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(54) Title: PASSIVELY ORIENTATED GUN FOR PLUG AND ABANDONMENT APPLICATIONS

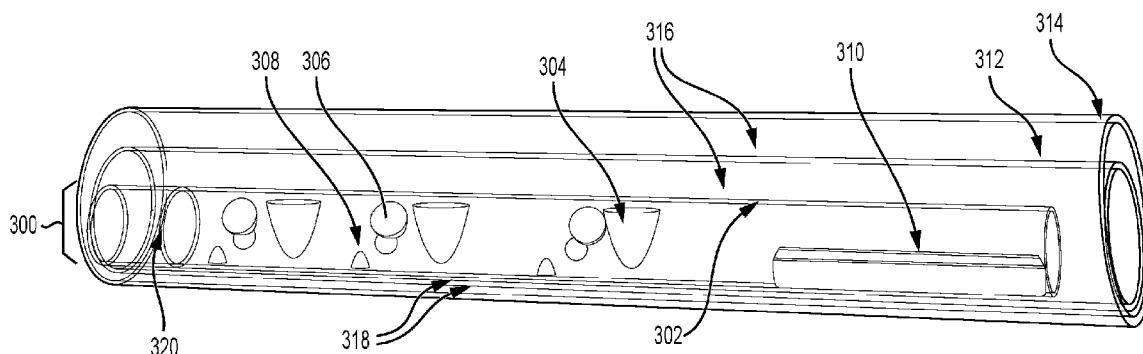


FIG. 3A

(57) Abstract: Systems and methods presented herein provide for a perforating gun for use in well decommissioning. A carrier for well decommissioning can comprise a perforating gun that includes multiple sizes of gun charges and a weighted spacer. The smallest gun charges can be linearly aligned with the weighted spacer in the perforated gun. The largest gun charges can be positioned opposite the smallest charges. The perforating gun can connect to another component of the carrier with a swivel assembly that allows the perforating gun to freely rotate within the wellbore in reference to the carrier. When lowered into a nonvertical wellbore, the weighted spacer can cause the perforating gun to rotate so that the smallest charges face downward and the largest charges face upward.



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PASSIVELY ORIENTATED GUN FOR PLUG AND ABANDONMENT APPLICATIONS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority benefit of U.S. Provisional Application No. 63/477469, filed December 28, 2022, the entirety of which is incorporated by reference herein and should be considered part of this specification.

BACKGROUND

[0002] Downhole mechanical service tools allow for performing operations within a wellbore. When it is time to decommission the well, casing and tubular elements might remain present in the wellbore. It may be difficult or even impossible to remove the casing and tubular elements as part of the decommissioning.

[0003] Perforating charges and mechanical cutters today are typically conveyed in the wellbore on either slickline, wireline, or coiled tubing. Although today live depth control has become common practice in well interventions, limited control is available for the positioning of a gunstring or mechanical tool within the primary tubular element that the toolstring is conveyed in.

[0004] As a result, the ability for the charges or mechanical cutter to create the necessary flow area (e.g., tunnel or slot) is impacted by the lack of control and precision of the toolstring. This might result in an ineffective conduit for fluid. This can also potentially lead to the destruction of other elements present in the construction of the well (e.g., another casing or jewelry element). Such other elements may be inadvertently cut as a consequence of the improper placement of the perforating charge or the mechanical cutter. Conversely, the inability

to control the positioning of the bottomhole assembly may prevent the successful cut of specific parts of the wellbore in a surgical manner (e.g., selectively severing the control lines behind a tubing without entirely cutting the tubing in a full 360-dega cut).

[0005] To advance the application of well decommissioning without the removal of the tubing string deployed in a well, new ways of orienting bottom assemblies are needed.

