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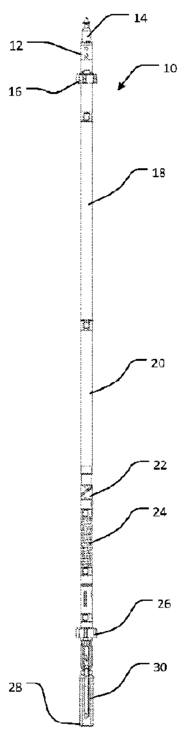

Fig.1

(57) Abrégé/Abstract:
A shock absorber (24) for a downhole tool (18) is disclosed. The shock absorber (24) includes a downhole portion (32) defining a bore (34), and an uphole portion (36) configured for direct or indirect connection to the downhole tool (18). The uphole portion (36) has a stanchion (38) extending from one end and which carries a piston (40). The piston (40) is slidably engaged with the bore (34) to allow relative axial movement of the uphole portion (36) and the downhole portion (32). A first resiliently deformable member (42) is arranged between the uphole portion (36) and the downhole portion (32), and arranged to be compressed when the uphole portion (36) and downhole portion (32) move axially relative to each other in a first direction. A second resiliently deformable member (44) is arranged between an end of the bore (34) and the piston (40) to be compressed when the uphole portion (36) and downhole portion (32) move axially relative to each other in a second direction opposite to the first direction.

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Abstract:

A shock absorber (24) for a downhole tool (18) is disclosed. The shock absorber (24) includes a downhole portion (32) defining a bore (34), and an uphole portion (36) configured for direct or indirect connection to the downhole tool (18). The uphole portion (36) has a stanchion (38) extending from one end and which carries a piston (40). The piston (40) is slidably engaged with the bore (34) to allow relative axial movement of the uphole portion (36) and the downhole portion (32). A first resiliently deformable member (42) is arranged between the uphole portion (36) and the downhole portion (32), and arranged to be compressed when the uphole portion (36) and downhole portion (32) move axially relative to each other in a first direction. A second resiliently deformable member (44) is arranged between an end of the bore (34) and the piston (40) to be compressed when the uphole portion (36) and downhole portion (32) move axially relative to each other in a second direction opposite to the first direction.

"Shock absorber for a downhole tool, and running gear for downhole surveying "

Technical Field

[0001] The present disclosure relates, generally, to shock absorber devices, and, particularly, to shock absorbers operable to reduce loads on a downhole tool, such as arranged in a drilling assembly. The disclosure also relates to running gear for downhole surveying.

Background

[0002] Downhole tools (also known as downhole instruments) are used during exploration drilling and often exposed to significant impact forces when being deployed into a borehole due to the travelling tool colliding with a drilling assembly, the drill string, and/or bedrock. Where such tools are configured for data acquisition, such as to allow downhole surveying and/or measure drill core sample orientation, the tool typically includes one or more sensors which can be sensitive to impacts. To reduce the effect of impacts on measurements captured with the tool, or causing damage to the tool, it is commonplace for a shock absorber to be coupled to a downhole-facing end of the tool. The shock absorber is arranged to compress when colliding with a downhole object, such as a core barrel assembly, to dissipate energy, consequently reducing transmission of impact force to the tool.

[0003] In some applications, a downhole tool coupled with a shock absorber forms part of a running gear assembly which may be used for downhole surveying. The running gear often includes an outer housing to receive the tool and shock absorber. The outer housing is typically configured as an inextensible sleeve. Running gear may be deployed into a borehole to engage another object, such as a core barrel assembly, and then retrieved to the surface to extract the object. When lifting the object with the connected running gear, the outer housing is arranged to transmit tensile force around the tool and shock absorber to allow wireline retrieval without compressing the shock absorber, which could otherwise damage the springs of the shock absorber.

[0004] The running gear is typically configured as an elongate assembly, measuring from one to four metres, and often being around three to four metres long, which includes various components connected axially together in series. Running gear may include, in this order: a wireline retrieval connector, such as a spear point structure; a downhole tool, such as a north seeking gyro; a battery for powering the tool; a shock absorber; one or more housings containing the tool, battery, and shock absorber; and an overshot, being a mechanism for releasably engaging an end of a tube or tool, such as a core barrel assembly.

[0005] When the running gear is being retrieved to the surface, the core barrel assembly can become jammed in the drill string. Should this occur, this may require an operator to activate a ratchet mechanism connected to, or forming part of, the overshot, such as a Reflex "Rota-Lock" device. The ratchet mechanism is configured to detach the overshot from the rest of the running gear when the operator tugs the wireline a defined number of times, allowing safe retrieval of the tool to the surface. However, such mechanisms can be unintentionally operated should the running gear experience non-smooth, jerky motion when being retrieved from the borehole, allowing the core barrel to fall back down the hole, potentially damaging the core and/or requiring extraction of drill string rods to remove the core barrel. This issue can be exacerbated where manual handling of the running gear is required at the hole collar, particularly where the running gear is over three metres long which can cause colliding with the drill rig mast.

[0006] For some applications, no release mechanism is fitted in the running gear, meaning that should a load being retrieved by the running gear, such as the core barrel, become jammed and an operator continue to tension the wireline, force exerted through the running gear can damage its components, particularly risking damage to the downhole tool which can be sensitive to significant forces. Also, in some scenarios, the operator may be required to cut the wireline to release the jammed core barrel. This can cause significant downtime and be complex to rectify, often requiring withdrawing drill string rods from the borehole to retrieve the running gear, including the downhole tool, and core barrel, and/or causing irreparable damage to the downhole tool.

[0007] Once retrieved to the surface, the running gear is entirely removed from the borehole to allow accessing the downhole tool to download data recorded by the tool. In restricted space environments, this can be difficult as there is limited room to manoeuvre the three to four metre long assembly. In such environments, the extracted running gear can collide with mine structures, other apparatus, and/or persons, presenting a significant safety hazard to drilling rig operators.

[0008] Any discussion of documents, acts, materials, devices, articles or the like which has been included in the present specification is not to be taken as an admission that any or all of these matters were common general knowledge in the field relevant to the present disclosure as it existed before the priority date of each of the appended claims.

Summary

[0009] Throughout this specification the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element, integer or step, or group of elements, integers or steps, but not the exclusion of any other element, integer or step, or group of elements, integers or steps.

[0010] According to some disclosed aspects, there is provided a shock absorber for a downhole tool, the shock absorber including a downhole portion defining a bore, an uphole portion configured for connection to the downhole tool, the uphole portion having a stanchion extending from one end, the stanchion carrying a piston slidably engaged with the bore to allow relative axial movement of the uphole portion and downhole portion, a first resiliently deformable member arranged between the uphole portion and the downhole portion to be compressed when the uphole portion and downhole portion move axially relative to each other in a first direction, and a second resiliently deformable member arranged between an end of the bore and the piston to be compressed when the uphole portion and downhole portion move axially relative to each other in a second direction opposed to the first direction, where the downhole portion has one or more abutment surfaces arranged to abut the piston to limit relative axial movement of the uphole portion and the downhole portion.

[0011] The one or more abutment surfaces may be defined by an annular shoulder arranged to extend into the bore and at least partially surround the second resiliently deformable member. In such embodiments, the shoulder may be defined by a collar mounted at a defined location along the bore. In some embodiments, the collar may be selectively positionable along the bore.

[0012] The piston may carry a resiliently deformable body arranged across a downhole end of the piston to allow abutting an end of the bore to be compressed.

[0013] The downhole portion may define at least one first flush port adjacent each end of the bore, each first flush port arranged to convey fluid from within the bore to outside of the downhole portion. The downhole portion may also define at least one second flush port arranged partway along the bore between the first flush ports, the, or each, second flush port arranged to convey fluid from within the bore to outside of the downhole portion. The, or each, second flush port may comprise a slot extending axially along the bore.

[0014] According to other aspects, there is provided a shock absorber for a downhole tool, the shock absorber including a downhole portion defining a bore, an uphole portion configured for connection to the downhole tool, the uphole portion having a stanchion extending from one end, the stanchion carrying a piston slidably engaged with the bore to allow relative axial movement of the uphole portion and downhole portion, a first resiliently deformable member arranged between the uphole portion and the downhole portion to be compressed when the uphole portion and downhole portion move axially relative to each other in a first direction, and a second resiliently deformable member arranged between an end of the bore and the piston to be compressed when the uphole portion and downhole portion move axially relative to each other in a second direction opposed to the first direction, where the downhole portion defines at least one first flush port adjacent each end of the bore, each first flush port arranged and dimensioned to convey fluid and particulate from within the bore to outside of the downhole portion.

[0015] The downhole portion may define at least one second flush port arranged partway along the bore between the first flush ports, the, or each, second flush port arranged and dimensioned to convey fluid and particulate from within the bore to outside of the downhole portion. The, or each, second flush port may comprise a slot extending axially along the bore.

[0016] The shock absorber described in any of the preceding paragraphs may also include a downhole member mounted at an end of the downhole portion, and a coupling device connected between the downhole member and the downhole portion to coaxially align the downhole portion and the downhole member, the coupling device having a frangible portion configured to fracture when force exerted through the device exceeds a defined threshold, such that fracturing the frangible portion separates the downhole portion from the downhole member.

[0017] The downhole member may define a recess in one end, and the downhole portion has a projection dimensioned to be received in the recess of the downhole member to cause the downhole portion to be rotationally locked to the downhole member. The downhole member may define a keyway adjacent the recess, and the downhole portion defines a key seat, and further including a key dimensioned to be received in the keyway and the key seat to inhibit relative rotation of the downhole portion and the downhole member.

[0018] According to other disclosed aspects, there is provided a coupling device for coupling two axially adjacent components of a downhole assembly, the device including an elongate body defining a longitudinal axis and having a pair of spaced engagement structures, each engagement structure configured to engage one of the axially adjacent components, the body including a frangible portion configured to fracture when force exerted on the body exceeds a defined threshold. The downhole assembly is typically configured as a wireline assembly including a downhole survey tool. It will be appreciated that the coupling device is suitable for coupling components of other downhole assemblies.

[0019] The frangible portion may include a necked region arranged between the engagement structures, the necked region shaped and dimensioned to allow fracture when tensile force exerted axially along the body exceeds the defined threshold.

[0020] One engagement structure may include a thread for threadedly engaging one of the components, and the other engagement structure include a flange having a surface extending perpendicularly to the longitudinal axis to allow frictionally engaging the other component. The flange may be configured such that, in use, the surface is arranged to face uphole to facilitate lifting one of the components.

[0021] According to further disclosed aspects, there is provided a coupling sub-assembly for a downhole assembly, the coupling sub-assembly including a first member defining a recess in one end, a second member having a projection dimensioned to be received in the recess of the first member, the second member configured to be rotationally locked relative to the first member, and the coupling device described in the above paragraphs and configured to be connected between the first member and the second member to coaxially align the members.

[0022] The first member may define a keyway adjacent the recess, and the second member define a key seat, and the sub-assembly also include a key dimensioned to be received in the keyway and the key seat to inhibit relative rotation of the first member and the second member.

