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Declarations under Rule 4.17:

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

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

TRIGGER FOR DOWNHOLE TOOL, METHOD AND SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Application No. 17/669896, filed on February 11, 2022, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] In the resource recovery industry many different tools are needed in the downhole environment to perform a plethora of operations necessary to creating, completing, or producing a well or sequestering fluid such as Carbon Dioxide or Hydrogen. Many of these tools need to be triggered to actuate at desired times or based upon desired conditions. Triggers therefore, are important to the industry. Unfortunately, triggers often come with tradeoffs such that the art is always receptive to novel triggers that provide different strengths and perhaps fewer weaknesses.

SUMMARY

[0003] An embodiment of a trigger including a carrier, a shuttle movably disposed on the carrier, an energy member disposed between the carrier and the shuttle, a degrade-on-demand trip member disposed to maintain potential energy in the energy member until activated.

[0004] An embodiment of a method for operating a downhole tool including sending a signal to the trip member of the trigger degrading the trip member, converting potential energy stored in the energy member from potential energy to kinetic energy, and actuating the downhole tool with the shuttle.

[0005] An embodiment of a wellbore system including a borehole in a subsurface formation, a string in the borehole, a trigger disposed within or as a part of the string.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The following descriptions should not be considered limiting in any way. With reference to the accompanying drawings, like elements are numbered alike:

[0007] Figure 1 is a schematic view of a first embodiment of a trigger as disclosed herein in a ready position;

[0008] Figure 1A is the view of Figure 1 but with potential energy stored in tension;

[0009] Figure 2 is a schematic view of the first embodiment of a trigger as disclosed herein in a triggered position;

[0010] Figure 3 is a schematic view of a second embodiment of a trigger as disclosed herein in a ready position;

[0011] Figure 3A is the view of Figure 3 but with potential energy stored in tension;

[0012] Figure 4 is a schematic view of the second embodiment of a trigger as disclosed herein in a triggered position;

[0013] Figure 5 is a schematic representation of a downhole tool including a trigger as disclosed herein; and

[0014] Figure 6 is a schematic illustration of a wellbore system including an embodiment of the trigger disclosed herein.

DETAILED DESCRIPTION

[0015] A detailed description of one or more embodiments of the disclosed apparatus and method are presented herein by way of exemplification and not limitation with reference to the Figures.

[0016] Referring to Figures 1 and 2, a trigger 10 is illustrated in a ready position and a triggered position, respectively. The trigger 10 includes a carrier 12 upon which a shuttle 14 rides. Disposed between the carrier 12 and the shuttle 14 is an energy member, 16 that may be one or more springs and may be a compression member(s) (or tension member(s), see below). Types of springs may vary and include coil springs, resilient material springs, gas springs, etc. Regardless of spring type, the member 16 is disposed in the trigger 10 in a compressed position while the trigger 10 is in the ready position. In this position, the member 16 stores potential energy that is available for rapid conversion to kinetic energy upon activation of the trigger 10. “Rapid” for purposes of this application is on the order of a few seconds at most. The trigger further comprises a trip member 18 that maintains the compressed state of member 16 until an activation is required. The trip member 18 comprises a material (material discussed later herein) that rapidly degrades on demand. The degrade-on-demand material does not degrade without a specific initiation action or regime (which is related to the specific degrade-on-demand material selected) and so may be exposed to wellbore fluid. This means that a dynamic seal is not required to segregate the trigger 10 from wellbore fluids and accordingly, the drag that a dynamic seal would present is avoided.

[0017] The energy member 16 is disposed adjacent a rod 20 of the carrier 12 and may be disposed around the rod 20. It is also contemplated as shown that two members 16 may be employed about two rods 20.

[0018] Degradation may be initiated with an electrical signal, electromagnetic signal such as radio frequency, or acoustic signal, for example. The signal may on its own cause the degradation or the signal may be received and used to initiate something else to cause the degradation such as, for example, to allow a local battery to provide a voltage to the material of the member 18. With the member 18 fully degraded, meaning it is essentially or entirely absent, the shuttle 14 is free to move along the carrier 12 under the impetus of the energy member 16. This movement is used to actuate a tool and can be used for any tool that is actuated by a moving member.

[0019] Since the member 18 is only loaded in compression a substantial amount of potential energy may be stored in the energy member 16. In an embodiment, one possible degrade-on-demand material that can be used will hold up to about 40,000 PSI (pounds per square inch) in compression.

[0020] It is to be appreciated that a tension spring 16a could be substituted for the energy member 16 and placed on the opposite side of the shuttle 14 and still between the shuttle 14 and carrier 12, if desired, see Figure 1A. The ultimate action of the trigger 10 would be the same.

