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(54) **DOWNHOLE DEVICE FOR DATA ACQUISITION DURING HYDRAULIC FRACTURING OPERATION AND METHOD THEREOF**

(75) Inventors: **James Lewellyn Miller**, Willis, TX (US); **Douglas R. Berrett**, Spring, TX (US)

(73) Assignee: **OMEGA WELL MONITORING LIMITED**, Aberdeen (GB)

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E21B 34/10	(2006.01)
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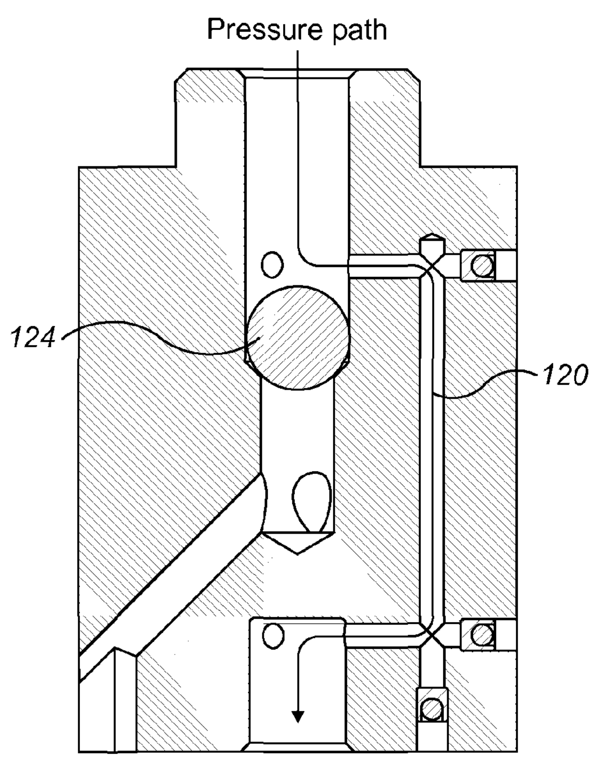
(57) **ABSTRACT**

A downhole system including a downhole device for data acquisition during fracing operations is disclosed. It includes a bypass device (**102**) operatively coupleable to for instance a frac plug (**10**) and is adapted to allow downhole fluid flow through the bypass device (**102**) and frac plug (**10**) but also permits the closure of that path whilst providing at least one second fluid path (**120**) for fluid communication between at least one data acquisition device (**108**) provided to detect at least one physical property such as pressure and a region inside the wellbore located uphole of the bypass device (**102**).



