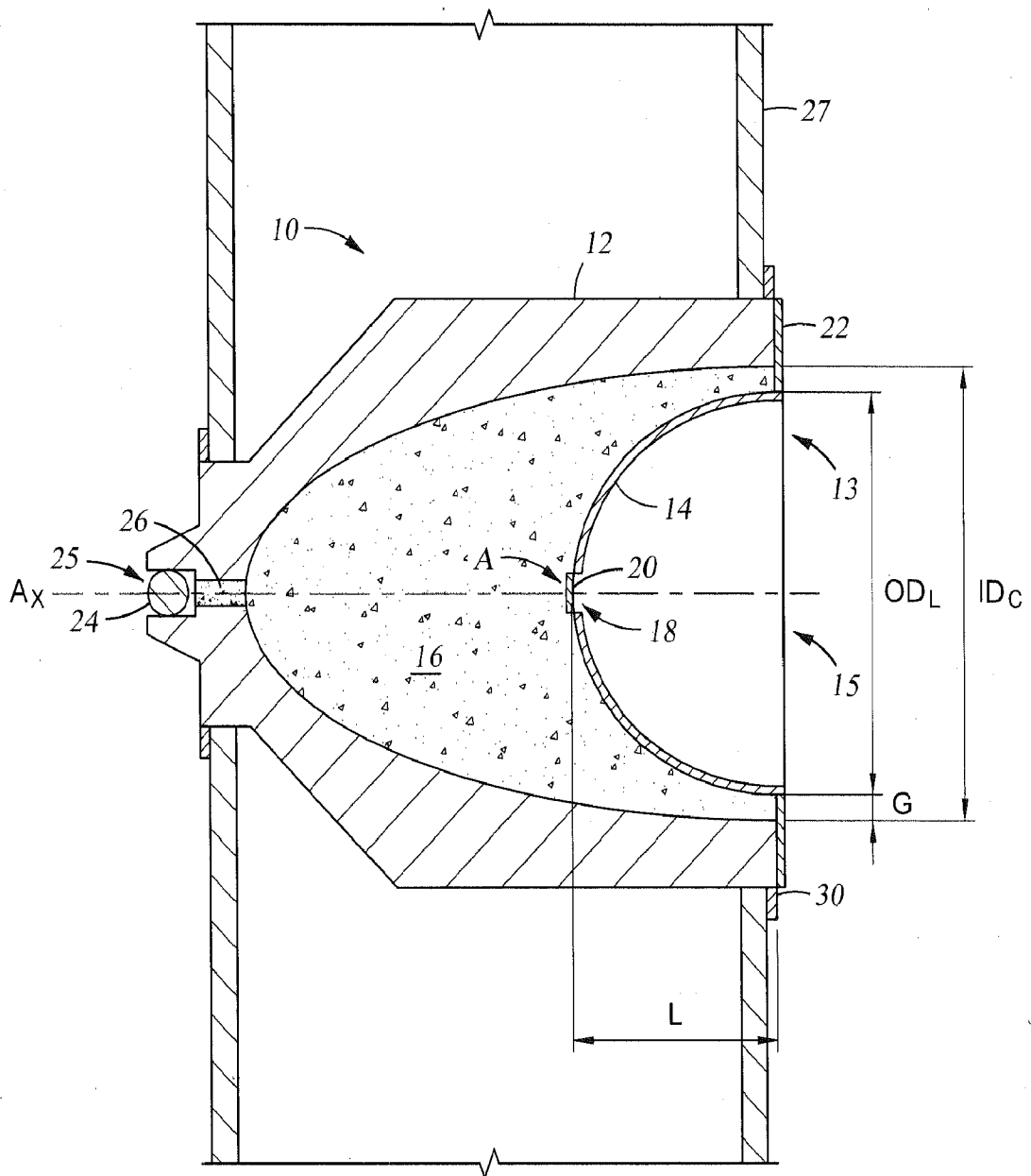


Fig. 1

SUBSTITUTE SHEET (RULE 26)