SUMMARY

[0006] Systems and methods are described herein for a passively orientating a perforated gun to optimize hole size in perforating gun systems, such as perforate, wash, and concrete ('PWC') and perforate, jet, and cement ('PJC') systems. In one example, a perforated gun can be orientated passively in the wellbore. For example, the perforated gun can have smaller charges facing one side and, moving radially around the gun, progressively larger charges facing the opposite side. A weighted spacer can passively orient the perforated gun in the wellbore. For example, the weighted spacer can be linearly aligned in the perforated gun with the smallest charges. In a nonvertical wellbore, the weight of the weighted spacer causes the perforated gun to rotate so that the smaller charges face the low side of the wellbore where the standoff gap (the distance between the outside casing and the wellbore wall) is smallest. The larger charges face the higher side of the wellbore where the standoff gap is greatest. In another example, the perforated gun can be passively oriented using rollers, such as PETROMAC rollers.

[0007] The perforated gun can run below the washing section of a PWC assembly and be decoupled by a swivel assembly. The system can provide for delivery of a PWC assembly, which can include the aforementioned perforated gun.

[0008] Passively orienting a perforated gun as described herein allows the perforated gun to be customized for maximum entrance hole size while preventing damage to other tubing and casing strings as required.

[0009] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the embodiments, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The accompanying drawings, which are incorporated in and constitute a part of this disclosure, illustrate various embodiments and aspects of the present invention. In the drawings:

[0011] FIG. 1 is an example illustration of a perforating gun positioned in an openhole wellbore.

[0012] FIG. 2 is an example illustration of a perforating gun system for use in generating a transient underbalanced condition in an openhole wellbore.

[0013] FIG. 3A is an example illustration of a vertical cross section of a passively oriented perforating gun.

[0014] FIG. 3B is an example illustration of a horizontal cross section of a passively oriented perforating gun.

[0015] FIG. 4 is an example flowchart of a method for well decommissioning.

DESCRIPTION OF THE EXAMPLES

[0016] Reference will now be made in detail to the present exemplary examples, including examples illustrated in the accompanying drawings. Wherever possible, the same

reference numbers will be used throughout the drawings to refer to the same or like parts. The described examples are non-limiting.

[0017] In the specification and appended claims: the terms “connect”, “connection”, “connected”, “in connection with”, and “connecting” are used to mean “in direct connection with” or “in connection with via another element”; and the term “set” is used to mean “one element” or “more than one element”. As used herein, the terms “up” and “down”, “upper” and “lower”, “upwardly” and “downwardly”, “upstream” and “downstream”, “above” and “below”; and other like terms indicating relative positions above or below a given point or element are used in this description to more clearly described some embodiments of the invention. However, when applied to equipment and methods for use in wells that are deviated or horizontal, such terms may refer to a left to right, right to left, or other relationship as appropriate.

[0018] Generally, tools, systems, and methods are provided for perforating in openhole completions to maximize wellbore and matrix cleanup efficiency (by loosening and/or removing filtercake formed on the openhole wellbore, penetrating into the underlying formation, and enlarging the effective radius of the wellbore past any drilling damage), connect natural fractures, and/or enable application of drilling fluid technology in difficult subsurface environments. The openhole perforating system of the present invention can be used for any hydrocarbon bearing formations with any lithology. In some examples of the present invention, an openhole wellbore may be perforated to remove filtercake in an underbalanced, overbalanced, or near-balanced well environment.

[0019] Systems and methods presented herein provide for a perforating gun for use in well decommissioning. A carrier for well decommissioning can comprise a perforating gun that includes multiple sizes of gun charges and a weighted spacer. The smallest gun charges can be

linearly aligned with the weighted spacer in the perforated gun. The largest gun charges can be positioned opposite the smallest charges. The perforating gun can connect to another component of the carrier with a swivel assembly that allows the perforating gun to freely rotate within the wellbore in reference to the carrier. When lowered into a nonvertical wellbore, the weighted spacer can cause the perforating gun to rotate so that the smallest charges face downward and the largest charges face upward.