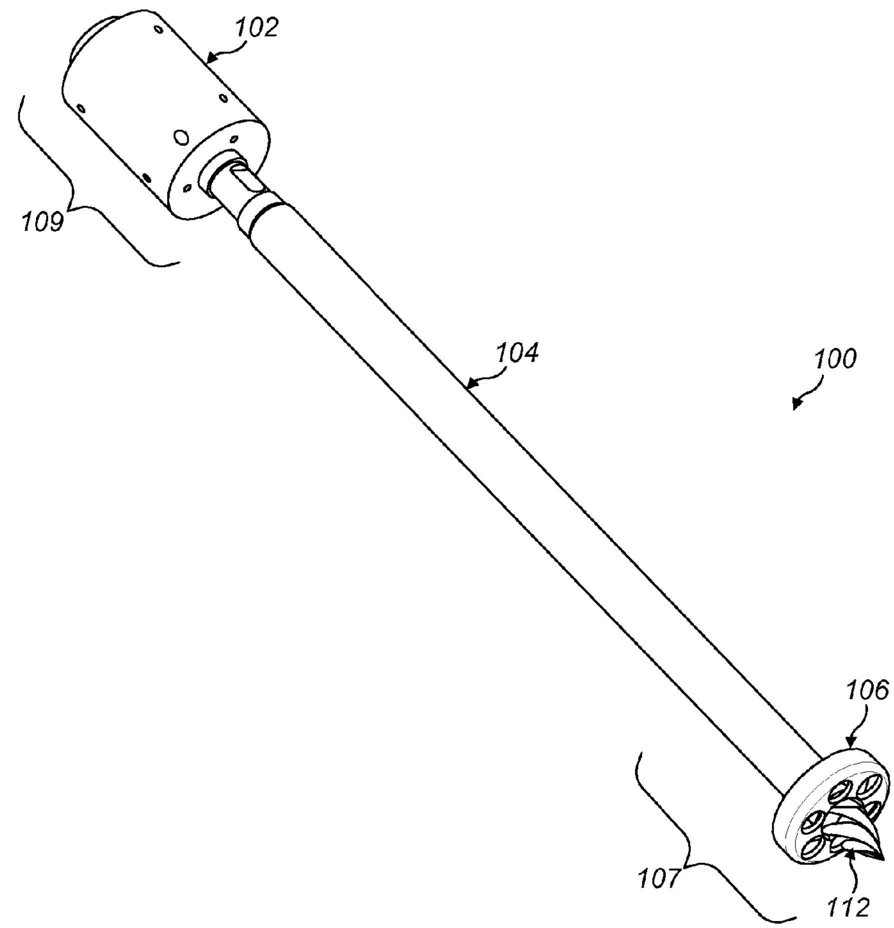


FIG. 1

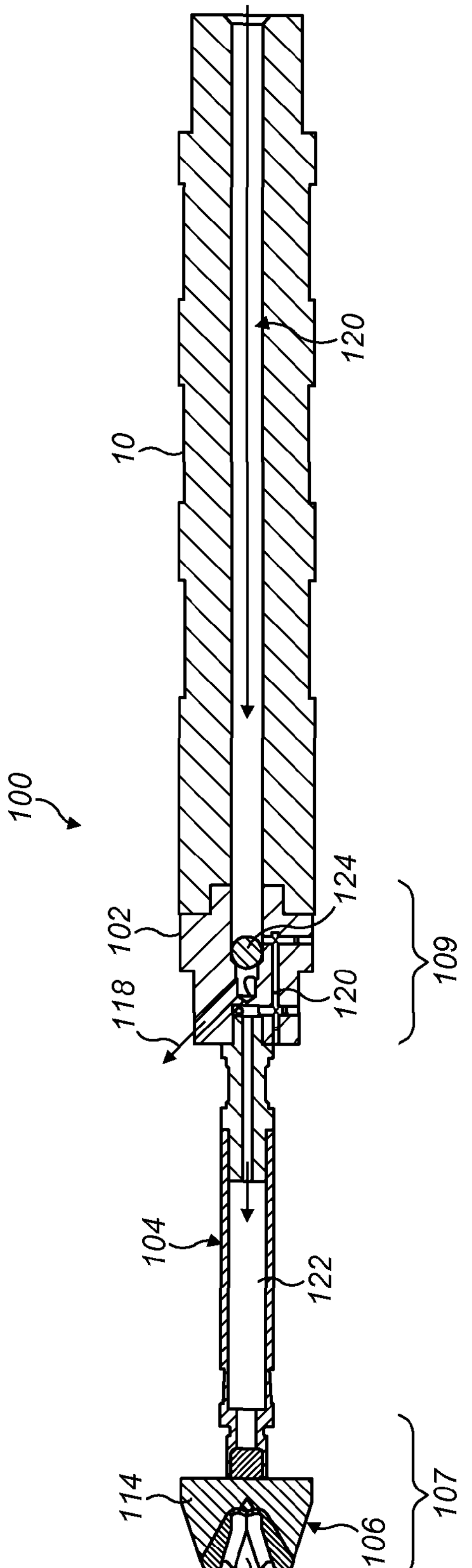


FIG. 2

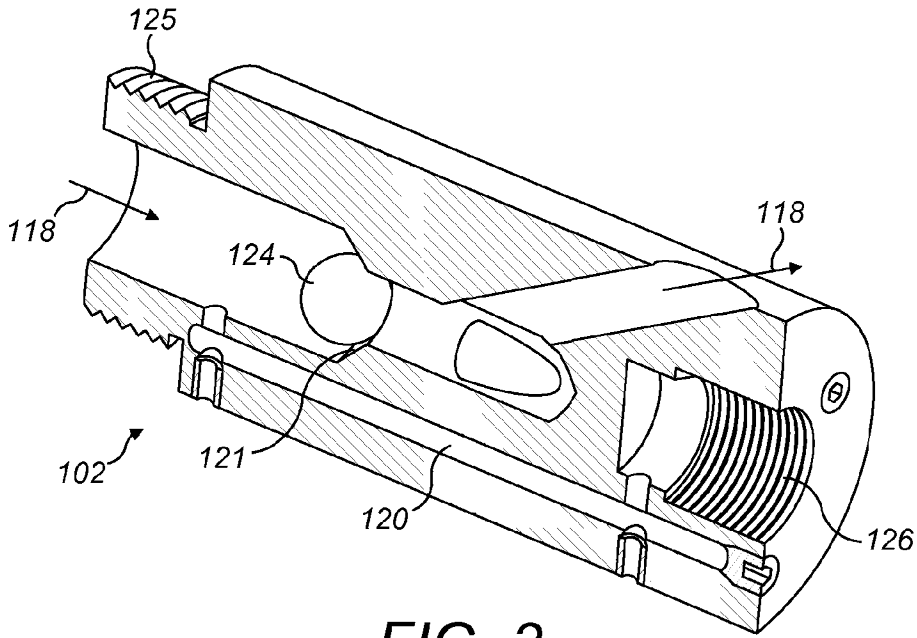