[0021] In another embodiment, referring to Figures 3-4, a trigger 22 includes a trip member 24, similar to but different from the trip member 18, is configured as a tensile member rather than as a compression member. In the tensile embodiment, the trip member 24 must be secured to the carrier 12 and to the shuttle 14 in some way. Illustrated in Figure 3 are flanges 26 and 28 on opposing ends of trip member 24 that are engaged with recesses 30 and 32, respectively, in shuttle 14 and carrier 12. Alternatively, threads may be employed instead of the flanges and recesses or other common mechanical securement arrangements may also be substituted. It is to be appreciated that the spring member 16 or 16a (see also Figure 3A) may be used similarly to the disclosure above. In this embodiment, when the trip member 24 is degraded it releases the shuttle 14 to move relative to carrier 12 in the same ways as in the foregoing embodiment of Figure 1. Shuttle 14 moves based upon spring 16 or 16a providing potential energy in the direction associated with the type of spring used. The member 24 holding, in a tensile manner, the member 16 or 16a, will have a utility up to about 50,000 PSI (pounds per square inch).

[0022] One embodiment of the material usable for trip member 18 or 24 is a matrix that includes an energetic material. The matrix comprises a polymer, a metal, a composite, or a combination comprising at least one of the foregoing, which provides the general material properties such as strength, ductility, hardness, density for tool functions. Exemplary matrix materials comprise matrix polymers that may include at least one of an epoxy, a phenolic resin, an epoxy phenolic resin, a vinyl ester, a polybismaleimide, a cyanate ester, or a polyester. Choices for an epoxy matrix can include polymerizing at least one of an aliphatic epoxide such as butanediol diglycidyl ether, a bisphenol epoxide such as bisphenol-A diglycidyl ether (CAS # 1675-54-3) and/or bisphenol-F diglycidyl ether, or a novolac epoxide such as phenol-formaldehyde polymer glycidyl ether (CAS # 28064-14-4). In an aspect, the epoxy contains a polymerized diglycidylether of a bisphenol wherein the number of the repeating units of the epoxy resin range from 0 to 18, preferably 0 to less than 2.5. The curing agent includes an active group that can react with an epoxy group. Examples of such an active group include amino groups and acid anhydride groups. In an aspect the curing agent is at least one of an aliphatic amine or an aromatic amine. Choices for a phenolic matrix can be produced from the polymerization of a phenol (C_6H_5OH), an alkyl-substituted phenol, a halogen-substituted phenol, or a combination thereof, and a formaldehyde compound such as formaldehyde ($CH_2C=O$). An epoxy phenolic matrix is phenolic resin modified at the phenolic hydroxyl group to include an epoxide functional group such as $-CH_2-(C_2H_3O)$, where $-(C_2H_3O)$ is a three-membered epoxide ring. A vinyl ester (vinyl acetate) matrix is a resin produced by the esterification of an epoxy resin with acrylic or methacrylic acids. The polybismaleimide can be synthesized by condensation of phthalic anhydride with an aromatic diamine, which yields bismaleimide such as 4,4'-bismaleimidodiphenylmethane, followed by subsequent Michael addition of more diamine to the double bond at the ends of the bismaleimide. The monomer bismaleimide can also be copolymerized with vinyl and allyl compounds, allyl phenols, isocyanates, aromatic amines, or a combination thereof. Cyanate esters are compounds generally based on a phenol or a novolac derivative, in which the hydrogen atom of the phenolic OH group is substituted by a cyanide group ($-OCN$). Suitable cyanate esters include those described in U.S. Pat. No. 6,245,841 and EP 0396383. Cyanate esters can be cured and postcured by heating, either alone, or in the presence of a catalyst. Curing normally occurs via cyclotrimerization (an addition process) of three CN groups to form three-dimensional networks comprising triazine rings. [0024] The polyester can be formed by the reaction of a dibasic organic acid and a dihydric alcohol. Choices for a polyester matrix can include orthophthalic polyesters that are made by phthalic anhydride

with either maleic anhydride or fumaric acid, or isophthalic polyesters that are made from isophthalic acid or terephthalic acid.

[0023] Optionally, a reinforcing fiber can be used to increase the tensile strength and the compressive strength of the material. The reinforcing fiber can comprise one of carbon fiber, glass fiber, polyethylene fiber, or aramid fiber. The form of the reinforcing fiber can include continuous fibers or short fibers. Continuous fibers can be disposed within the degradable article along a reinforcing direction, providing a continuous path for load bearing, while short fibers can be blended into the polymer matrix in a random or semi-random orientation. Short fibers can include staple fibers, chopped fibers, or whiskers. Staple fibers typically have a lengths of about 10 to about 400 mm. Chopped fibers can have a lengths of about 3 to about 50 mm while whiskers are a few millimeters length. Combinations of the fibers in different forms and different compositions can be used. Exemplary continuous fiber composite can have a tensile strength of about 40 to about 50 kilopound per square inch (ksi). Exemplary short fiber composite can have a compressive strength of about 25 to about 40 ksi.

[0024] Optionally, the matrix material further comprises additives such as carbides, nitrides, oxides, precipitates, dispersoids, glasses, carbons, excess metal/metal alloy that does not participate in an oxidation-reduction reaction or the like in order to control the mechanical strength and density of the degradable article.