[0020] FIG. 1 is an example illustration of a perforating gun 10 positioned in an openhole (non-cased) wellbore 20 having a producing formation 22 coated in filtercake 24. In another embodiment, the perforating gun is intended to be run through tubing (not shown). The perforating gun 10 may include a sealed gun carrier 12 (or other sealed chamber) and one or more shaped charges 14 arranged therein. The gun carrier 12 may be attached to an adapter 30 that is in turn connected to a carrier line 40 for suspending and carrying the perforating gun 10 into the openhole wellbore 20. The carrier line 40 may include, but is not limited to, a wireline, a slickline, e-line, drill pipe, or coiled tubing. The gun carrier 12 is sealed to generate a pressure differential in which the internal pressure of the carrier is less than the surrounding wellbore pressure. In operation the perforating gun 10 is lowered on a carrier line 40 through the wellbore 20 and positioned adjacent or proximate the surrounding formation 22. To assist in removal of the filtercake 24, the perforating gun 10 is ignited. In one example, the gun carrier 12 is configured with a linear displacement measurement (not shown) sensor that collects data.

[0021] FIG. 2 illustrates a perforating gun 10 configured with shaped charges 14 (or other explosive charges) for penetrating the only the sealed gun carrier 12 and not the surrounding formation 22. The perforating gun 10 can also be configured with shaped charges 14 (or other explosive charges) for penetrating the sealed gun carrier 12 and the surrounding

formation 22. In both examples, once the gun carrier 12 is ruptured, the transient underbalanced pressure differential between the surrounding wellbore and the volume within the gun carrier causes a surge to break or otherwise remove the filtercake 24 from the wellbore 20.

[0022] FIG. 3A is an example illustration of a vertical cross section of a passively oriented perforating gun 300, and FIG. 3B is an example illustration of a horizontal cross section of the same passively oriented perforating gun 300. The perforating gun 300 can run below a washing section (not shown) of a PWC assembly. The perforating gun 300 can include a gun housing 302. In one example, the gun housing 302 can connect to the washing section with a swivel assembly 320.

[0023] Within the housing 302, the perforating gun 300 can include charges of varying sizes. For example, the perforating gun 300 includes large charges 304, medium charges 306, and small charges 308. Although FIGs. 3A and 3B include three charge sizes, this is merely exemplary and not meant to be limiting in any way. For example, the perforating gun 300 can include two charges or more than three charges.

[0024] The perforating gun 300 can include a weighted spacer 310. The weighted spacer 310 can be a solid material that creates an uneven weight distribution of perforating gun 300 such that, if able to rotate freely in a horizontal orientation, the gun housing 302 settles with the weighted spacer 310 facing downward. This orientation is illustrated in FIGs. 3A and 3B. The small charges 308 can be linearly aligned with the weight spacer 310 in the gun housing 302 as shown. The large charges 304 can be aligned opposite the weighted spacer 310 as shown. Any another sized medium charges 306 can be radially oriented between the small charges 308 and large charges 304 based on their size. For example, charges can grow in size in a radial direction from the alignment of the small charges 308 to the large charges 304.

[0025] The perforating gun 300 is shown positioned within two layers of casings, an inner casing 312 and an outer casing 314. This is merely exemplary, and the perforating gun 300 can be inserted into a wellbore with no casings, a single casing, or more than two casings, for example. The inner casing 312 and outer casing 314 can be pipes that are assembled and inserted into a wellbore. Particularly in a nonvertical wellbore, the inner casing 312 passively rests against the low side of the outer casing 314, and the perforating gun 300 passively rests against the low side of the inner casing 312. As used herein, the term “low side” refers to a portion of a component, such as a casing or perforating gun, facing downward in the direction of the Earth’s gravitation force. The term “high side” refers to a portion of a component facing upward in the opposite the Earth’s gravitation force.

[0026] With the inner casing 312 and the perforating gun 300 passively resting on the low sides, this creates a large annular standoff gap 316 on the high side and a small annular standoff gap 318 on the low side. The standoff gaps increase moving radially from the small annular standoff gap 318 to the large annular standoff gap 316. The weighted spacer 310 causes the perforating gun 300 to passively orient itself with the small charges 308 facing the low side where they have to shoot across the small annular standoff gap 318. The large charges 304 become oriented facing the high side where they have to shoot across the large annular standoff gap 316. Medium charges 306 are oriented facing a standoff gap that is smaller than the large annular standoff gap 316 and larger than the small annular standoff gap 318. In other words, weighted spacer 310 causes the perforating gun 300 to orient itself so that the charges 304, 306, and 308 face an annular standoff gap 316, 318 proportional to their charge size.