FIG. 3

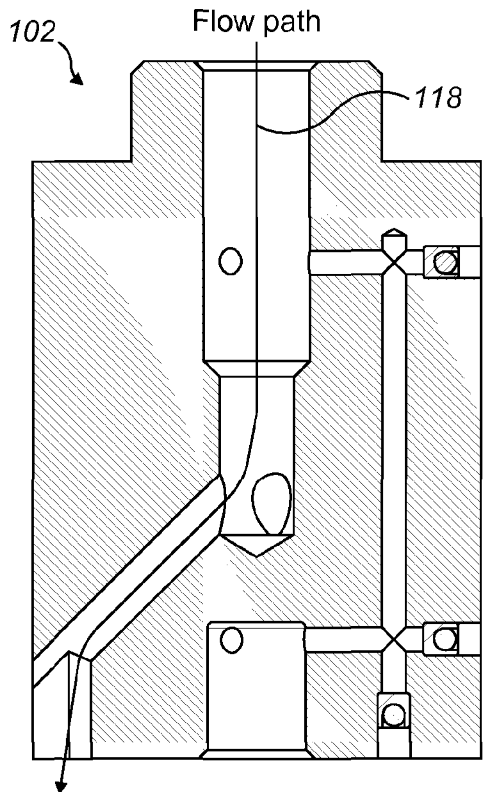


FIG. 4

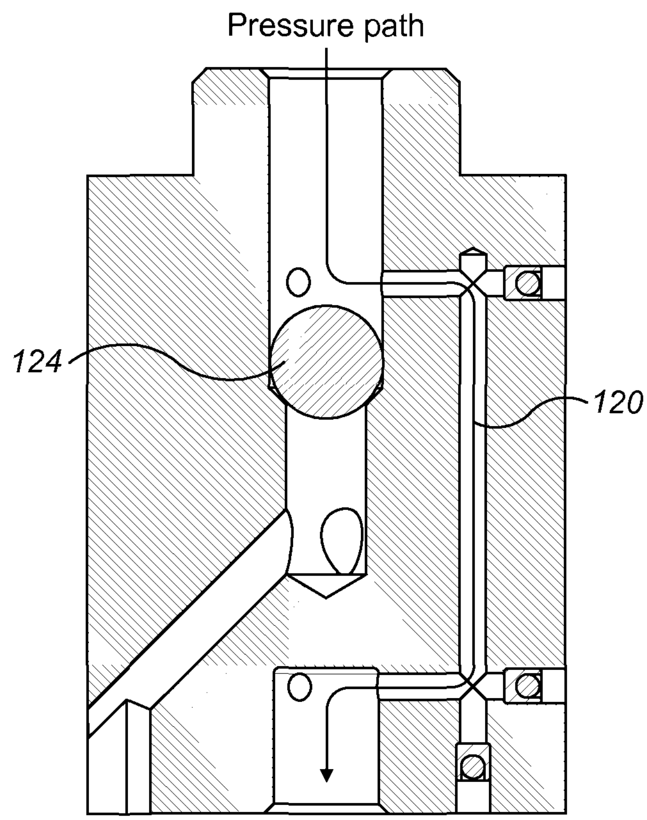


FIG. 5

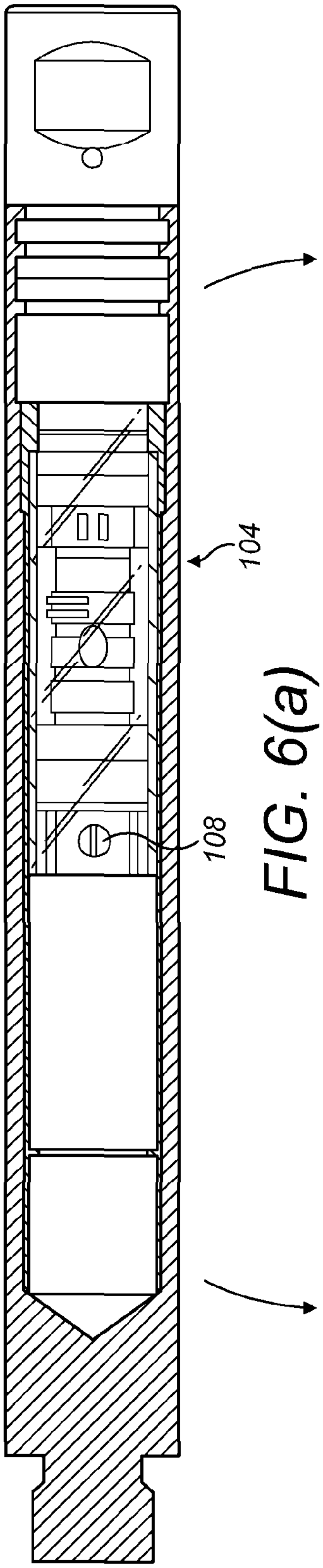


FIG. 6(a)

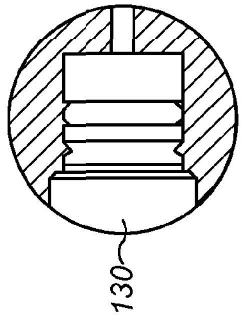


FIG. 6(c)

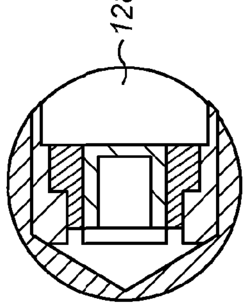


FIG. 6(b)