[0023] According to other disclosed aspects, there is provided a releasable coupling assembly for releasably coupling axially adjacent components of a downhole assembly, the releasable coupling assembly including a downhole body configured to connect to one of the axially adjacent components, an uphole body configured to connect to the other of the axially adjacent components, each of the downhole body and the uphole body having a complementary engagement structure configured to releasably engage the bodies, and a sleeve rotatably mounted on one of the downhole body and the uphole body, the sleeve configured to be manually rotatable to axially translate between a locked position to cover the engagement structures, and an unlocked position to expose the engagement structures to allow uncoupling the axially adjacent components.

[0024] The uphole body may include a wireline retrieval connector configured for releasable connection to an overshot.

[0025] The releasable coupling assembly may also include a retention mechanism arranged to retain the sleeve in the locked position or the unlocked position. The sleeve may define at least one downhole recess arranged adjacent a downhole end, and at least one uphole recess arranged adjacent an uphole end, and the retention mechanism include a detent structure biased to extend radially to allow engaging the at least one downhole recess or the at least one uphole recess.

[0026] One of the axially adjacent components may be a downhole tool.

[0027] One engagement structure may include a slot extending perpendicularly to the axis of the body, and the other engagement structure include a keyed portion shaped to slidably engage the slot.

[0028] According to further disclosed aspects, there is provided a running gear assembly for downhole surveying, the assembly including a wireline retrieval connector arranged at an uphole end of the assembly, a downhole tool arranged downstream of the wireline retrieval connector, a shock absorber as described in any of the above paragraphs, the shock absorber arranged downstream of the downhole tool, and an overshot arranged at a downhole end of the assembly.

[0029] According to further disclosed aspects, there is provided a running gear assembly for downhole surveying, the assembly including a wireline retrieval connector arranged at an uphole end of the assembly, a downhole tool arranged downstream of the wireline retrieval connector, a shock absorber arranged downstream of the downhole tool, a coupling device as described in any of the above paragraphs, the coupling device arranged downstream of the downhole tool to couple two axially adjacent components of the assembly and an overshot arranged at a downhole end of the assembly.

[0030] According to further disclosed aspects, there is provided a running gear assembly for downhole surveying, the assembly including a wireline retrieval connector arranged at an uphole end of the assembly, a downhole tool arranged downstream of the wireline retrieval connector, a releasable coupling assembly as described in any of the above paragraphs, the assembly arranged downstream of the downhole tool, a shock absorber arranged downstream of the releasable coupling assembly, and an overshot arranged at a downhole end of the assembly.

[0031] According to further disclosed aspects, there is provided a running gear assembly for downhole surveying, the assembly including a wireline retrieval connector arranged at an uphole end of the assembly, a downhole tool arranged downstream of the wireline retrieval connector, a shock absorber arranged downstream of the downhole tool, the shock absorber including a downhole portion defining a bore, an uphole portion configured for connection to the downhole tool, the uphole portion having a stanchion extending from one end, the stanchion carrying a piston slidably engaged with the bore to allow relative axial movement of the uphole portion and downhole portion, a first resiliently deformable member arranged between the uphole portion and the downhole portion to be compressed when the uphole portion and downhole portion move axially relative to each other in a first direction, and a second resiliently deformable member arranged between an end of the bore and the piston to be compressed when the uphole portion and downhole portion move axially relative to each other in a second direction opposed to the first direction, where the downhole portion has one or more abutment surfaces arranged to abut the piston to limit relative axial movement of the uphole portion and the downhole portion, a coupling device arranged downstream of the shock absorber to couple two axially adjacent components of the assembly, the coupling device including an elongate body defining a longitudinal axis and having a pair of spaced engagement structures, each engagement structure configured to engage one of the axially adjacent components, the body including a frangible portion configured to fracture when force exerted on the body exceeds a defined threshold, and an overshot arranged at a downhole end of the assembly.

[0032] The running gear assembly may also include a releasable coupling assembly connected between two adjacent components of the assembly, the releasable coupling assembly including a downhole body configured to connect to one of the adjacent components, an uphole body configured to connect to the other of the adjacent components, each of the downhole body and the uphole body having a complementary engagement structure configured to releasably engage the bodies, and a sleeve rotatably mounted on one of the downhole body and the uphole body, the sleeve configured to be manually rotatable to axially translate between a locked position to cover the engagement structures, and an unlocked position to expose the engagement structures to allow uncoupling the adjacent components.

[0033] It will be appreciated embodiments may comprise steps, features and/or integers disclosed herein or indicated in the specification of this application individually or collectively, and any and all combinations of two or more of said steps or features.

Brief Description of Drawings

[0034] Embodiments will now be described by way of example only with reference to the accompany drawings in which:

[0035] Figures 1 and 2 are side views of a running gear assembly;

[0036] Figures 3 and 4 are a perspective view and side view, respectively, of a shock absorber which may form part of the running gear shown in Figs. 1 and 2. In these figures, the shock absorber is illustrated with an end cap sub-assembly mounted at a downhole end;

[0037] Figures 5 and 6 are cross-section views of the shock absorber as shown in Figs. 3 and 4;

[0038] Figures 7 and 8 are a detailed view and detailed cross-section view, respectively, of the shock absorber shown in Figs. 3 to 6;

[0039] Figure 9 is an alternative detailed cross-section view of the downhole end of the shock absorber shown in Figs. 3 to 8, illustrating a coupling device arranged to couple the downhole end to the end cap sub-assembly;

[0040] Figure 10 is a side view of the coupling device shown in Fig. 9, illustrated in isolation;

[0041] Figures 11 and 12 are perspective and cross-section views, respectively, of a coupling sub-assembly including the coupling device shown in Fig. 10;

[0042] Figure 13 is an exploded view of the coupling sub-assembly shown in Figs. 11 and 12;

[0043] Figures 14 and 15 are side views of a releasable coupling assembly shown in a locked and unlocked configuration;

[0044] Figures 16 and 17 are cross-section views of the releasable coupling assembly shown in Figs. 14 and 15;

[0045] Figures 18 is a side view of an alternative releasable coupling assembly; and

[0046] Figure 19 is an exploded view of the releasable coupling assembly shown in Fig. 18.

Description of Embodiments

[0047] In the drawings, reference numeral 10 generally designates a running gear assembly 10 for a downhole assembly, such as a wireline assembly deployable into a borehole for downhole surveying, and/or for retrieving a core barrel assembly (not illustrated).

[0048] In the embodiment illustrated in Figs. 1 and 2, the running gear 10 includes a plurality of components connected together in series along a common axis. At an uphole end 12 is a wireline retrieval connector configured to be connected to a wireline. In one embodiment, the wireline retrieval connector is a spear point structure 14. In other embodiments (not illustrated), the connector additionally or alternatively includes an eyelet arranged to connect to the wireline. Arranged downstream of the spear point 14 is a first centraliser 16 shaped to arrange the running gear 10 centrally in a drill string (not illustrated), a downhole tool 18, and a battery 20. The downhole tool 18 is typically configured as a data acquisition tool or instrument configured for wireline retrieval and used for exploration or mining. The tool 18 typically includes one or more sensors operable to record or measure parameters downhole to generate data. In the illustrated embodiments, the downhole tool 18 is configured as a north seeking gyro for downhole surveying however it will be appreciated that the gyro may be substituted with a wide range of other downhole tools 18. In the illustrated embodiment, the battery 20 is shown adjacent from and separate to the tool 18. It will be appreciated that, in other embodiments (not illustrated), the battery 20 and tool 18 are integrated.

[0049] In the illustrated embodiment 10, a releasable coupling assembly 22 is arranged downstream of the battery 20. As will be described in greater detail below, the coupling assembly 22 is operable to allow decoupling adjacent components of the running gear assembly 10 to sever the running gear 10 into two discrete portions. In some embodiments (not illustrated), the running gear 10 includes more than one coupling assembly 22 to allow breaking the running gear 10 into three, or more portions, and in other embodiments (not illustrated), the coupling assembly 22 is absent from the running gear 10. It will be appreciated that the location of the coupling assembly 22 downstream of the battery 20 to couple the battery 20 and a shock absorber 24 is exemplary and that, in other embodiments, the coupling assembly 22 may be alternatively positioned and/or configured within the running gear 10, such as upstream of, and/or integrated to, the downhole tool 18 to allow coupling the tool 18 to an uphole component.

[0050] The shock absorber 24 is arranged downstream of the downhole tool 18 and coupling assembly 22. As will be described in greater detail below, the shock absorber 24 is arranged to be compressed when a downhole end 28 of the running gear 10 collides with another object, such as a core barrel assembly or the bedrock, to reduce force being transmitted to the downhole tool 18.

[0051] Downstream of the shock absorber 24 is a second centraliser 26 shaped to arrange the running gear 10 centrally in the drill string, and, at a downhole end 28, is an overshot 30. The overshot 30 is operable to automatically engage another structure, such as a spear point or eyelet, upon impact with the structure. For example, when the running gear 10 is lowered by wireline sufficiently far into the borehole, the overshot 30 is operable to engage a wireline retrieval connector of a core barrel assembly. Once engaged with the core barrel assembly, the running gear 10 can be retrieved by reeling in the wireline to lift the core barrel assembly to the surface.

[0052] It will be appreciated that the running gear assembly 10 is configurable to have more, or less, components than the embodiment shown in Figure 1, such as to suit particular use requirements. For example, in some embodiments (not illustrated), the running gear assembly 10 includes a wireline retrieval connector arranged at an uphole end of the assembly 10, a downhole tool arranged downstream of the wireline retrieval connector, the shock absorber 24 arranged downstream of the downhole tool, and the overshot 30 arranged at a downhole end of the assembly. In other embodiments (not illustrated), the running gear assembly 10 includes a wireline retrieval connector arranged at an uphole end of the assembly 10, a downhole tool arranged downstream of the wireline retrieval connector, an alternative shock absorber arranged downstream of the downhole tool, the coupling device 64, described below, arranged downstream of the downhole tool to couple two axially adjacent components of the assembly, and the overshot 30 arranged at a downhole end of the assembly. In yet other embodiments (not illustrated), the running gear assembly 10 includes a wireline retrieval connector arranged at an uphole end of the assembly 10, a downhole tool arranged downstream of the wireline retrieval connector, the releasably coupling assembly 22 arranged upstream or downstream of the downhole tool, a shock absorber arranged downstream of the releasable coupling assembly, and the overshot 30 arranged at a downhole end of the assembly.

[0053] Figs. 3 to 9 illustrate the shock absorber 24 connected to an end cap sub-assembly 63 in isolation. In these figures, the shock absorber 24 is configured for impact, via the end cap sub-assembly 63, with other objects or structures, such as bedrock. It will be appreciated that the shock absorber 24 is configurable to fit to, or form part of, alternative downhole assemblies to the running gear 10, configured for diamond drilling or reverse circulation (RC) drilling.

[0054] In the illustrated embodiment, and best shown in Fig. 5, the shock absorber 24 includes a downhole portion 32 defining a bore 34, and an uphole portion 36 configured for direct or indirect connection to the downhole tool 18. The uphole portion 36 has a stanchion 38 extending from one end and which carries a piston 40. The piston 40 is slidably engaged with the bore 34 to allow relative axial movement of the uphole portion 36 and the downhole portion 32. A first resiliently deformable member, in the form of an outer compression spring 42, is arranged between the uphole portion 36 and the downhole portion 32. The spring 42 is arranged to be compressed when the uphole portion 36 and downhole portion 32 move axially relative to each other in a first direction. A second resiliently deformable member, in the form of an inner compression spring 44, is arranged between an end of the bore 34 and the piston 40 to be compressed when the uphole portion 36 and downhole portion 32 move axially relative to each other in a second direction opposed to the first direction.