[0027] FIG. 4 is an example flowchart of a method for well decommissioning. At stage 410, a carrier with a PWC assembly can be lowered into a wellbore. The carrier can be attached

to a slickline, wireline, coiled tubing, or other line. An operator can control the lowering of the carrier. In an example, a roller assembly of the carrier can assist in traversing downward through the wellbore and around obstacles.

[0028] At stage 420, the perforating gun can passively orient itself in the wellbore. For example, the wellbore can be nonvertical in reference to the Earth's gravitational pull. A weighted spacer in the perforating gun can cause the perforating gun to rotate until the weighted spacer is at the low side of the wellbore. The perforating gun can have small charges oriented in line with the weighted spacer so that they also face the low side. The perforating gun can have large charges facing the high side. The perforating gun can also have other sized charges facing other directions based on their size and the annular standoff gap.

[0029] In some examples, a roller assembly can be used to orient, or assist in orienting, the perforating gun. For example, an operator can control the roller assembly and move the perforating gun into position. With a roller assembly, the operator can move the perforating gun longitudinally and around its central axis.

[0030] When the perforating gun is in position, at stage 430, the perforating charges can be ignited. For example, this can be done by an operator at the surface who can perform an action that sends a signal to the perforating gun that causes the charges to ignite.

[0031] Other embodiments of the invention will be apparent to those skilled in the art from consideration of the specification and practice of the invention disclosed herein. It is understood that the control functionality can be carried out by a processor-enabled device, which can be separate from or part of the slot cutter, depending on the example. Also, the terms slot cutter and cutting device are used interchangeably. It is intended that the specification and

examples be considered as exemplary only, with a true scope and spirit of the invention being indicated by the following claims.

WHAT IS CLAIMED IS:

1. A perforating gun for well decommissioning, comprising:
a tubular housing;
a weighted spacer;
first gun charges of a first size linearly aligned with the weighted spacer inside the tubular housing; and
second gun charges of a second size, the size of the second gun charges being larger than the size of the first gun charges, wherein the second gun charges are positioned opposite the first gun charges inside the tubular housing.
2. The perforating gun of claim 1, wherein the perforating gun is connected to a washing section of a perforate, wash, and concrete ('PWC') assembly.
3. The perforating gun of claim 2, wherein the perforating gun is connected to the PWC assembly by a swivel assembly that allows the perforating gun to rotate relative to the PWC assembly.
4. The perforating gun of claim 2, wherein the PWC assembly is attached to one of a slickline, wireline, and coiled tubing.
5. The perforating gun of claim 1, further comprising third gun charges of a third size, the size of the third gun charges being larger than the size of the first gun charges and smaller than the size of the second gun charges.

6. The perforating gun of claim 2, wherein the third gun charges are radially positioned inside the tubular housing between the first gun charges and the second gun charges.
7. The perforating gun of claim 1, wherein the weighted spacer abuts a portion of an inner surface of the tubular housing.
8. A method for well decommissioning, comprising:
lowering a carrier with a perforating gun into a nonvertical wellbore, wherein the
perforating gun passively orients itself using a weighted spacer and a swivel
assembly;
detonating perforating charges in the perforating gun.
9. The method of claim 8, wherein the perforating gun comprises:
a tubular housing,
first gun charges of a first size linearly aligned inside the tubular housing with the
weighted spacer;
second gun charges of a second size, the size of the second gun charges being larger than
the size of the first gun charges, wherein the second gun charges are positioned
opposite the first gun charges inside the tubular housing.
10. The method of claim 8, wherein the perforating gun passively orients itself by allowing a
gravitation force to rotate the perforating gun such that the weighted spacer and the first

gun charges face a low side of the perforating gun, and the second charges face a high side of the perforating gun.