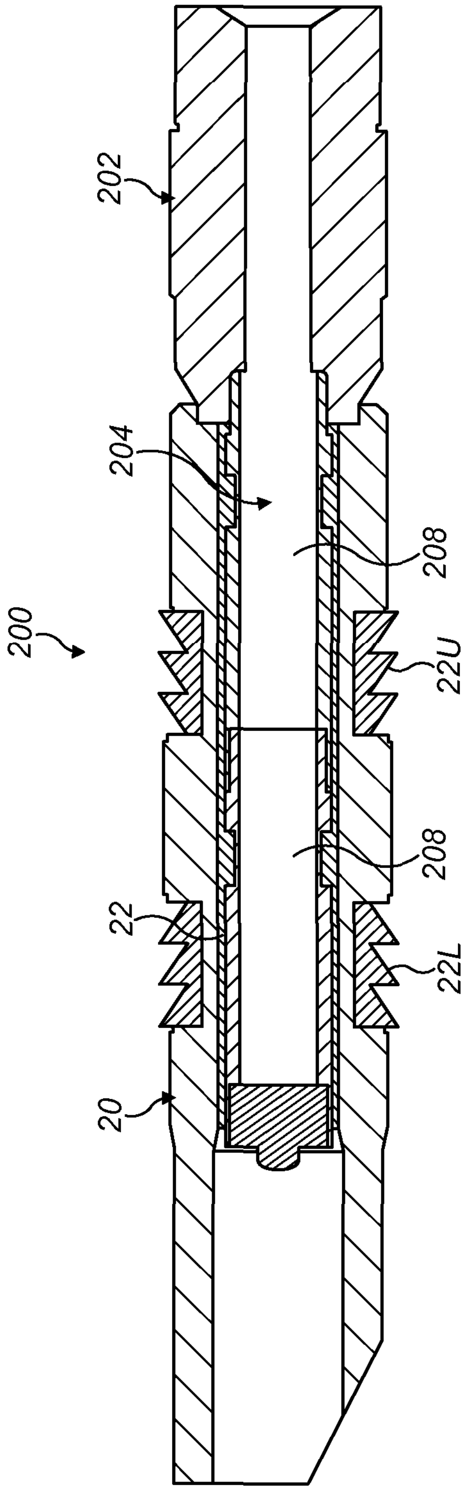


FIG. 7

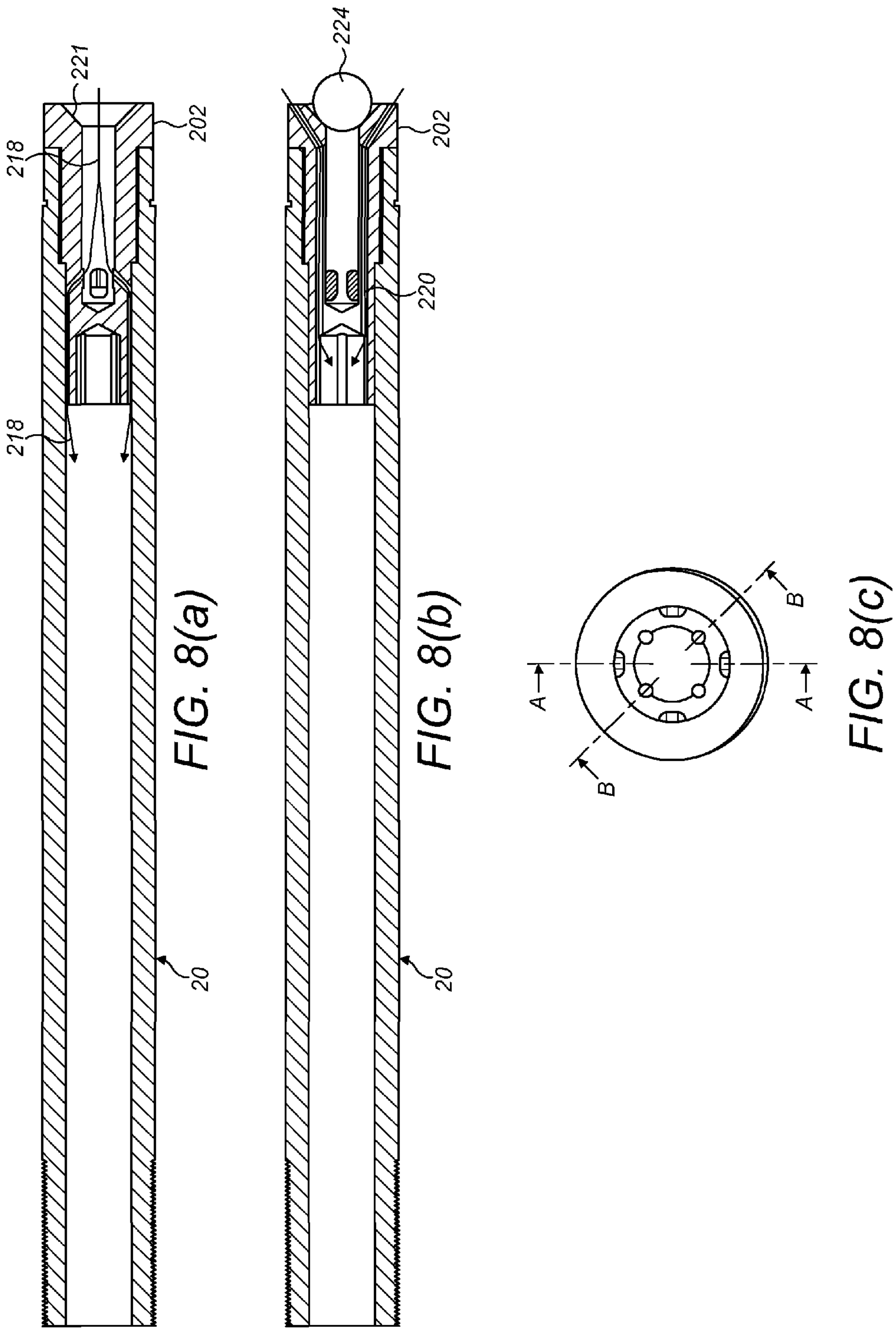


FIG. 8(a)