[0055] The outer spring 42 is arranged to act as a bound spring to absorb energy when the uphole portion 36 and piston 40 move in the first direction relative to the downhole portion 32, typically being a downhole direction, such as is caused by the shock absorber 24, or connected running gear 10, impacting a core barrel assembly. The inner spring 44 is arranged to act as a rebound spring to absorb energy when the uphole portion 36 and piston 40 move in the second direction relative to the downhole portion 32, typically being an uphole direction, immediately after the bound stroke. It will be appreciated that configuring the resiliently deformable members as springs 42, 44 is exemplary and that configuring these members in other ways, such as elastomeric sleeves, is within the scope of this disclosure.

[0056] The downhole portion 32 has one or more abutment surfaces 46 arranged to abut the piston 40 to limit relative axial movement of the uphole portion 36 and the downhole portion 32. The abutment surface(s) 46 are arranged at a specific position along the bore 34 to restrict movement of the piston 40 in the second direction. This position is based on a determined limit of compression of the spring 44 which causes damage to the spring 44. The arrangement of the abutment surface(s) 46 therefore inhibits or prevents the inner spring 44 being compressed sufficiently to damage the spring 44. This can prove useful where the shock absorber 24 is arranged such that significant force is exerted axially through the shock absorber 24 to tension the shock absorber 24. This may occur when the shock absorber 24 is fitted in the running gear 10 and the running gear 10 is connected to and lifting a core barrel assembly. This may also occur where the shock absorber 24 directly connects to another downhole component and moved to lift the component from the borehole. It will be appreciated that, in some embodiments (not illustrated), tensioning the shock absorber 24, such as to lift another connected component, is not required, and therefore no abutment surface 46 is present.

[0057] In the illustrated embodiment, the abutment surface(s) 46 is defined by an annular shoulder 48 arranged to extend into the bore 34 and at least partially surround the second resiliently deformable member, being the inner spring 44. The shoulder 48 is arranged to face an uphole oriented side of the piston 40 to allow the piston to collide with, and prevent passing, the shoulder 48 when moving in the second direction. In other embodiments (not illustrated), the abutment surfaces 46 are defined by a continuous or discontinuous shoulder defined by the downhole portion 32. This may include one or more protrusions, such as fins, splines, or ribs, integrally formed with, or connected to, the downhole portion 32 to extend into the bore 34. In yet other embodiments (not illustrated), the abutment surfaces 46 are defined by one or more protrusions, such as a boss or pins, arranged to extend from an end of the bore 34 between the spring 44 and the stanchion 38.

[0058] The shoulder 48 is defined by an annular collar or ring 50 fixedly mounted to the downhole portion 32 at a defined location along the bore 34 to surround the inner spring 44 to define a single abut surface 46. In this embodiment, the collar 50 is trapped between two bodies 53, 54 of the downhole portion, where threadedly engaging the bodies 53, 54 secures the collar 50 along the bore 34 in a pocket defined in one of the bodies 54 arranged to seat the collar 50. The collar 50 defines a continuous annular shoulder 48 arranged as a seat for a rim of the piston 40. In some embodiments, the collar 50 comprises a plurality of discrete portions (not illustrated), such as forming segments arranged in an annular array about the bore 34, to define a discontinuous annular shoulder 48.

[0059] In some embodiments (not illustrated), the axial position of the collar 50 relative to the bore 34 is adjustable by operating an adjustment mechanism, such as positioning the collar 50 along a thread defined by part of the downhole portion 32. Such embodiments may allow adjusting the compression limit of the inner spring 44, for example, to adapt the shock absorber 24 for different load requirements[.

[0060] Best shown in Fig. 6, the piston 40 carries a resiliently deformable body 52 arranged across a downhole end of the piston 40 to allow abutting an end 54 of the bore 34 to be compressed. The body 52 acts as a buffer arranged to absorb force at the maximum extent of travel of the piston 40 in the first direction. This can inhibit the outer spring 42 being compressed sufficiently to cause damage to the spring 42, and/or prevent the piston 40 colliding with the end 54 of the bore 34. The body 52 is typically configured to have a stiffness greater than the stiffness of the outer spring 42 to enhance protecting the spring 42. In some embodiments, the body 42 is formed from an elastomer having a specific shore hardness configured to enhance wear resistance, such as being around 80A to 100A.

[0061] The body 52 defines a double-curved end face 56 which can enhance deformation of the body 52 and consequently dissipating force through the body 52. It will be appreciated that the double-curved end face 56 structure is exemplary, and that the end face 56 is configurable in other ways, such as defining domes, or carrying a layer of second, less dense material, to enhance buffering.

[0062] Best shown in Figs. 7 and 8, the downhole portion 32 defines at least one first flush port 58 at, or proximal to, each end of the bore 34. In the illustrated embodiment, the downhole portion 52 defines at least one second flush port 60 arranged between the first flush ports 58. Each flush port 58, 60 is arranged to convey fluid from within the bore 34 to outside of the downhole portion 32. This allows air and/or particulate, such as drilling fluid or mud, to be urged out of the bore 34 by the piston 40 travelling in the first or second direction along the bore 34. This arrangement can advantageously provide a self-cleaning function whereby movement of the piston 40 maintains a clear path through the bore 34. This can be particularly useful where the shock absorber 24 is operated in environments containing particulate which can collect and harden at the ends of the bore 34 which can inhibit movement of the piston 40 and potentially cause downtime to maintain the shock absorber 24.

[0063] Each flush port 58, 60 is dimensioned to allow particulate, such as drill cuttings, to be flushed from the bore 34 by the moving piston 40. The flush ports 58, 60 may define a minimum width or diameter of around 10 mm. The flush ports 58, 60 may also define a maximum width of around 15 mm to prevent a user from inserting a finger into the bore 34.

[0064] The second flush port 60 is configured to define an elongate slot extending in an axial direction partway along the bore 34. It will be appreciated that, in other embodiments (not illustrated), the first and/or second flush ports 58, 60 define alternative shapes, such as triangular or elliptical, and may include a linear and/or annular array of flush ports 58, 60.

[0065] Best shown in Fig. 9, the end cap sub-assembly 63 is mounted at an end of the downhole portion 32 of the shock absorber 24 by a coupling device 64. The coupling device 64 is connected between a sleeve 62 of the sub-assembly 63 and the downhole portion 32 to coaxially align the downhole portion 32 and the sleeve 62. The coupling device 64 includes a frangible portion, in the illustrated embodiments in the form of a necked region 66, configured to fracture when force exerted through the device 62 exceeds a defined threshold. Fracturing the frangible portion 66 separates the downhole portion 32 from the sleeve 62 to release the shock absorber 24 from the end cap sub-assembly 63. Where the shock absorber 24 is connected, via the coupling device 64, at its downhole end to another component or assembly which becomes stuck in the drill string, the arrangement and configuration of the coupling device 64 will cause the necked region 66 to break when the wireline is tensioned beyond the defined threshold, consequently allowing retrieval of the shock absorber 24 from the drill string.

[0066] Fig. 10 illustrates the coupling device 64 in isolation. The coupling device 64 has an elongate body 68 defining a longitudinal axis, and a pair of engagement structures 70 spaced along the axis, each structure 70 being configured to engage axially adjacent components of a downhole assembly, such as the downhole portion 32 of the shock absorber 24 and the sleeve 62 of the end cap sub-assembly 63, as shown in Fig. 9. It will be appreciated that the coupling device 64 is not limited to coupling components of the shock absorber 24 and may be used to couple other downhole components, as will be described in greater detail below.

[0067] A first engagement structure 70 is arranged at one end of the device 64 and in the form of a threaded portion 72 to allow threadedly engaging another component. A second engagement structure 70 is spaced partway along the device 64 and in the form of a flange 74 to allow frictionally engaging another component. It will be appreciated that the configuration of these structures 70 is exemplary and that other structures suitable for engaging another component are within the scope of this disclosure.

[0068] The flange 74 includes a surface 76 extending perpendicularly to the longitudinal axis of the body 68 to allow frictionally engaging another component. The flange 74 is configured such that in use, the surface 76 is arranged to face uphole to facilitate lifting the engaged component.

[0069] The necked region 66 is arranged between the engagement structures 70 and configured to fracture when the device 64 is exposed to tensile force exceeding a defined threshold. In other embodiments (not illustrated), the device 64 additionally or alternatively includes a frangible portion configured to fracture by shearing when the device 64 is exposed to tensile force exceeding a defined threshold, such as including a weakened region of the flange 74. In yet other embodiments (not illustrated), the device 64 additionally or alternatively includes a frangible portion configured to fracture when the device 64 is exposed to torsional force exceeding a defined threshold. The threshold is specified according to the usage requirements of the device 64. This may be, for example, fracture at 20,000 N with a tolerance of +/- 1,000 N. In some embodiments, the threshold is defined as a percentage of the typical maximum rated load of a tool which the device 64 is connected to.

[0070] Figs. 11 to 13 show the coupling device 64 arranged in a coupling sub-assembly 80 for a downhole assembly, such as the running gear 10. The coupling sub-assembly 80 includes a first member, in the form of a sleeve 82 defining a recess 84 in one end, and a second member, in the form of a shaft 86 having a projection 88 dimensioned to be received in the recess 84 of the sleeve 82. The shaft 86 is configured to be rotationally locked relative to the sleeve 82. The coupling device 64 is connectable between the sleeve 82 and the shaft 86 to coaxially align these components.

[0071] Best shown in Fig. 13, the sleeve 82 defines a keyway 90 adjacent the recess 84, and the shaft 86 defines a key seat 92. The sub-assembly 80 also includes a key 94 dimensioned to be received in the keyway 90 and the key seat 92 to inhibit relative rotation of the first sleeve 82 and the second sleeve 86. It will be appreciated that, in other embodiments (not illustrated), the key 94 may be integrally formed with the second sleeve 86 such that the key seat 92 is absent. It will also be appreciated that the arrangement of the key 94, key seat 92 and key way 90 are one approach to rotationally lock the sleeves 82, 86 relative to each other and that other approaches are within the scope of this disclosure. For example, in some embodiments (not illustrated), the projection 88 defines a hex section and the recess 84 defines a complementary hex recess. In yet other embodiments (not illustrated), the projection 88 and recess 84 define alternatively shaped complementary structures to inhibit relative rotation but allow relative axial movement.

[0072] Returning to Fig. 9, the shock absorber 24 includes at least some of the features of the coupling sub-assembly 80. It will be appreciated that common reference numerals indicate common features. In this embodiment, the downhole portion 32 defines the keyseat 92 and the downhole sleeve 62 defines the keyway. The key 94 is housed in the keyseat 92 and the keyway 94 to inhibit relative rotation of the downhole portion 32 and downhole sleeve 62.