11. The method of claim 10, wherein a swivel assembly connected to the perforating gun allows the perforating gun to freely rotate within the wellbore.
12. The method of claim 8, the carrier comprising a roller assembly that assists the carrier in traversing downward through the wellbore and around obstacles.
13. The method of claim 12, wherein the roller assembly is on an opposite side of the carrier from the perforating gun.
14. The method of claim 8, wherein the carrier is attached to one of a slickline, wireline, and coiled tubing.
15. A system for decommissioning a well, comprising:
 - a carrier that includes a perforating gun, the perforating gun comprising:
 - a tubular housing;
 - a weighted spacer;
 - first gun charges of a first size linearly aligned with the weighted spacer inside the tubular housing; and
 - second gun charges of a second size, the size of the second gun charges being larger than the size of the first gun charges, wherein the second gun charges are positioned opposite the first gun charges inside the tubular housing;

a cable configured to lower the carrier within a wellbore; and
a control unit for lowering the carrier into the wellbore and igniting the first and second charges.

16. The system of claim 15, wherein carrier further includes a perforate, wash, and concrete ('PWC') assembly, the perforating gun being connected to a lower end of a washing section of the PWC.
17. The system of claim 16, wherein the perforating gun connects to the washing section of the PWC assembly by a swivel assembly that allows the perforating gun to rotate freely within the wellbore relative to the PWC assembly.
18. The system of claim 15, wherein the carrier is attached to one of a slickline, wireline, and coiled tubing.
19. The system of claim 15, the carrier further including a roller assembly that assists the carrier in traversing downward through the wellbore and around obstacles.
20. The system of claim 15, wherein the weighted spacer abuts a portion of an inner surface of the tubular housing.

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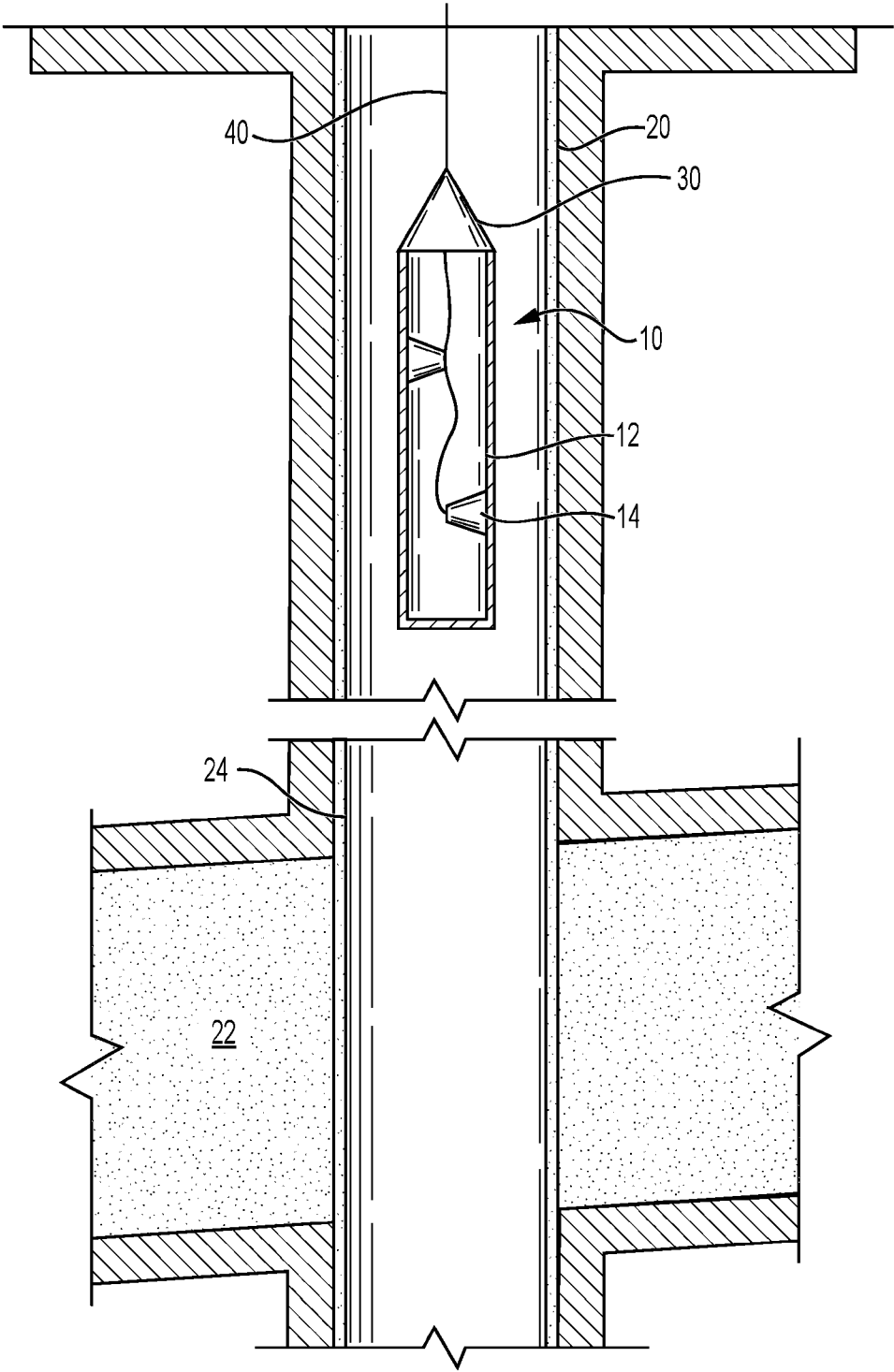