[0025] The energetic material may comprise a thermite, a reactive multi-layer foil, an energetic polymer, or a combination comprising at least one of the foregoing. Use of energetic materials disclosed herein is advantageous as these energetic materials are stable at wellbore temperatures but produce an extremely intense exothermic reaction following activation, which facilitates the rapid disintegration of the disintegrable articles. Additionally, the matrix material may be the energetic material.

[0026] Thermite compositions can include, for example, a metal powder (a reducing agent) and a metal oxide (an oxidizing agent) that produces an exothermic oxidation-reduction reaction known as a thermite reaction. Choices for a reducing agent include aluminum, magnesium, calcium, titanium, zinc, silicon, boron, and combinations including at least one of the foregoing, for example, while choices for an oxidizing agent include boron oxide, silicon oxide, chromium oxide, manganese oxide, iron oxide, copper oxide, lead oxide, and combinations including at least one of the foregoing, for example.

[0027] Energetic polymers are materials possessing reactive groups, which are capable of absorbing and dissipating energy. During the activation of energetic polymers, energy absorbed by the energetic polymers cause the reactive groups on the energetic

polymers, such as azido and nitro groups, to decompose releasing gas along with the dissipation of absorbed energy and/or the dissipation of the energy generated by the decomposition of the active groups. The heat and gas released promote the disintegration of the disintegrable articles.

[0028] Energetic polymers include polymers with azide, nitro, nitrate, nitroso, nitramine, oxetane, triazole, or tetrazole containing groups. Polymers or co-polymers containing other energetic nitrogen containing groups can also be used. Optionally, the energetic polymers further include fluoro groups such as fluoroalkyl groups.

[0029] Exemplary energetic polymers include nitrocellulose, azidocellulose, polysulfide, polyurethane, poly glycidyl ether, a fluoropolymer combined with nano particles of combusting metal fuels, polybutadiene; polyglycidyl nitrate such as polyGLYN, butanetriol trinitrate, glycidyl azide polymer (GAP), for example, linear or branched GAP, GAP diol, or GAP triol, poly[3-nitratomethyl-3-methyl oxetane](polyNIMMO), poly(3,3-bis-(azidomethyl)oxetane (polyBAMO) and poly(3-azidomethyl-3-methyl oxetane) (polyAMMO), polyvinylnitrate, polynitrophenylene, nitramine polyethers, or a combination comprising at least one of the foregoing.

[0030] The reactive multi-layer foil can comprise aluminum layers and nickel layers. The reactive multi-layer foil can also comprise titanium layers and boron carbide layers. In specific embodiments, the reactive multi-layer foil includes alternating aluminum and nickel layers. Further information can be obtained by review of US Patent Number 10,450,840, which is incorporated herein by reference in its entirety.

[0031] In use, either of the embodiments may be made a part of another tool that requires a mechanical movement to be actuated. That tool may be run to depth and then a signal sent to the trigger 10 or 22. Once the signal is sent the degrade-on-demand material will degrade and the trigger 10 or 22 will convert the potential energy stored in the member 16 or 16a into kinetic energy that will actuate the associated tool.

[0032] Referring to Figure 5, a downhole tool 40 is illustrated including a trigger 10, 22 as disclosed herein. As noted above, the tool 40 may be any type of downhole tool that requires a physical movement to actuate. The trigger 10, 22 provides that physical movement by moving the shuttle upon the signal to degrade being received at the member 18, 24.

[0033] Finally, referring to Figure 6, disclosed herein is a wellbore system 50. The system 50 comprises a borehole 52 in a subsurface formation 54. Disposed in the borehole is a string 56. Disposed as a part of the string 56 or within the string 56 is the trigger 10 or 22 disclosed herein placed in operable connection with a tool to be actuated, such as tool 40.

[0034] Set forth below are some embodiments of the foregoing disclosure:

[0035] Embodiment 1: A trigger including a carrier, a shuttle movably disposed on the carrier, an energy member disposed between the carrier and the shuttle, a degrade-on-demand trip member disposed to maintain potential energy in the energy member until activated.

[0036] Embodiment 2: The trigger as in any prior embodiment wherein the trip member is impervious to a downhole environment.

[0037] Embodiment 3: The trigger as in any prior embodiment wherein the trip member is in compression by the energy member.

[0038] Embodiment 4: The trigger as in any prior embodiment wherein the trip member is in tension by the energy member.

[0039] Embodiment 5: The trigger as in any prior embodiment wherein the energy member is a compression member.

[0040] Embodiment 6: The trigger as in any prior embodiment wherein the energy member is a tension member.

[0041] Embodiment 7: The trigger as in any prior embodiment wherein the carrier comprises a rod upon which the shuttle is sliding engaged.

[0042] Embodiment 8: The trigger as in any prior embodiment wherein the carrier comprises two rods upon which the shuttle is slidingly engaged.

[0043] Embodiment 9: The trigger as in any prior embodiment wherein the energy member is two members, one disposed adjacent each of the two rods.

[0044] Embodiment 10: A downhole tool including a tool, a trigger as in any prior embodiment operably connected to the tool.