[0073] Figs. 14 to 19 illustrate a releasable coupling assembly 100 for releasably coupling axially adjacent components of a downhole assembly, such as a downhole tool and a shock absorber. It will be appreciated that the releasable coupling assembly 100 is configurable to fit to, or form part of, alternative downhole assemblies to the running gear 10, such as is used for RC drilling. The releasable coupling assembly 100 includes a downhole body 102 configured to connect to one of the axially adjacent components, and an uphole body 104 configured to connect to the other of the axially adjacent components. Each of the downhole body 102 and the uphole body 104 have a complementary engagement structure 106 configured to releasably engage the bodies 102, 104. The coupling assembly 100 also includes a sleeve 108 rotatably mounted on one of the downhole body 102 and the uphole body 104. The sleeve 108 is configured to be manually rotatable to axially translate between a locked position (Figs. 14 and 16) to cover the engagement structures 106, and an unlocked position (Figs. 15 and 17) to expose the engagement structures 106 to allow uncoupling the axially adjacent components.

[0074] Figs. 14 to 17 illustrate a first embodiment 110 of the releasable coupling assembly 100, and Figs. 18 and 19 illustrate a second embodiment 22 of the assembly 100, being the releasable coupling assembly 22 shown in Fig. 1 forming part of the running gear assembly 10. Whilst this embodiment 22 is shown fitted to the running gear assembly 10 it will be appreciated that this embodiment 22, and the first embodiment 110, can be employed to releasably couple any axially adjacent components of downhole assemblies, and are not limited to use within the running gear assembly 10. It will be understood that the two embodiments 110, 22 share features and that common reference numerals indicate common features.

[0075] The sleeve 108 defines a helical slot 107 arrange to extend partway around the sleeve 108 . Each uphole body 104 includes a radially extending shaft 105 dimensioned to be received in the slot 107. Rotating the sleeve 108 between the locked position and the unlocked position causes sidewalls of the slot 107 to ride along the shaft 105 to guide movement of the sleeve 108.

[0076] Best shown in Figs. 16 and 17, each embodiment 22, 110 includes a retention mechanism 130 operable to retain the sleeve 108 in the locked position or the unlocked position. The sleeve 108 defines at least one downhole recess 132 arranged adjacent one end, and at least one uphole recess 134 arranged adjacent the other end, and the retention mechanism 130 includes a detent structure biased to extend radially to allow engaging the at least one downhole recess 132 or the at least one uphole recess 134. In the illustrated embodiment, the detent structure comprises a pair of bearings 136 urged outwardly from the uphole body 104 by a compression spring 137 housed in the uphole body 104. It will be appreciated that, in other embodiments (not illustrated), the retention structure is alternatively configured to allow engaging the sleeve 108 in the locked and unlocked positions, such as including a leaf or bow string to urge an engagement structure radially to allow engaging the sleeve 108.

[0077] Best shown in Fig. 19, the engagement structures 106 of each of the illustrated embodiments 22, 110 are configured to slidably interlock such that, when the sleeve 108 is rotated to the unlocked position to exposes the structure 106, decoupling requires moving the bodies 102, 104 transverse to a longitudinal axis of the assembly 22, 110. The downhole body 102 defines a keyed portion 112 and the uphole body 104 defines a complementary shaped slot 114 for receiving the keyed portion 112. The keyed portion 112 defines a flared free end 116 arranged to inhibit withdrawing the keyed portion 112 from the slot 114 in an axial direction. The keyed portion 112 also defines a tapered base 118 to further enhance engagement between the bodies 102, 104.

[0078] The uphole body 104 of the second embodiment 22 includes a wireline retrieval connector including a spear point structure 120. In other embodiments (not illustrated), the wireline retrieval connector includes an eyelet. Configuring the uphole body 104 in this way allows rapidly connecting the body 104 to a conventional releasable engagement mechanism, such as an overshot. Where the coupling assembly 22 is arranged partway along an elongate downhole assembly, such as the running gear 10 illustrated in Fig. 1, operating the coupling assembly 22 allows splitting the downhole assembly into two portions, reattaching the uphole body 104 to the coupling assembly 22 , and connecting an overshot to the spear point structure 120 to continue extracting the downhole assembly from a drill string.

[0079] Use of the running gear assembly 10 typically involves activating the downhole tool 18 and deploying the assembly 10 into a drill string or borehole by suspending the assembly by a wireline (not illustrated) connected to the spear point structure 14, typically via a further overshot (not illustrated). As the assembly 10 descends into the drill string or borehole, the downhole tool 18 records or measures parameters to generate and store data. Measured parameters are typically geophysical, geological, geomechanical, and/or navigational parameters, including, but not limited to, dip, azimuth, gamma, magnetic susceptibility, density, porosity, electrical resistivity, temperature, acceleration, pressure, acoustic velocity, magnetic field measurements. The assembly 10 is lowered until the overshot 30 collides within another component, typically being a backend of a core barrel assembly, causing operation of the shock absorber 24, described in greater detail below. The collision causes the overshot 30 to automatically engage the component. The running gear assembly 10 is then retrieved to the surface by retracting the wireline, again causing operation of the shock absorber 24.

[0080] Where the releasable coupling assembly 22 forms part of the running gear assembly 10 and is revealed duration extraction of the running gear 10 from the borehole or drill string, the releasable coupling assembly 22 may be operated by an operator manually rotating the sleeve 108 to the unlocked position to expose the engagement structures 106. The operator then secures the downhole body 102 relative to the surface, such as by inserting a pin through a component of the assembly 10, and operates the engagement structures 106 to separate the uphole body 104 from the downhole body 102, consequently splitting the running gear assembly 10 into a portion arranged out of the hole, and a portion arranged in the hole. The uphole body 104 is then re-engaged with the downhole body 102, the sleeve 108 returned to the locked position, and the further overshot engaged with the spear point structure 120. The remainder of the running gear assembly 10 is then extracted.

[0081] Use of the shock absorber 24 involves the shock absorber 24 being lowered down a borehole or drill string until the downhole portion 32 collides, directly or indirectly via one or more connected components, with a static object, such as a core barrel assembly. The collision inhibits further movement of the downhole portion 32 in the downhole direction, causing the uphole portion 36 to move in the first direction relative to the downhole portion 32. This movement causes the piston 40 to travel along the bore 34 to expel fluid, and potentially also particulate, from the flush ports 58, 60, and cause the uphole portion 36 to compress the outer (bound) spring 42. Some collision may cause the resiliently deformable body 52 to press against the downhole end 54 of the bore 34. The piston 40 may then travel in the second direction causing compression of the inner (rebound) spring 44. Once connected to another object, such as the core barrel assembly, the shock absorber 24 may be lifted from the borehole or drill string, causing the piston 40 to travel in the second direction until abutting the abutment surface 46 of the collar 50, where the piston 40 is inhibited from further movement in the second direction.

[0082] During extraction of the running gear assembly 10 from the borehole or drill string, the running gear 10, or a component connected to the running gear 10, such as a core barrel assembly, may become jammed. Should tension continue to be applied to the wireline and the tensile force exceed the defined threshold of the coupling device 64, this causes the necked region 66 to fracture. The fracture of the device 64 uncouples the downhole sleeve 62 from the remainder of the shock absorber 24, allowing retrieval of the shock absorber, and all components of the running gear 10 upstream of the shock absorber 24, including the downhole tool 18, to the surface.

[0083] It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the above-described embodiments, without departing from the broad general scope of the present disclosure. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

CLAIMS:

1. A shock absorber for a downhole tool, the shock absorber including:

a downhole portion defining a bore;

an uphole portion configured for connection to the downhole tool, the uphole portion having a stanchion extending from one end, the stanchion carrying a piston slidably engaged with the bore to allow relative axial movement of the uphole portion and downhole portion;

a first resiliently deformable member arranged between the uphole portion and the downhole portion to be compressed when the uphole portion and downhole portion move axially relative to each other in a first direction; and

a second resiliently deformable member arranged between an end of the bore and the piston to be compressed when the uphole portion and downhole portion move axially relative to each other in a second direction opposed to the first direction,

the downhole portion having one or more abutment surfaces arranged to abut the piston to limit relative axial movement of the uphole portion and the downhole portion.

2. The shock absorber of claim 1, wherein the one or more abutment surfaces are defined by an annular shoulder arranged to extend into the bore and at least partially surround the second resiliently deformable member.

3. The shock absorber of claim 2, wherein the shoulder is defined by a collar mounted at a defined location along the bore.

4. The shock absorber of any one of the preceding claims, wherein the piston carries a resiliently deformable body arranged across a downhole end of the piston to allow abutting an end of the bore to be compressed.

5. The shock absorber of any one of the preceding claims, wherein the downhole portion defines at least one first flush port adjacent each end of the bore, each first flush port arranged to convey fluid from within the bore to outside of the downhole portion.

6. The shock absorber of claim 5, wherein the downhole portion defines at least one second flush port arranged partway along the bore between the first flush ports, the, or each, second flush port arranged to convey fluid from within the bore to outside of the downhole portion.

7. The shock absorber of claim 6, wherein the, or each, second flush port comprises a slot extending axially along the bore.

8. A shock absorber for a downhole tool, the shock absorber including:

a downhole portion defining a bore;

an uphole portion configured for connection to the downhole tool, the uphole portion having a stanchion extending from one end, the stanchion carrying a piston slidably engaged with the bore to allow relative axial movement of the uphole portion and downhole portion;

a first resiliently deformable member arranged between the uphole portion and the downhole portion to be compressed when the uphole portion and downhole portion move axially relative to each other in a first direction;

a second resiliently deformable member arranged between an end of the bore and the piston to be compressed when the uphole portion and downhole portion move axially relative to each other in a second direction opposed to the first direction

the downhole portion defines at least one first flush port adjacent each end of the bore, each first flush port arranged and dimensioned to convey fluid and particulate from within the bore to outside of the downhole portion.

9. The shock absorber of claim 10, wherein the downhole portion defines at least one second flush port arranged partway along the bore between the first flush ports, the, or each, second flush port arranged and dimensioned to convey fluid and particulate from within the bore to outside of the downhole portion.

10. The shock absorber of claim 9, wherein the, or each, second flush port comprises a slot extending axially along the bore.

11. The shock absorber of any one of the preceding claims, further including:

a downhole member mounted at an end of the downhole portion; and

a coupling device connected between the downhole member and the downhole portion to coaxially align the downhole portion and the downhole member, the coupling device having a frangible portion configured to fracture when force exerted through the device exceeds a defined threshold, such that fracturing the frangible portion separates the downhole portion from the downhole member.

12. The shock absorber of claim 11, wherein the downhole member defines a recess in one end, and the downhole portion has a projection dimensioned to be received in the recess of the downhole member to cause the downhole portion to be rotationally locked to the downhole member.

13. The shock absorber of claim 12, wherein the downhole member defines a keyway adjacent the recess, and the downhole portion defines a key seat, and further including a key dimensioned to be received in the keyway and the key seat to inhibit relative rotation of the downhole portion and the downhole member.

14. A coupling device for coupling two axially adjacent components of a downhole assembly, the device including:

an elongate body defining a longitudinal axis and having a pair of spaced engagement structures, each engagement structure configured to engage one of the axially adjacent components,

the body including a frangible portion configured to fracture when force exerted on the body exceeds a defined threshold.

15. The coupling device of claim 14, wherein the frangible portion includes a necked region arranged between the engagement structures, the necked region shaped and dimensioned to allow fracture when tensile force exerted axially along the body exceeds the defined threshold.