FIG. 1

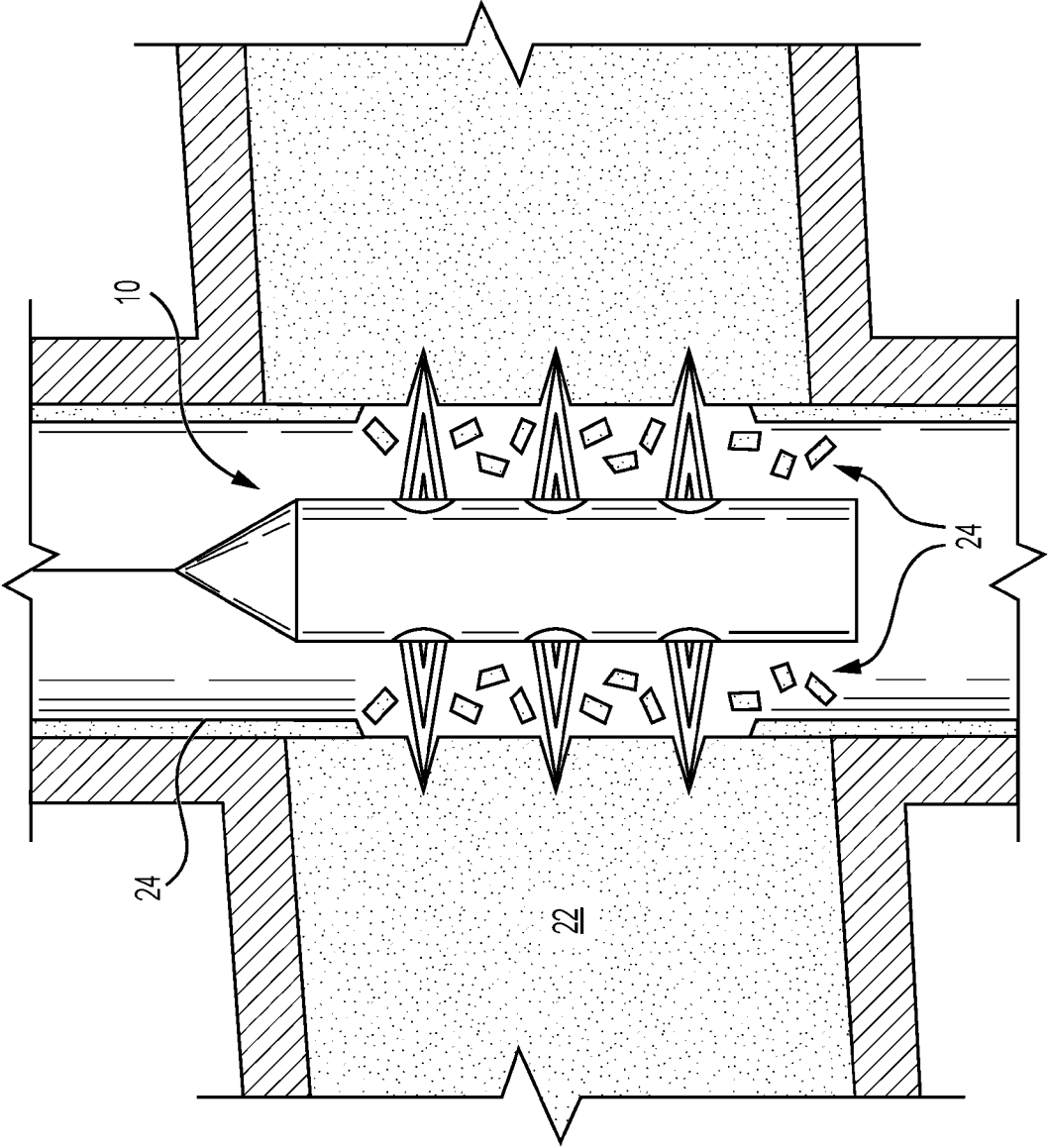


FIG. 2