[0045] Embodiment 11: A method for operating a downhole tool including sending a signal to the trip member of the trigger as in any prior embodiment, degrading the trip member, converting potential energy stored in the energy member from potential energy to kinetic energy, and actuating the downhole tool with the shuttle.

[0046] Embodiment 12: A wellbore system including a borehole in a subsurface formation, a string in the borehole, a trigger as in any prior embodiment disposed within or as a part of the string.

[0047] The use of the terms “a” and “an” and “the” and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. Further, it should be noted that the terms “first,” “second,”

and the like herein do not denote any order, quantity, or importance, but rather are used to distinguish one element from another. The terms “about”, “substantially”, “essentially”, and “generally” are intended to include the degree of error associated with measurement of the particular quantity based upon the equipment available at the time of filing the application. For example, “about” and/or “substantially”, “essentially” and/or “generally” can include a range of $\pm 8\%$ or 5% , or 2% of a given value.

[0048] The teachings of the present disclosure may be used in a variety of well operations. These operations may involve using one or more treatment agents to treat a formation, the fluids resident in a formation, a wellbore, and / or equipment in the wellbore, such as production tubing. The treatment agents may be in the form of liquids, gases, solids, semi-solids, and mixtures thereof. Illustrative treatment agents include, but are not limited to, fracturing fluids, acids, steam, water, brine, anti-corrosion agents, cement, permeability modifiers, drilling muds, emulsifiers, demulsifiers, tracers, flow improvers etc. Illustrative well operations include, but are not limited to, hydraulic fracturing, stimulation, tracer injection, cleaning, acidizing, steam injection, water flooding, cementing, etc.

[0049] While the invention has been described with reference to an exemplary embodiment or embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment disclosed as the best mode contemplated for carrying out this invention, but that the invention will include all embodiments falling within the scope of the claims. Also, in the drawings and the description, there have been disclosed exemplary embodiments of the invention and, although specific terms may have been employed, they are unless otherwise stated used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention therefore not being so limited.

What is claimed is:

1. A trigger (10, 22) characterized by:
a carrier (12);
a shuttle (14) movably disposed on the carrier (12);
an energy member (16) disposed between the carrier (12) and the shuttle (14);
a degrade-on-demand trip member (18) disposed to maintain potential energy in the energy member (16) until activated.
2. The trigger (10, 22) as claimed in claim 1 wherein the trip member (18) is impervious to a downhole environment.
3. The trigger (10, 22) as claimed in claim 1 wherein the trip member (18) is in compression by the energy member (16).
4. The trigger (10) as claimed in claim 1 wherein the trip member (18) is in tension by the energy member (16).
5. The trigger (10, 22) as claimed in claim 1 wherein the energy member (16) is a compression member.
6. The trigger (10, 22) as claimed in claim 1 wherein the energy member (16) is a tension member (24).
7. The trigger (10, 22) as claimed in claim 1 wherein the carrier (12) comprises a rod (20) upon which the shuttle (14) is slidingly engaged.
8. The trigger (10, 22) as claimed in claim 1 wherein the carrier (12) comprises two rods (20) upon which the shuttle (14) is slidingly engaged.
9. The trigger (10, 22) as claimed in claim 1 wherein the energy member (16) is two members, one disposed adjacent each of the two rods (20).
10. A downhole tool (40) characterized by:
a tool (40);
a trigger (10, 22) as claimed in claim 1 operably connected to the tool (40).
11. A method for operating a downhole tool (40) characterized by:
sending a signal to the trip member (18) of the trigger (10, 22) as claimed in claim 1;
degrading the trip member (18);
converting potential energy stored in the energy member (16) from potential energy to kinetic energy; and
actuating the downhole tool (40) with the shuttle (14).
12. A wellbore system (50) characterized by:
a borehole (52) in a subsurface formation (54);

a string (56) in the borehole (52);

a trigger (10, 22) as claimed in claim 1 disposed within or as a part of the string (56).