16. The coupling device of claim 14 or 15, wherein one engagement structure comprises a thread for threadedly engaging one of the components, and the other engagement structure comprises a flange having a surface extending perpendicularly to the longitudinal axis to allow frictionally engaging the other component.

17. The coupling device of claim 16, wherein the flange is configured such that, in use, the surface is arranged to face uphole to facilitate lifting one of the components.

18. A coupling sub-assembly for a downhole assembly, the coupling sub-assembly including:

a first member defining a recess in one end;

a second member having a projection dimensioned to be received in the recess of the first member, the second member configured to be rotationally locked relative to the first member; and

the coupling device of claim 14 configured to be connected between the first member and the second member to coaxially align the members.

19. The coupling sub-assembly of claim 18, wherein the first member defines a keyway adjacent the recess, and the second member defines a key seat, and further including a key dimensioned to be received in the keyway and the key seat to inhibit relative rotation of the first member and the second member.

20. A releasable coupling assembly for releasably coupling axially adjacent components of a downhole assembly, the releasable coupling assembly including:

a downhole body configured to connect to one of the axially adjacent components,

an uphole body configured to connect to the other of the axially adjacent components, each of the downhole body and the uphole body having a complementary engagement structure configured to releasably engage the bodies, and

a sleeve rotatably mounted on one of the downhole body and the uphole body, the sleeve configured to be manually rotatable to axially translate between a locked position to cover the engagement structures, and an unlocked position to expose the engagement structures to allow uncoupling the axially adjacent components.

21. The coupling assembly of claim 20, wherein the uphole body includes a wireline retrieval connector configured for releasable connection to an overshot.

22. The coupling assembly of claim 20 or 21, further including a retention mechanism arranged to retain the sleeve in the locked position or the unlocked position.

23. The coupling assembly of claim 20, wherein the sleeve defines at least one downhole recess arranged adjacent a downhole end, and at least one uphole recess arranged adjacent an uphole end, and the retention mechanism includes a detent structure biased to extend radially to allow engaging the at least one downhole recess or the at least one uphole recess.

24. The coupling assembly of claim 23, wherein one of the axially adjacent components is a downhole tool.

25. The coupling assembly of any one of claims 20 to 24 wherein one engagement structure includes a slot extending perpendicularly to the axis of the body, and the other engagement structure includes a keyed portion shaped to slidably engage the slot.

26. A running gear assembly for downhole surveying, the assembly including:
a wireline retrieval connector arranged at an uphole end of the assembly;
a downhole tool arranged downstream of the wireline retrieval connector;
a shock absorber according to claim 1, the shock absorber arranged downstream of the downhole tool; and
an overshot arranged at a downhole end of the assembly.

27. A running gear assembly for downhole surveying, the assembly including:
a wireline retrieval connector arranged at an uphole end of the assembly;
a downhole tool arranged downstream of the wireline retrieval connector;

a shock absorber arranged downstream of the downhole tool;

a coupling device according to claim 14, the coupling device arranged downstream of the downhole tool to couple two axially adjacent components of the assembly; and

an overshot arranged at a downhole end of the assembly.

28. A running gear assembly for downhole surveying, the assembly including:

a wireline retrieval connector arranged at an uphole end of the assembly;

a downhole tool arranged downstream of the wireline retrieval connector;

a releasable coupling assembly according to claim 20, the assembly arranged downstream of the downhole tool;

a shock absorber arranged downstream of the releasable coupling assembly; and

an overshot arranged at a downhole end of the assembly.

29. A running gear assembly for downhole surveying, the assembly including:

a wireline retrieval connector arranged at an uphole end of the assembly;

a downhole tool arranged downstream of the wireline retrieval connector;

a shock absorber arranged downstream of the downhole tool, the shock absorber including:

a downhole portion defining a bore;

an uphole portion having a stanchion extending from one end, the stanchion carrying a piston slidably engaged with the bore to allow relative axial movement of the uphole portion and downhole portion;

a first resiliently deformable member arranged between the uphole portion and the downhole portion to be compressed when the uphole portion and downhole portion move axially relative to each other in a first direction;

a second resiliently deformable member arranged between an end of the bore and the piston to be compressed when the uphole portion and downhole portion move axially relative to each other in a second direction opposed to the first direction;

the downhole portion having one or more abutment surfaces arranged to abut the piston to limit relative axial movement of the uphole portion and the downhole portion;

a coupling device arranged downstream of the shock absorber to couple two axially adjacent components of the assembly, the coupling device including an elongate body defining a longitudinal axis and having a pair of spaced engagement structures, each engagement structure configured to engage one of the axially adjacent components, the body including a frangible portion configured to fracture when force exerted on the body exceeds a defined threshold; and

an overshot arranged at a downhole end of the assembly.

30. The running gear assembly of claim 29, including a releasable coupling assembly connected between two adjacent components of the assembly, the releasable coupling assembly including:

a downhole body configured to connect to one of the adjacent components,

an uphole body configured to connect to the other of the adjacent components, each of the downhole body and the uphole body having a complementary engagement structure configured to releasably engage the bodies, and

a sleeve rotatably mounted on one of the downhole body and the uphole body, the sleeve configured to be manually rotatable to axially translate between a locked position to cover the engagement structures, and an unlocked position to expose the engagement structures to allow uncoupling the adjacent components.