Fig. 2

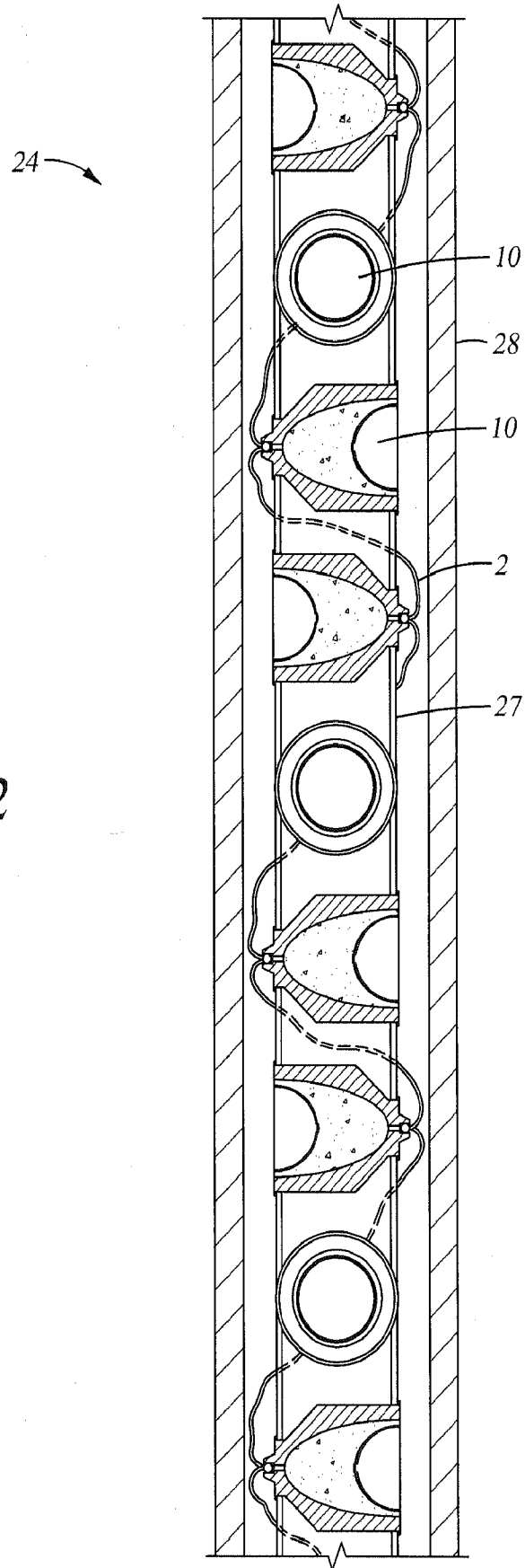
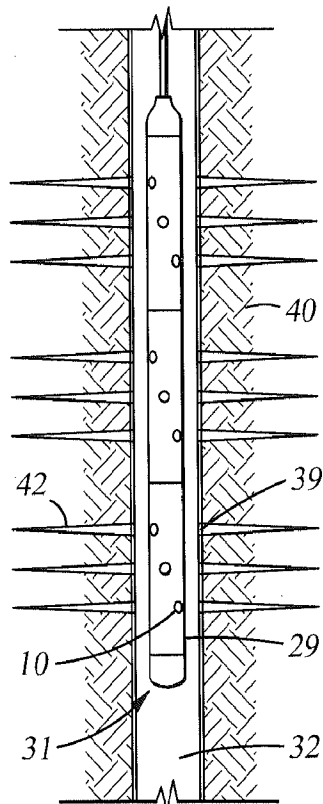
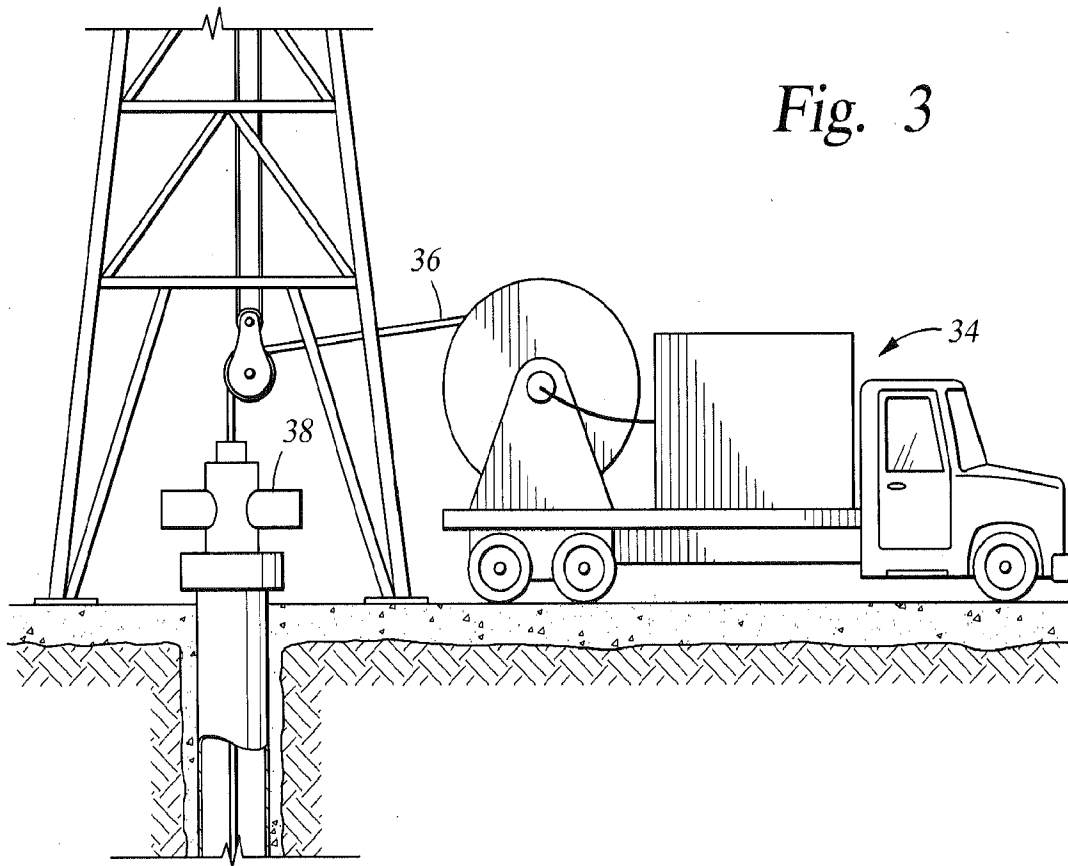