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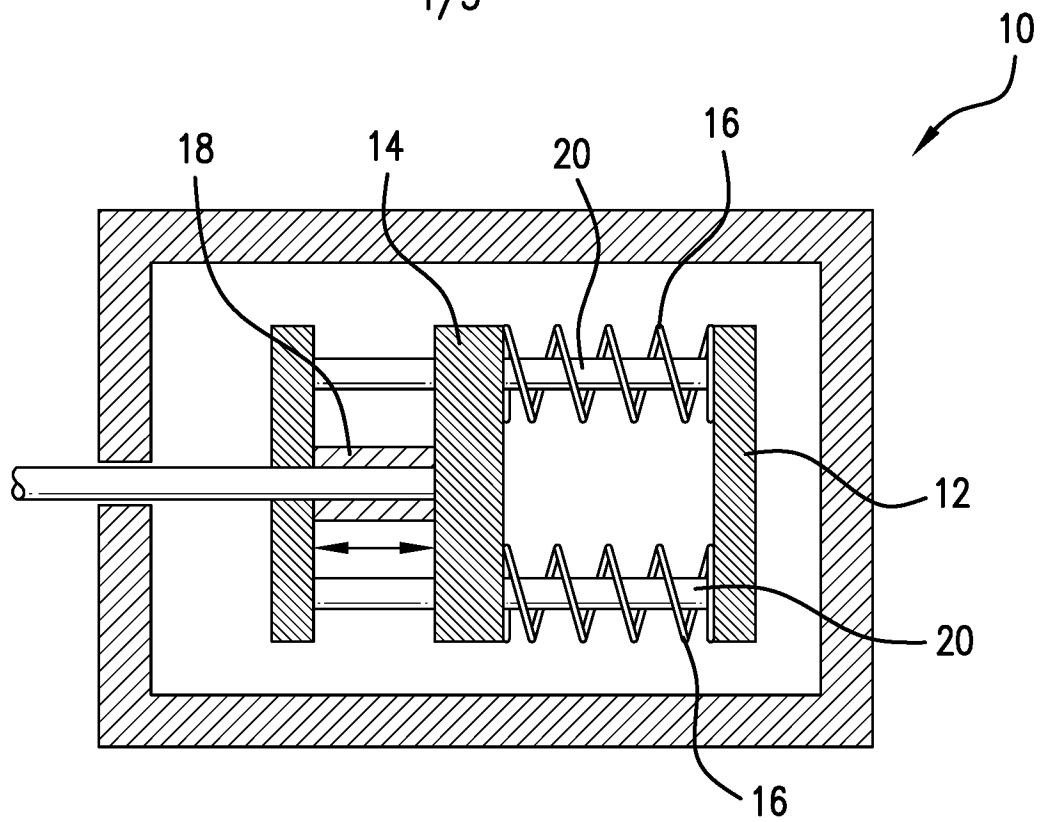