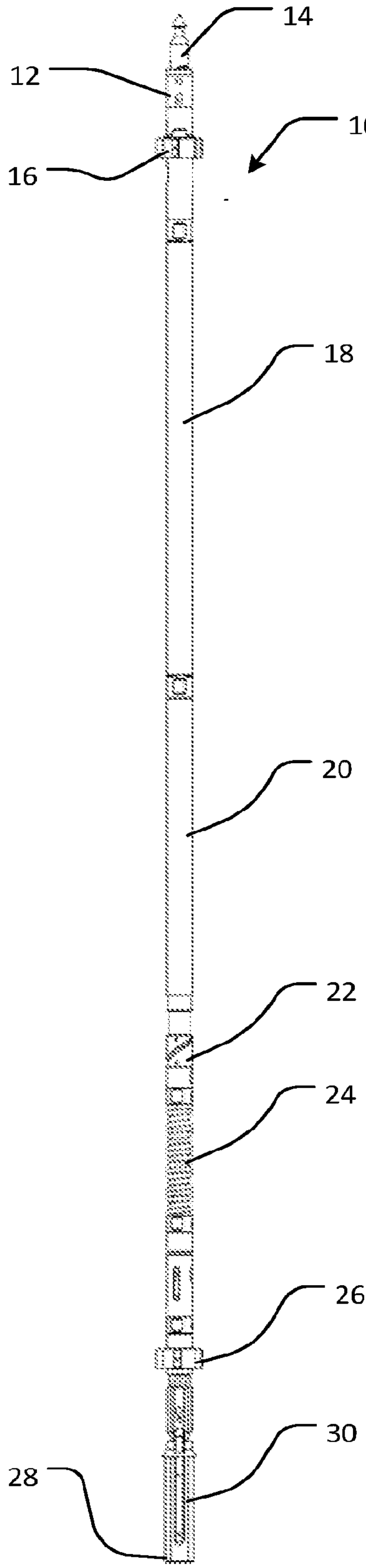

Fig.1

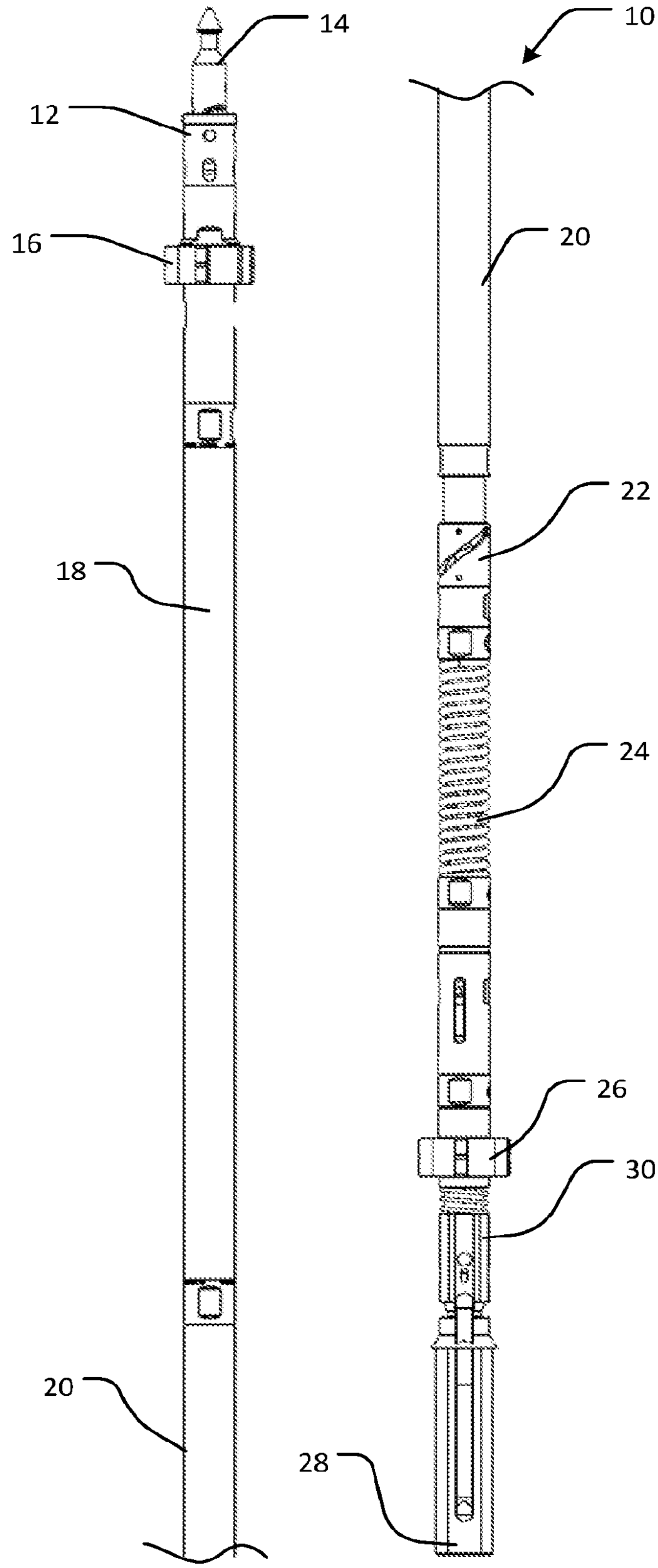

Fig. 2

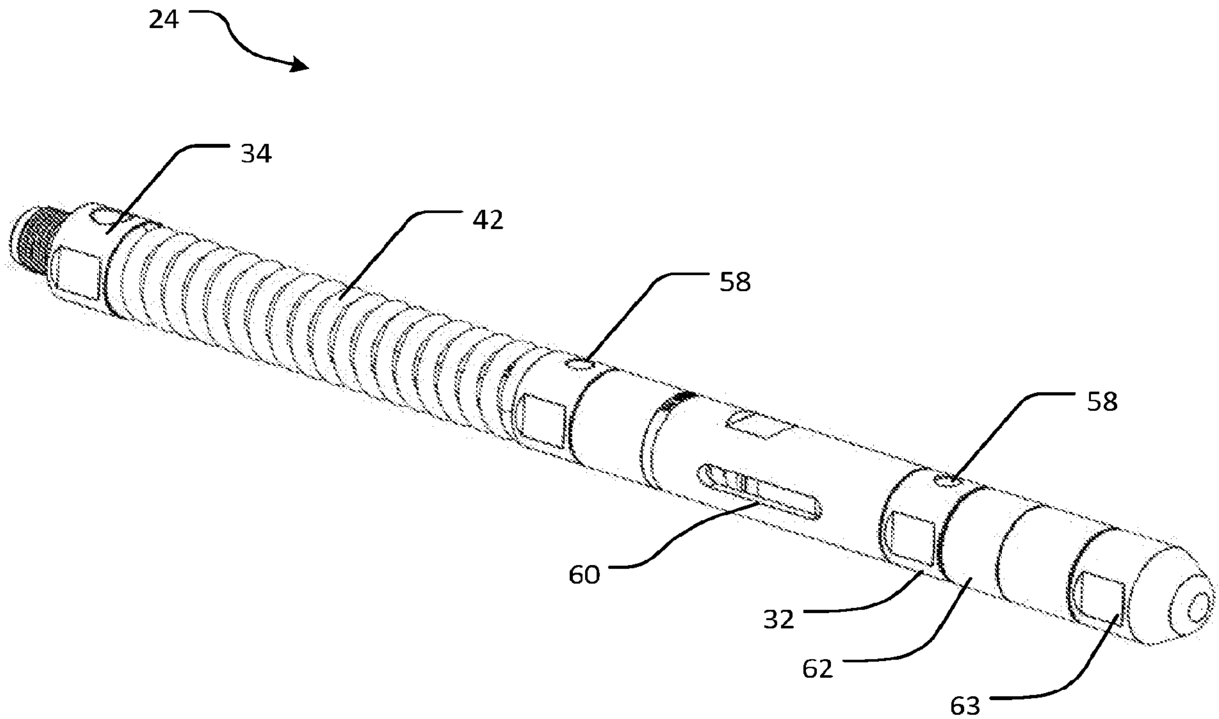

Fig. 3

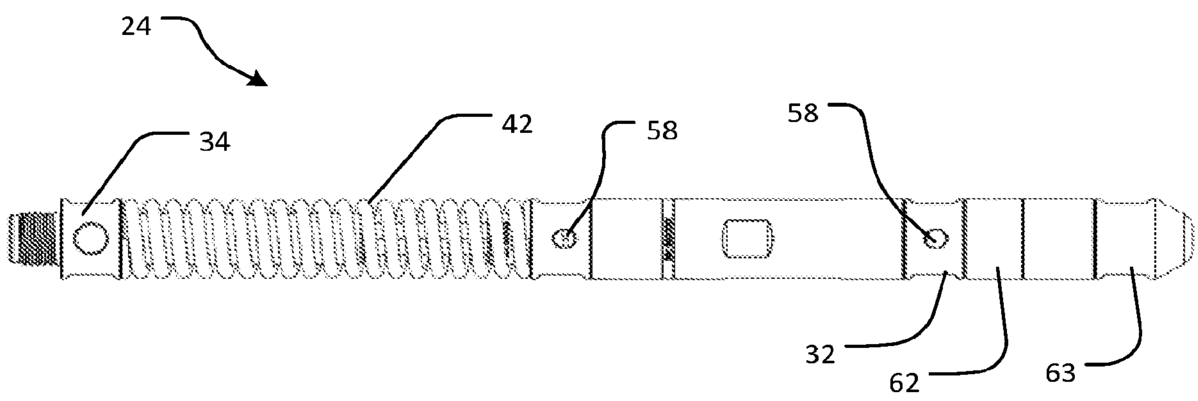

Fig. 4

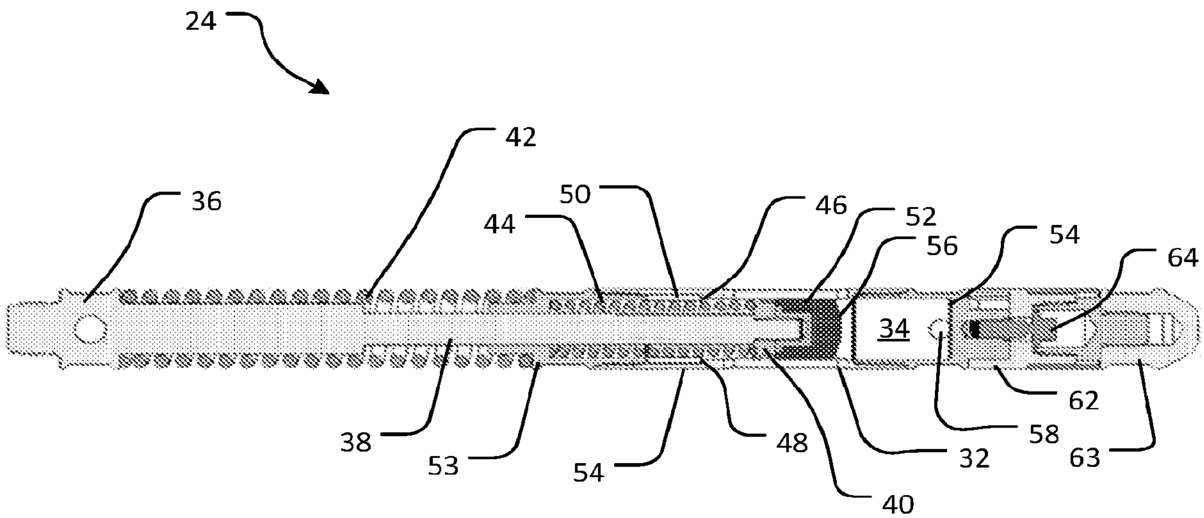
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Fig. 5

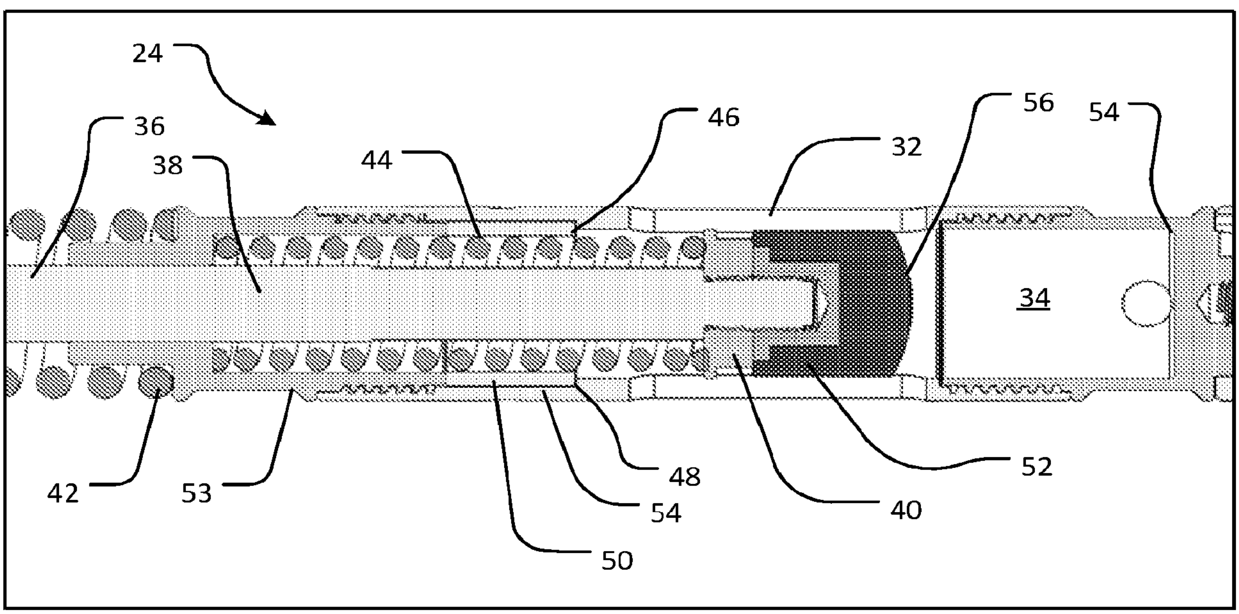
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Fig. 6