Fig. 3



SUBSTITUTE SHEET (RULE 26)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/057334**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 1/028; F42B 3/08; E21B 43/117; F42B 12/18; F42B 1/02; 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: shaped charge, diameter, liner, explosive, space, gap, hole, opening, slot and gap

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 7493861 B1 (WALTERS, WILLIAM P.) 24 February 2009 See column 2, lines 41-66 and figure 1.	1-17
Y	EP 1286124 A1 (HALLIBURTON ENERGY SERVICES, INC.) 26 February 2003 See paragraph [0044] and figure 1.	1-8, 10-11, 13-17
Y	US 5847312 A (WALTERS et al.) 08 December 1998 See column 3, lines 6-12 and figure 1.	3, 9-12, 14
A	US 2013-0061771 A1 (BETANCOURT et al.) 14 March 2013 See paragraphs [0018]-[0026]; claims 8-12; and figures 2-3.	1-17
A	US 2009-0235836 A1 (PRATT et al.) 24 September 2009 See paragraphs [0022]-[0030] and figures 1-4.	1-17



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

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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

08 January 2015 (08.01.2015)

Date of mailing of the international search report

08 January 2015 (08.01.2015)

Name and mailing address of the ISA/KR

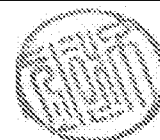
International Application Division
Korean Intellectual Property Office
189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan City, 302-701,
Republic of Korea

Facsimile No. +82-42-472-7140

Authorized officer

CHOI, Hyun Goo

Telephone No. +82-42-481-8288



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/057334

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 7493861 B1	24/02/2009	None	
EP 1286124 A1	26/02/2003	None	
US 5847312 A	08/12/1998	None	
US 2013-0061771 A1	14/03/2013	DE 112012003804 T5 GB 201401545 D0 GB 2510714 A NO 20140136 A WO 2013-040003 A2 WO 2013-040003 A3	10/07/2014 19/03/2014 13/08/2014 11/02/2014 21/03/2013 02/05/2013
US 2009-0235836 A1	24/09/2009	EP 1682846 A2 EP 1682846 A4 EP 1682846 B1 EP 2439482 A2 EP 2439482 A3 US 2005-0115448 A1 US 7712416 B2 WO 2005-103602 A2 WO 2005-103602 A3	26/07/2006 29/07/2009 15/01/2014 11/04/2012 05/12/2012 02/06/2005 11/05/2010 03/11/2005 16/02/2006