FIG. 1

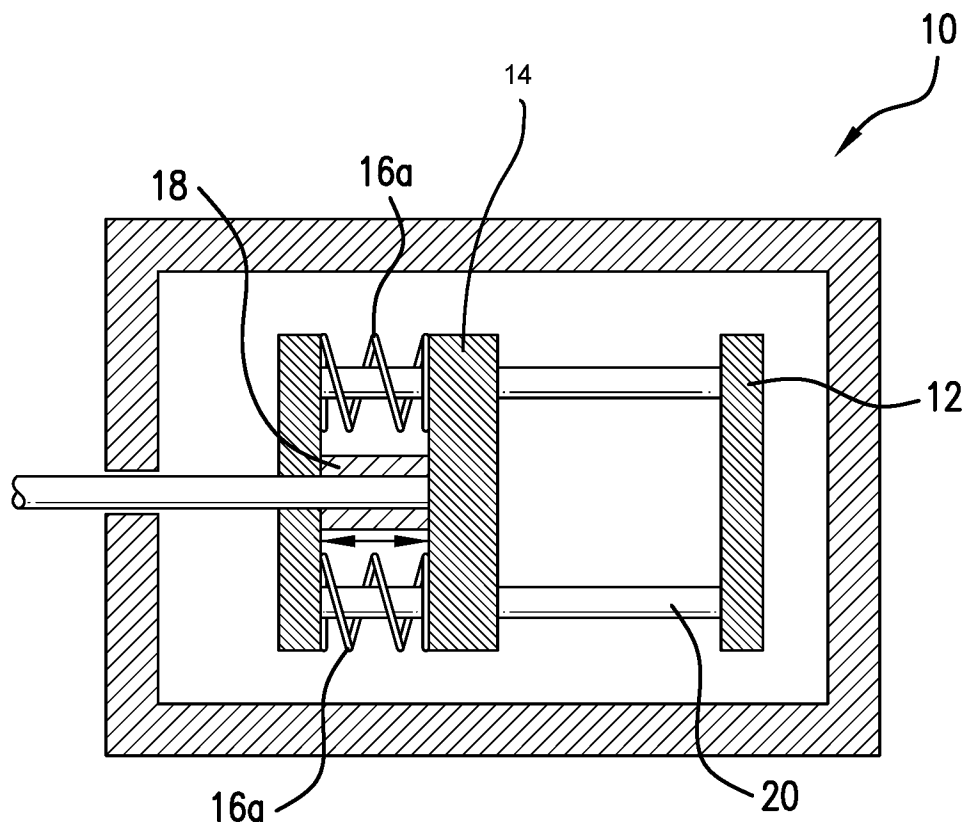


FIG. 1A

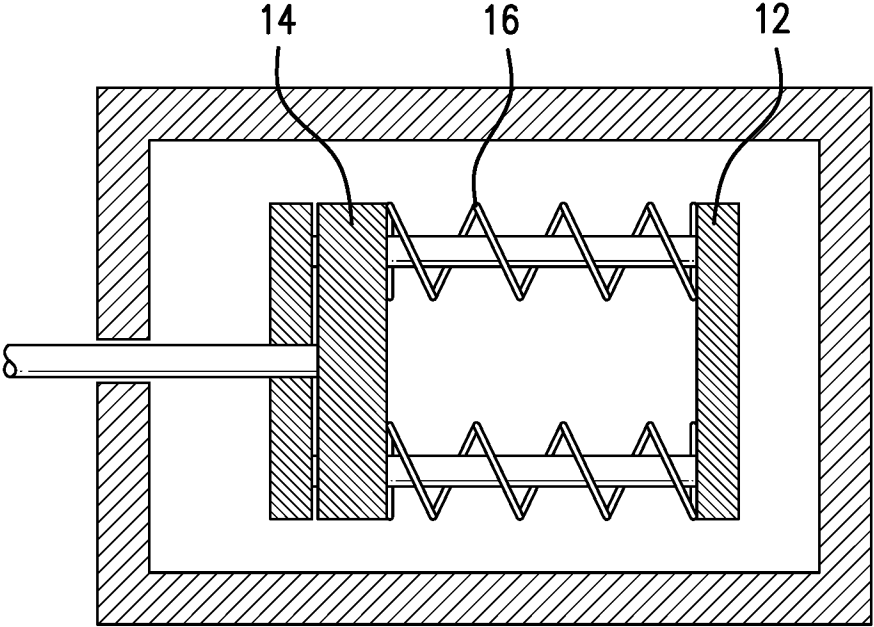


FIG.2

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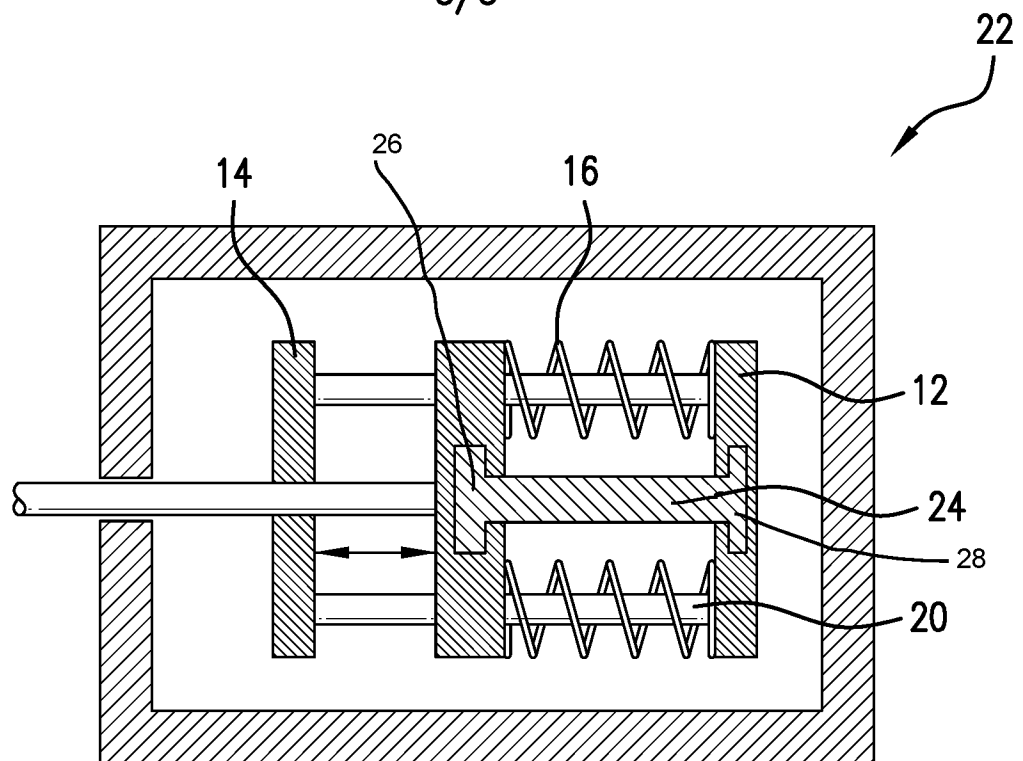