FIG. 8(b)

FIG. 8(c)

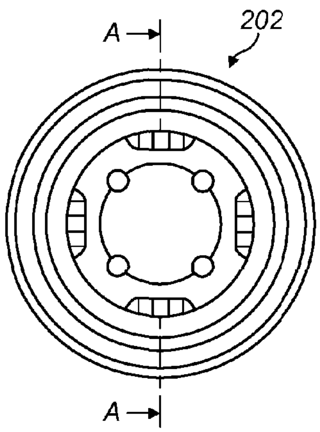


FIG. 9(a)

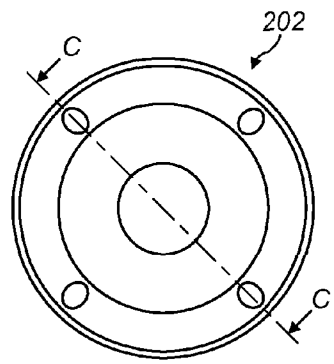


FIG. 9(b)

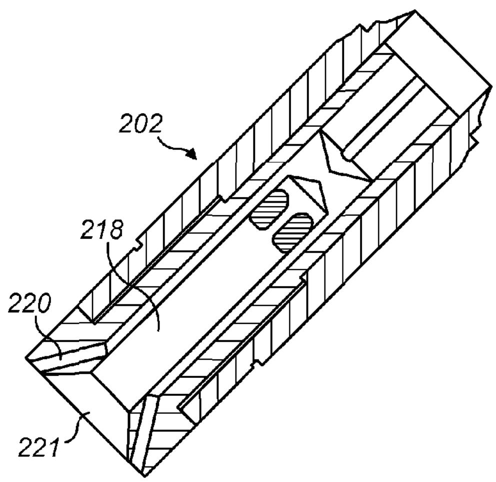


FIG. 9(c)

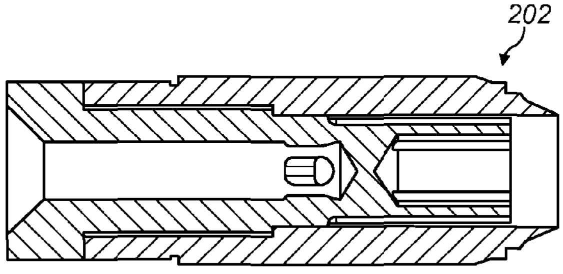


FIG. 9(d)