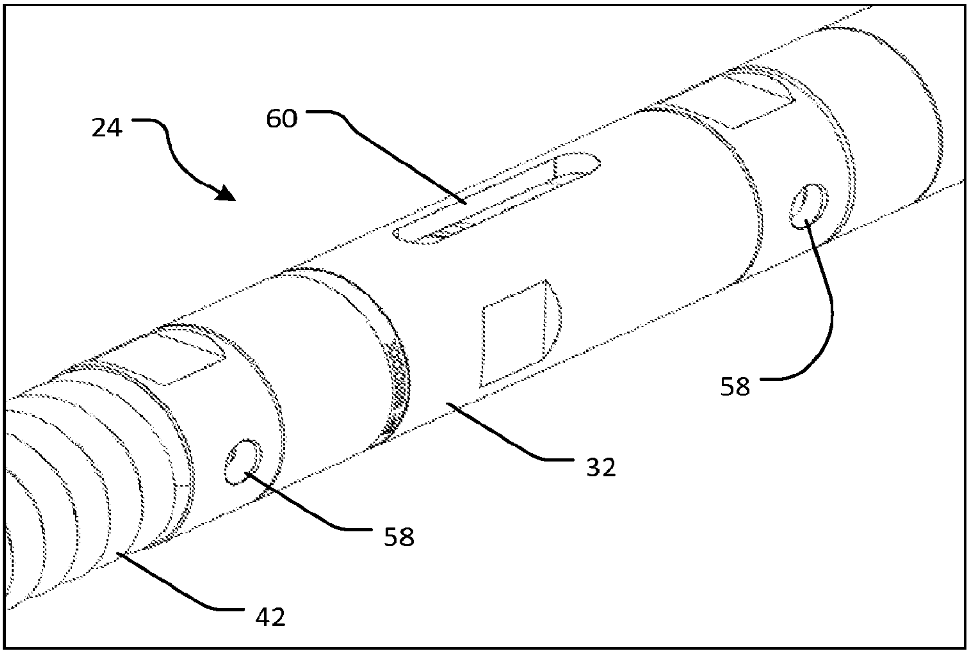


Fig. 7

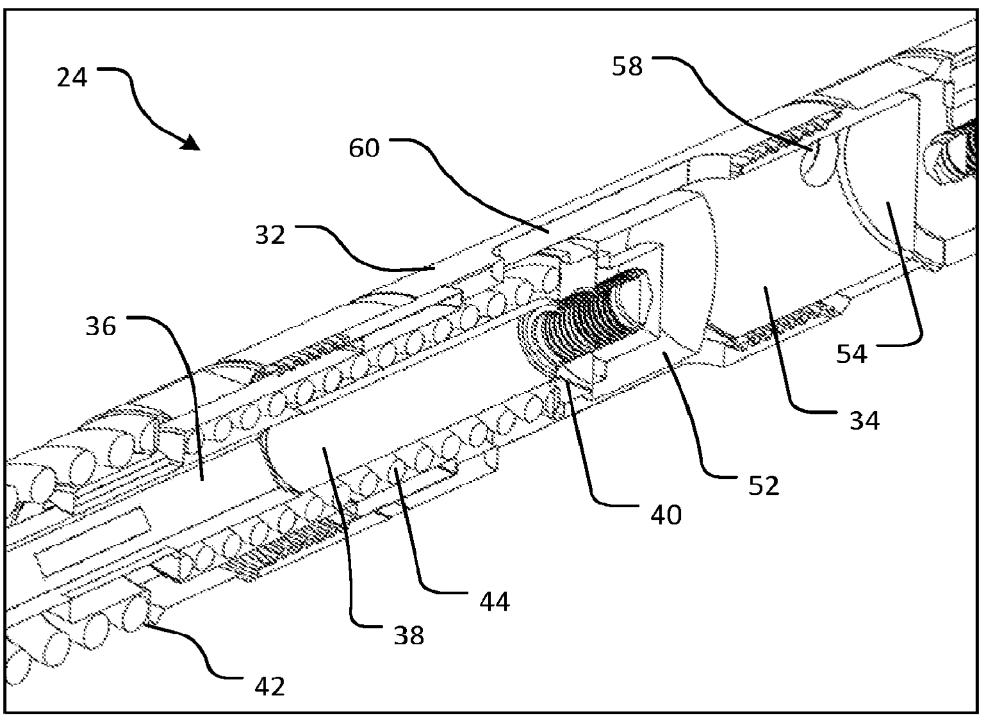


Fig. 8

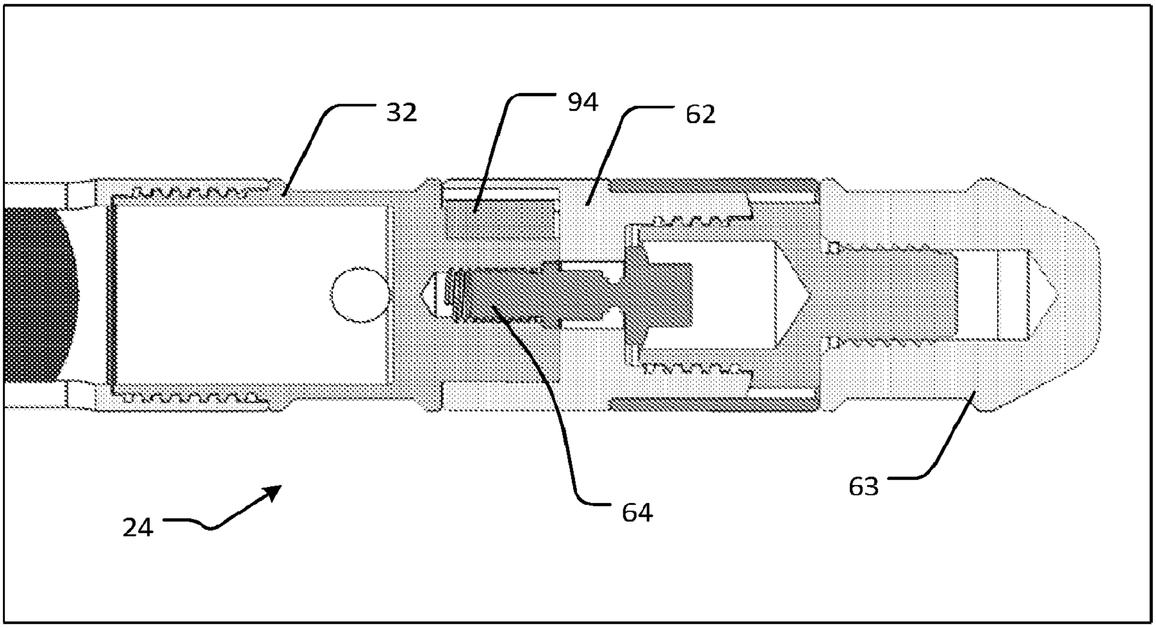


Fig. 9

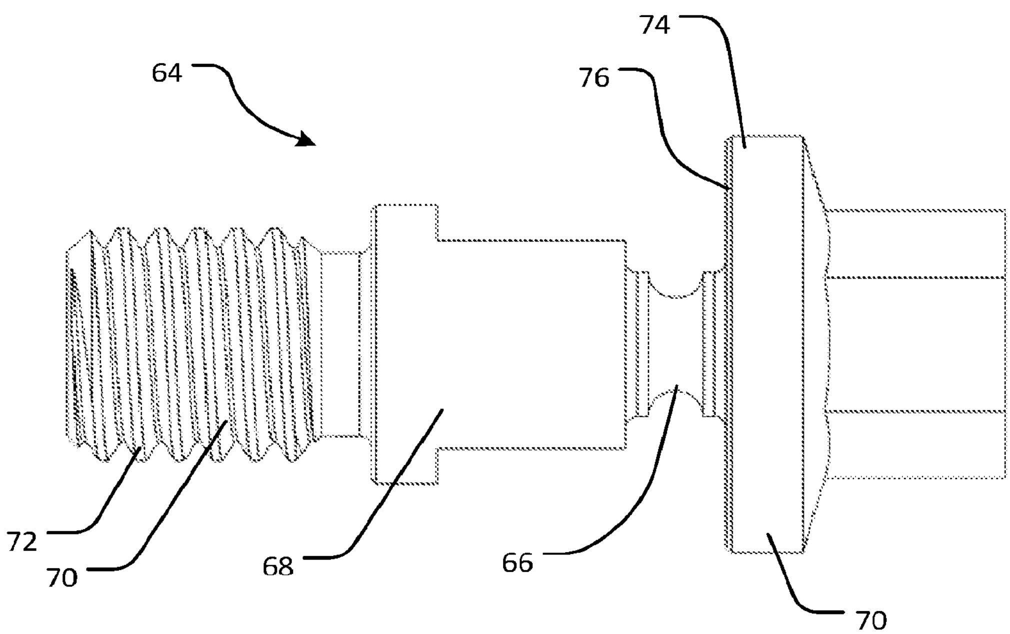


Fig. 10

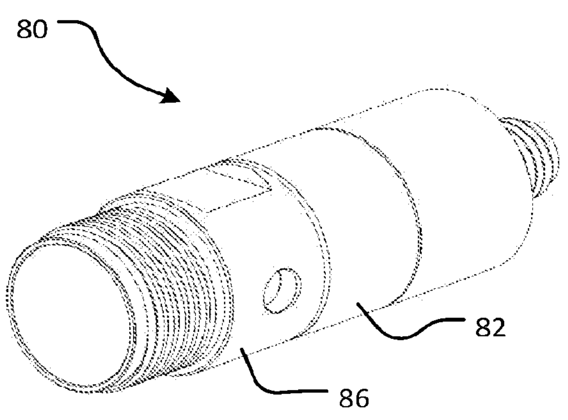


Fig. 11

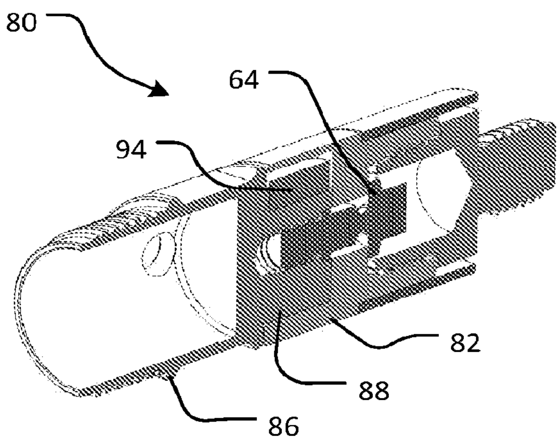


Fig. 12

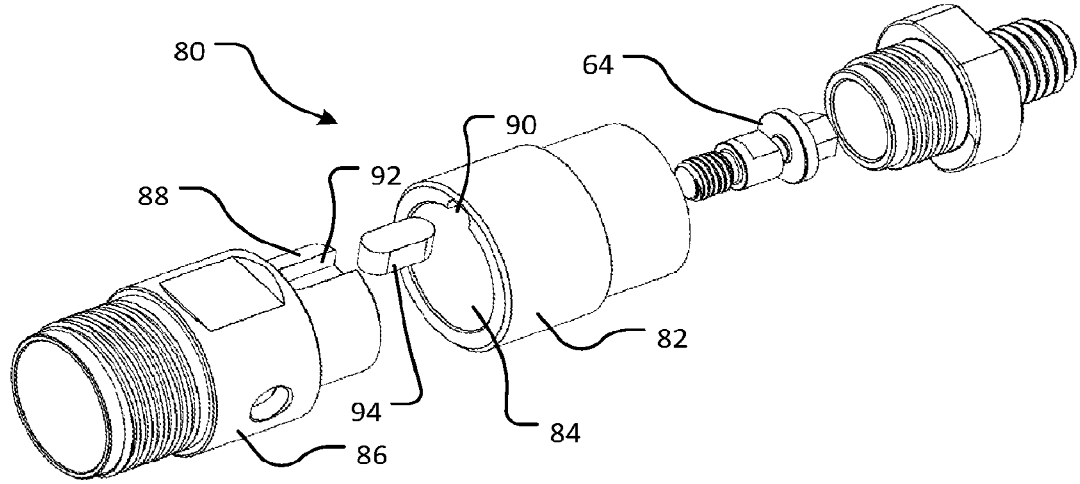


Fig. 13

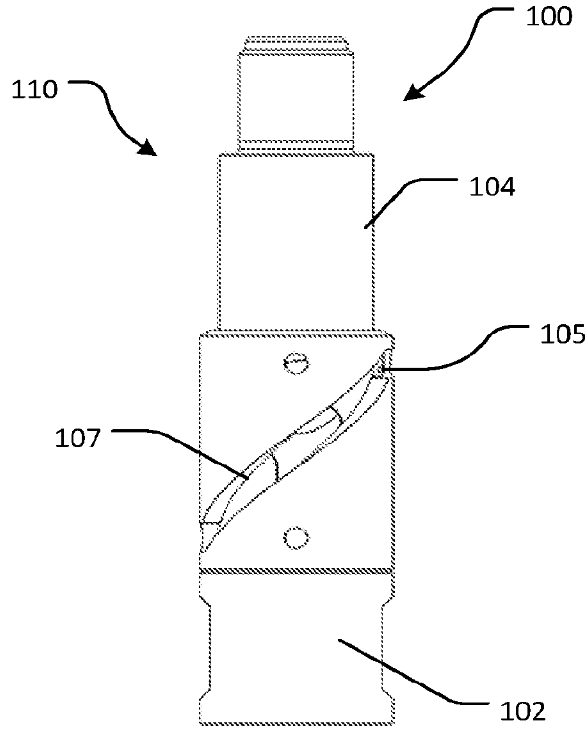


Fig. 14