FIG.3

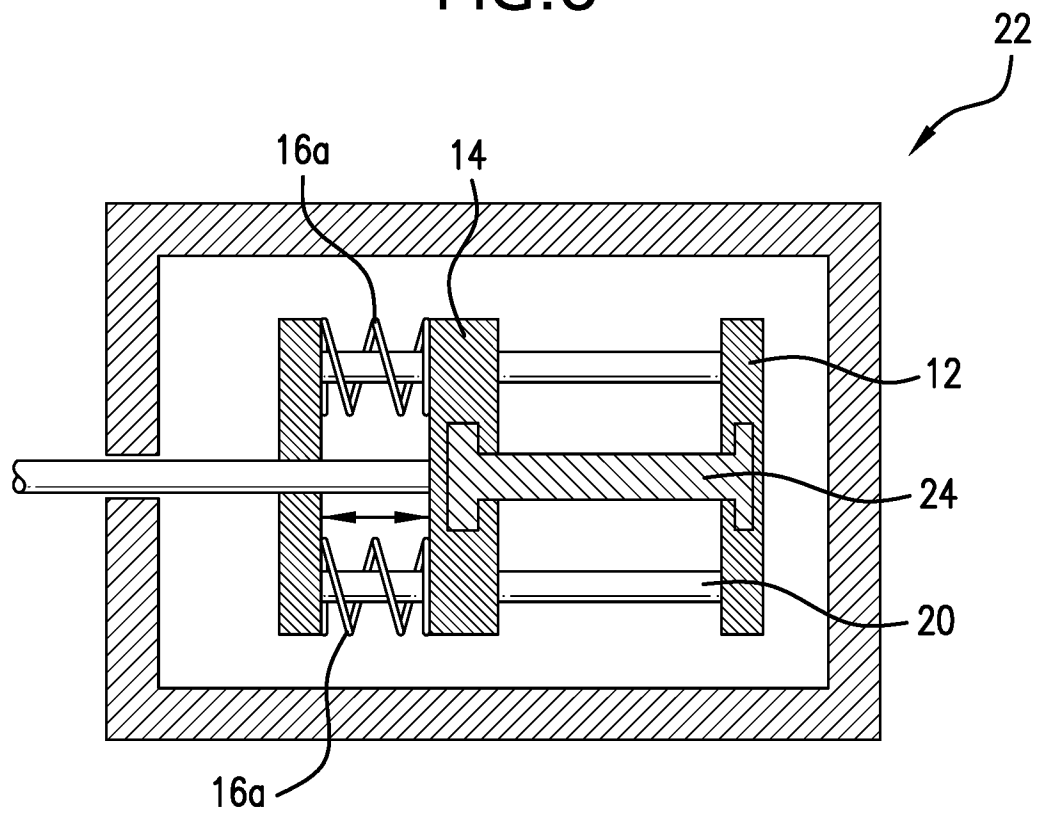


FIG. 3A

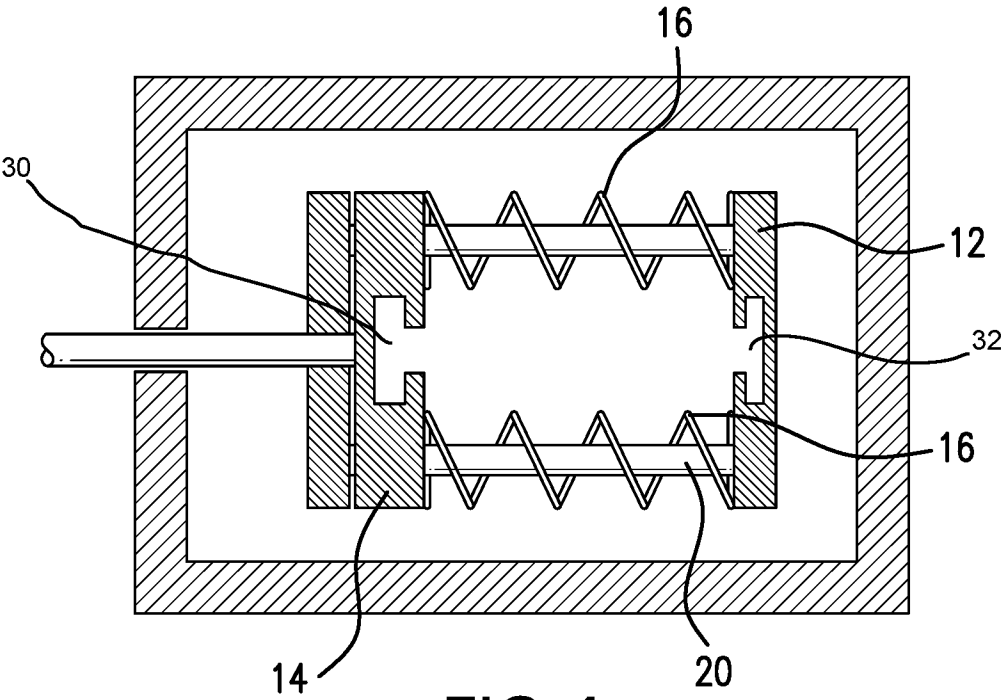


FIG. 4

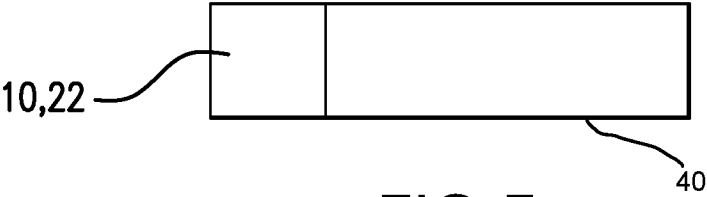


FIG. 5

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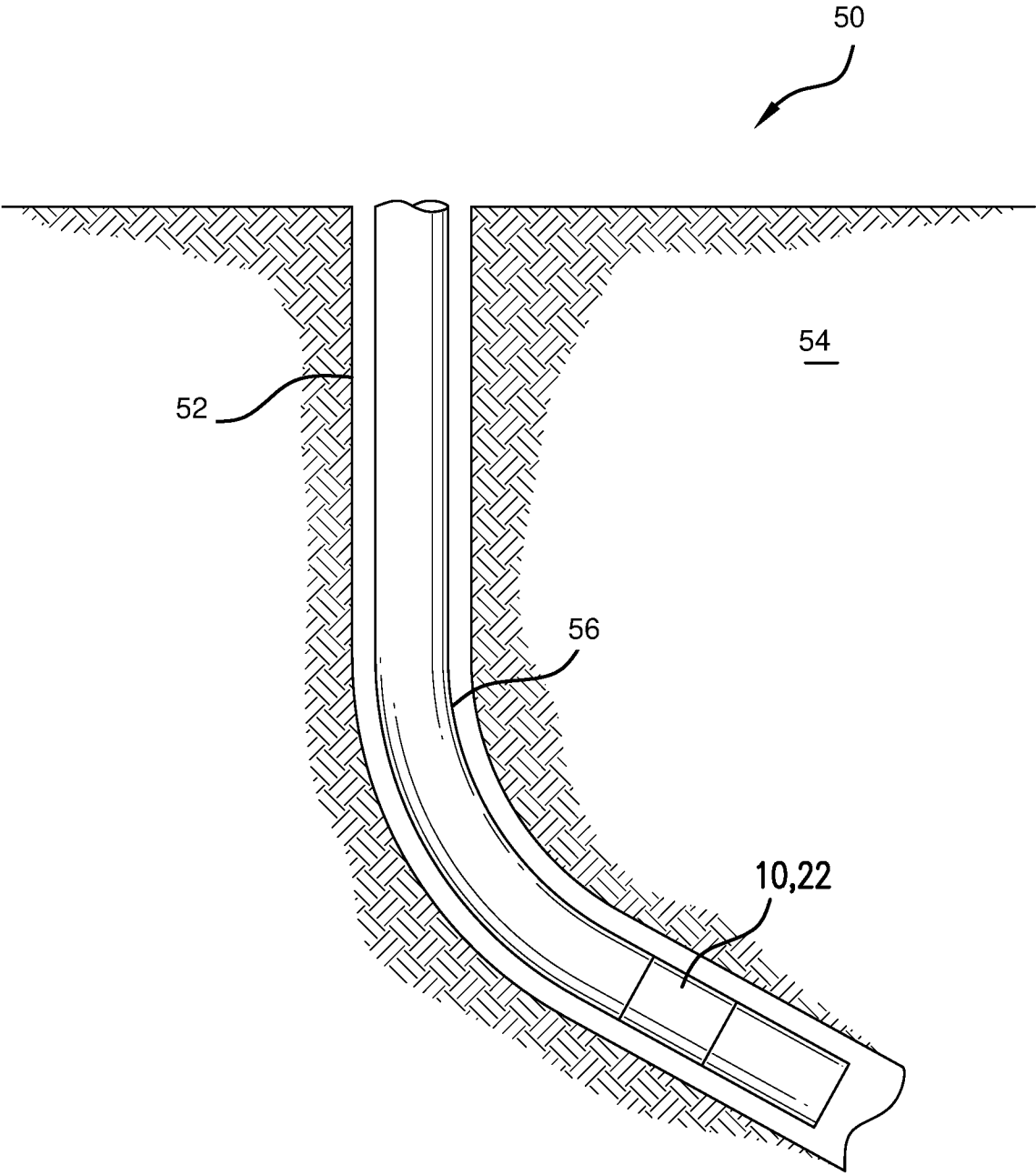


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2023/012608

A. CLASSIFICATION OF SUBJECT MATTER**E21B 33/072(2006.01)i; E21B 41/00(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 33/072(2006.01); E21B 23/01(2006.01); E21B 29/00(2006.01); E21B 33/068(2006.01); E21B 33/12(2006.01);
E21B 33/128(2006.01); E21B 33/13(2006.01); E21B 34/06(2006.01); E21B 43/25(2006.01); E21B 47/06(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: downhole tool, trigger, carrier, shuttle, energy member, trip member

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2021-0123309 A1 (HE et al.) 29 April 2021 (2021-04-29) paragraphs [0016]-[0018], [0020], claims 13, 18 and figures 2-4, 7	1-12
A	US 2020-0040702 A1 (STONE, MATTHEW) 06 February 2020 (2020-02-06) paragraphs [0012]-[0014] and figures 1-3	1-12
A	US 2021-0238942 A1 (KLX ENERGY SERVICES L.L.C.) 05 August 2021 (2021-08-05) paragraphs [0021]-[0025] and figures 1-2B	1-12
A	US 2020-0032612 A1 (BAKER HUGHES OILFIELD OPERATIONS L.L.C.) 30 January 2020 (2020-01-30) paragraphs [0026]-[0029] and figures 3A-3C	1-12
A	US 2016-0102520 A1 (SCHLUMBERGER TECHNOLOGY CORPORATION) 14 April 2016 (2016-04-14) claims 1, 8, 16, 17 and figures 2-6	1-12

☐ 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

31 May 2023

Date of mailing of the international search report

01 June 2023

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/US2023/012608

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
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				CN	114729565	A	08 July 2022
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				AU	2019-315790	B2	02 February 2023
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