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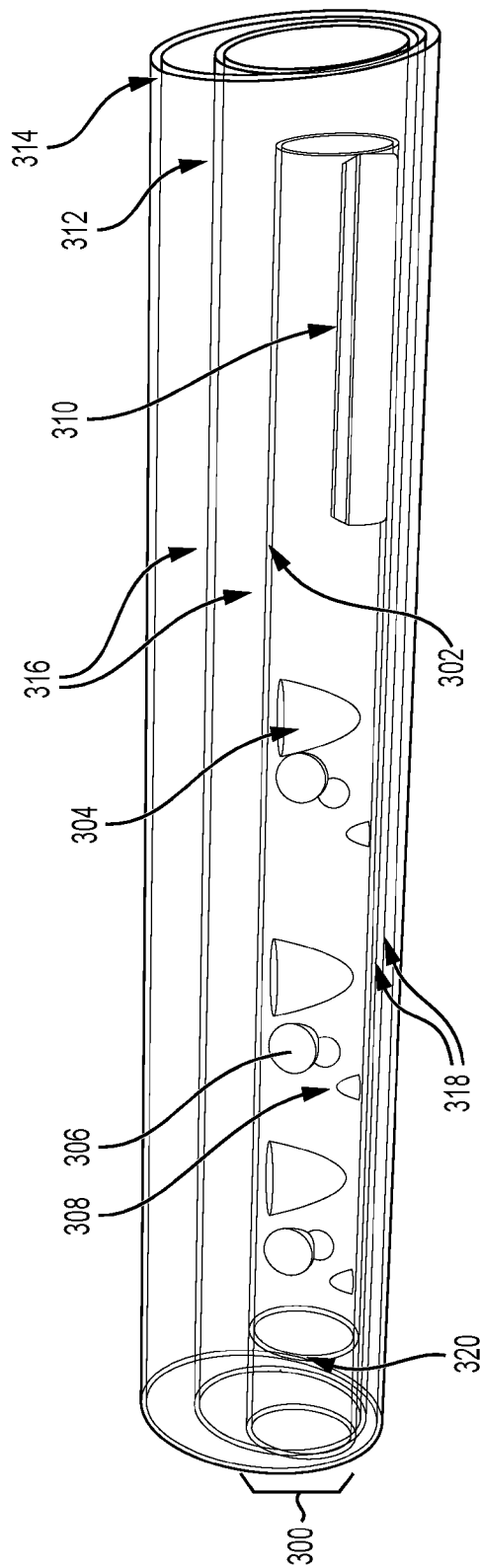