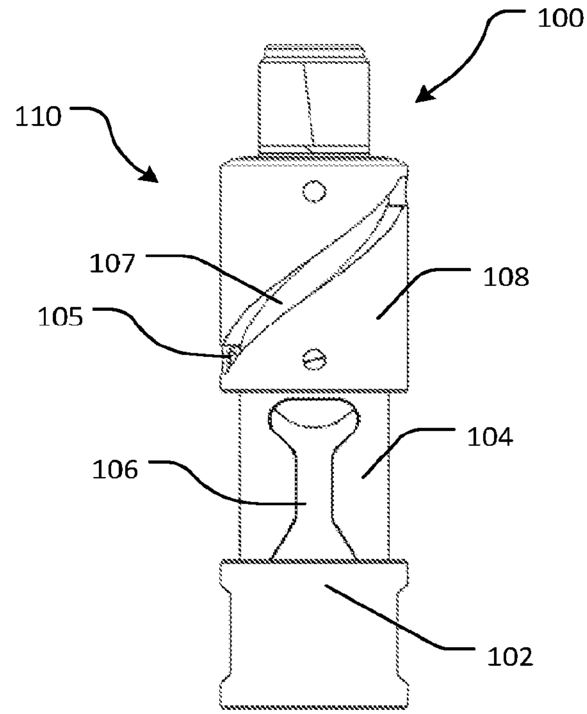


Fig. 15

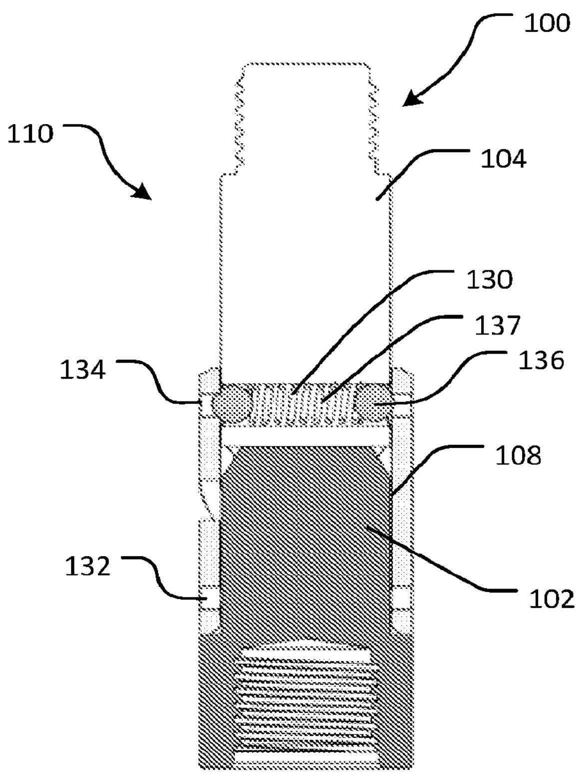


Fig. 16

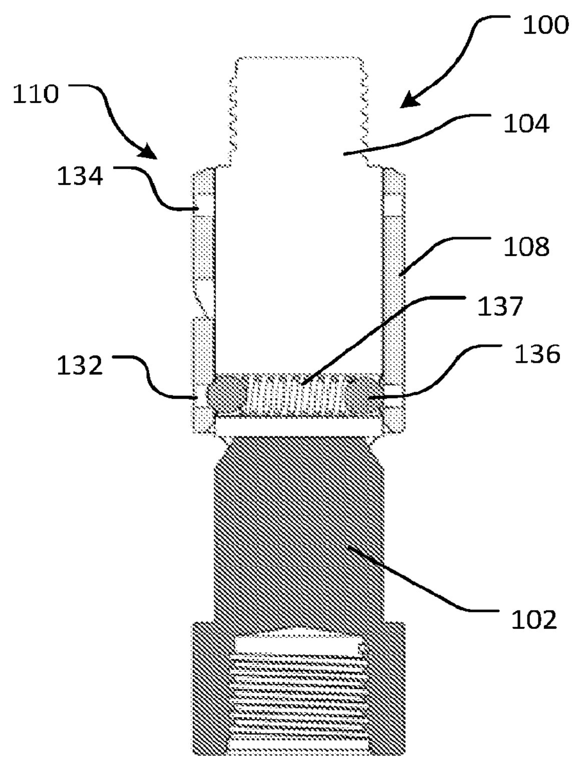
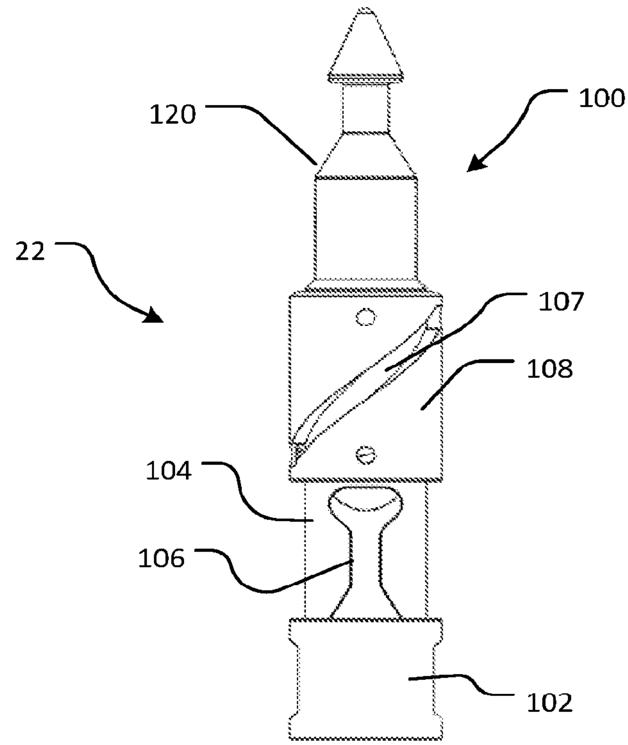


Fig. 17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102

Fig. 18

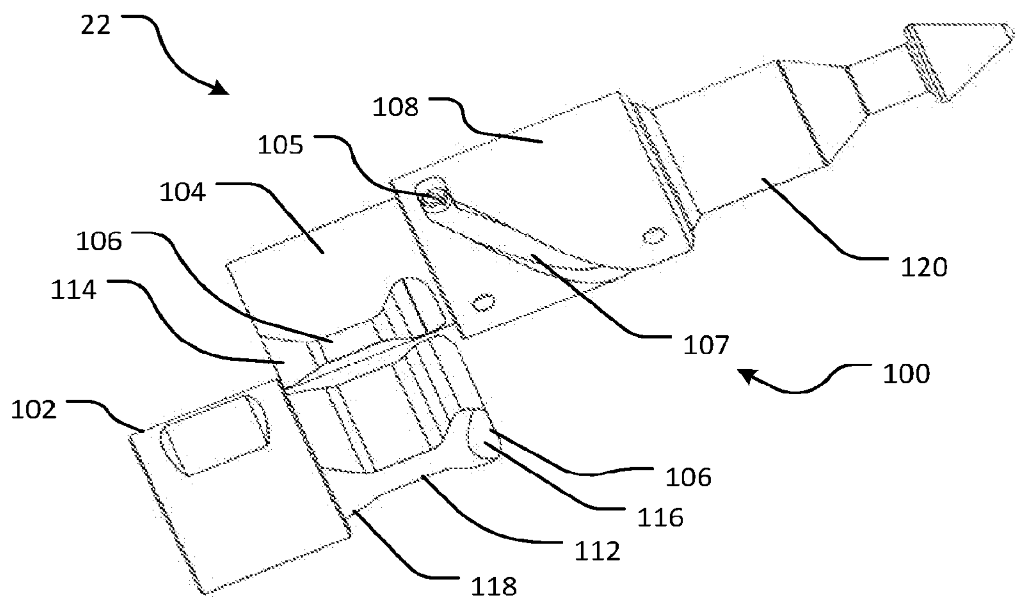
22
108
105
104
106
114
102
120
107
100
106
116
112
118

Fig. 19

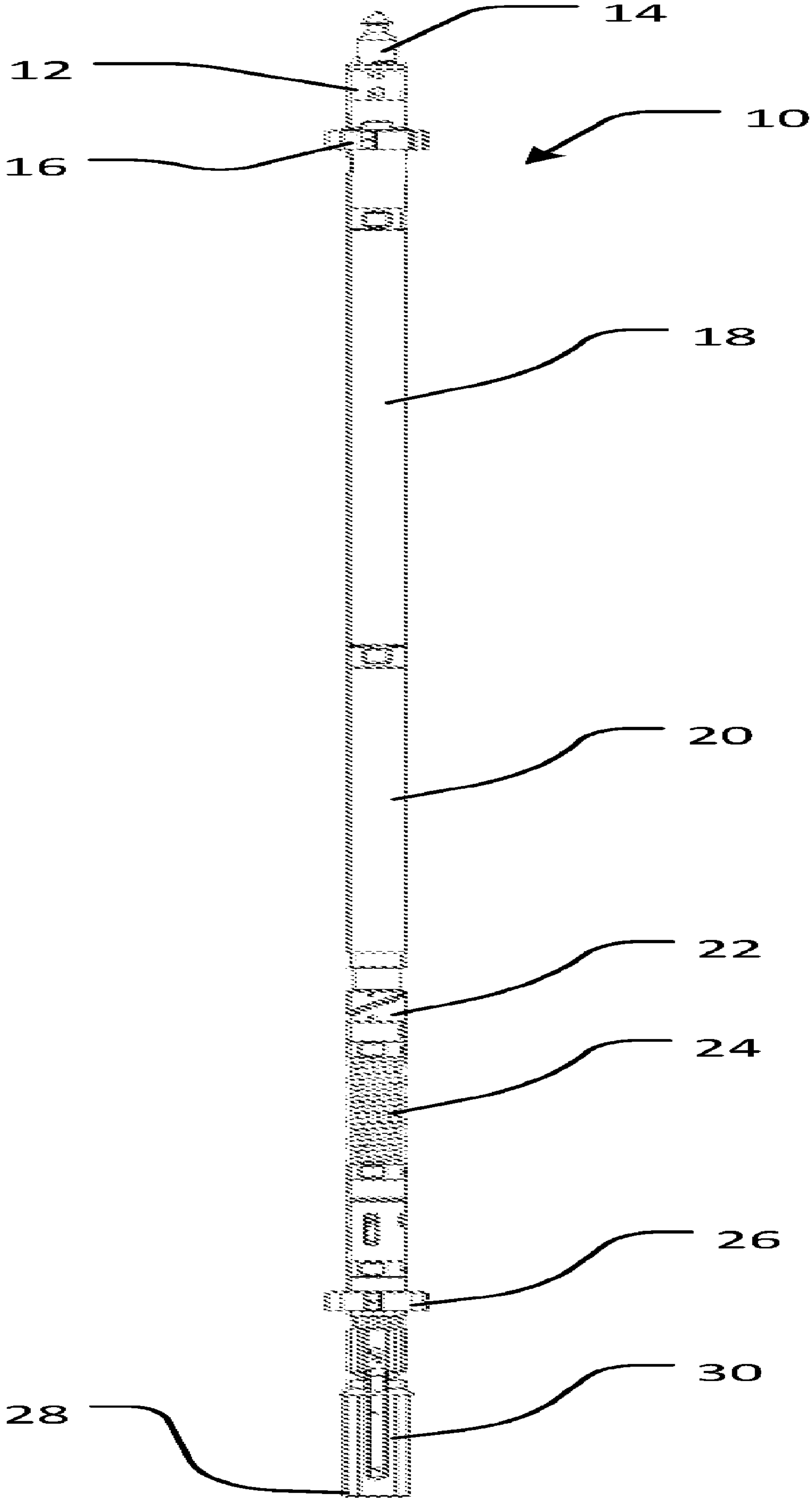

Fig.1