FIG. 3A

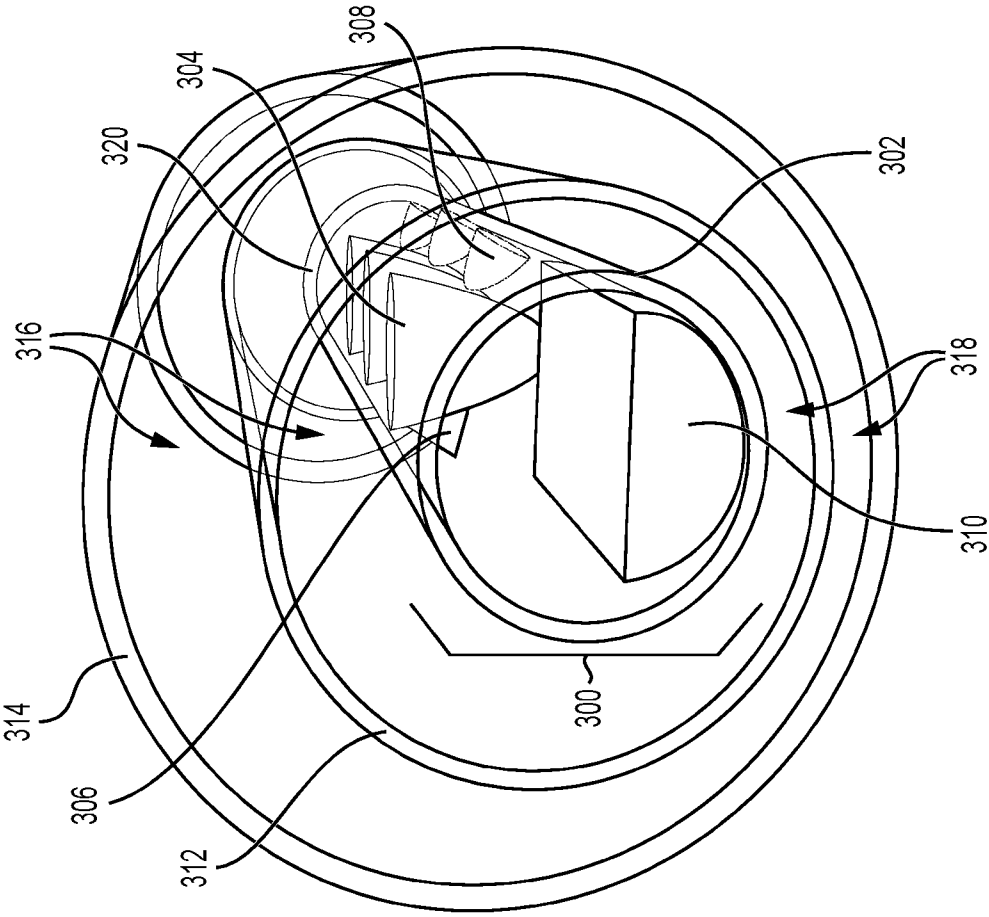


FIG. 3B

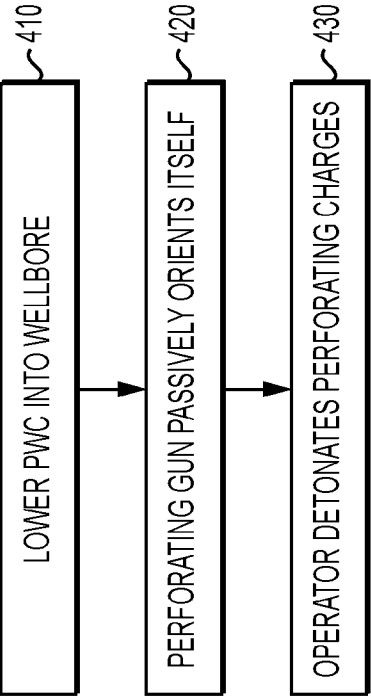


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/083872

A. CLASSIFICATION OF SUBJECT MATTER E21B 43/116(2006.01)i; E21B 43/119(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 43/116(2006.01); E21B 29/02(2006.01); E21B 43/117(2006.01); E21B 43/119(2006.01) 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: perforating gun, well, tubular housing, weight spacer, charge, size, carrier, swivel, roller, washing, roller		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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☐ 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 "D" document cited by the applicant in the international application "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 05 April 2024		Date of mailing of the international search report 05 April 2024
Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon 35208, Republic of Korea Facsimile No. +82-42-481-8578		Authorized officer PARK, Tae Wook Telephone No. +82-42-481-3405

INTERNATIONAL SEARCH REPORT
Information on patent family members

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