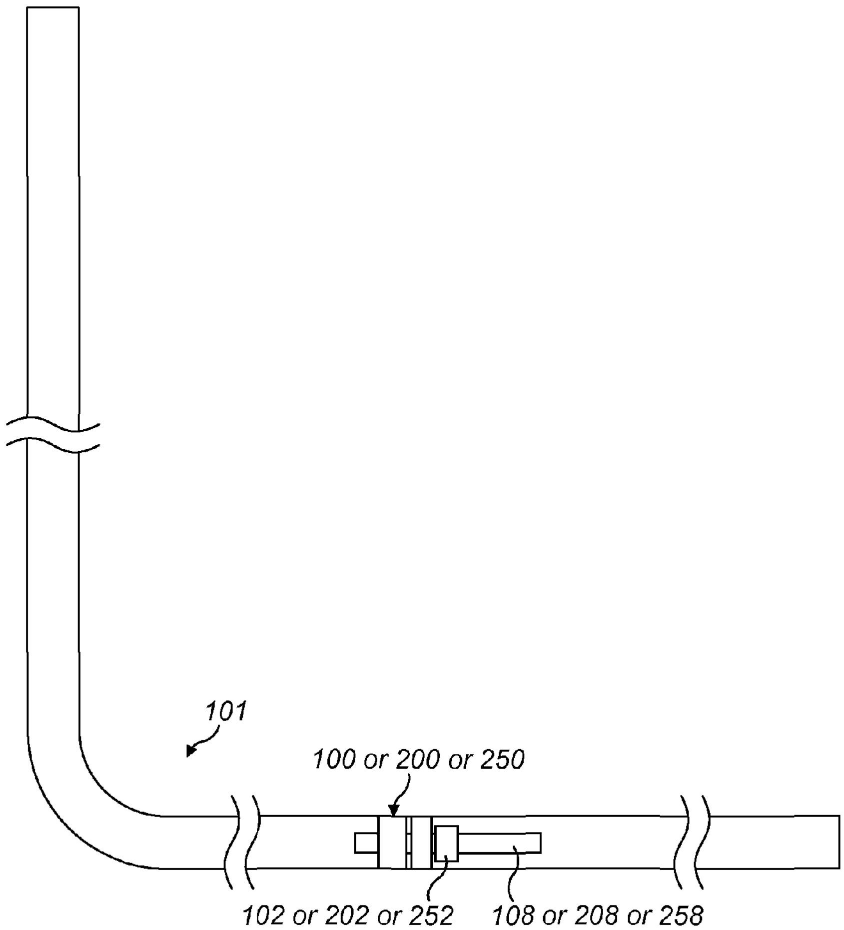


FIG. 10

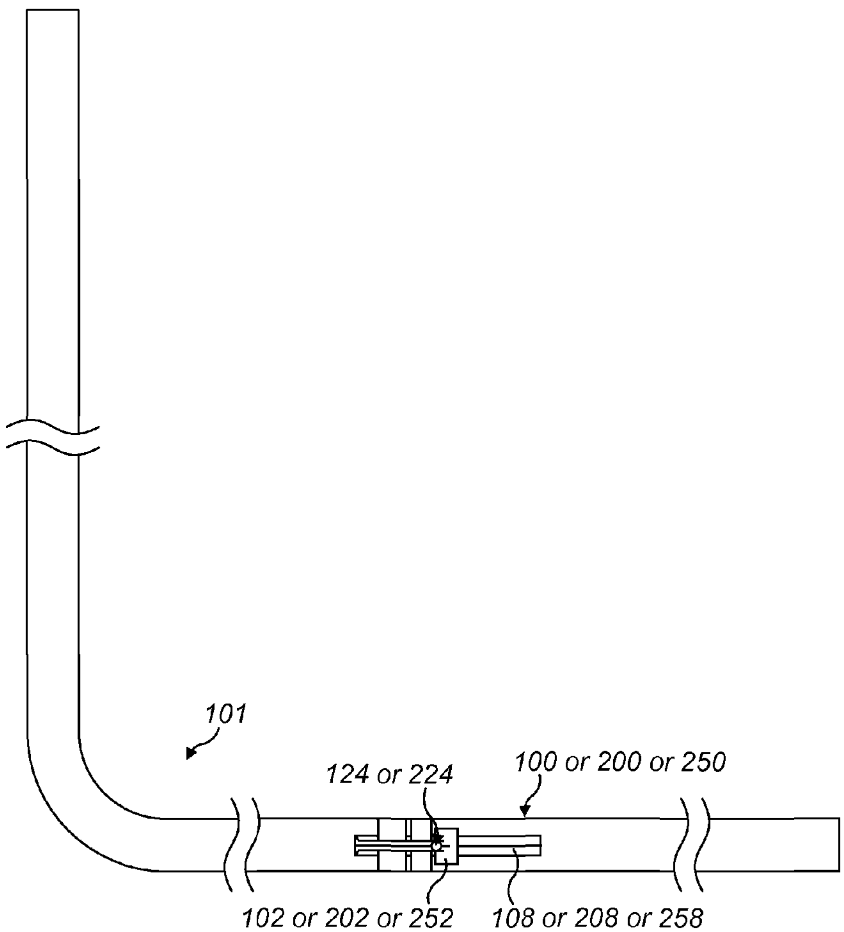

101
124 or 224
100 or 200 or 250
102 or 202 or 252
108 or 208 or 258

FIG. 11

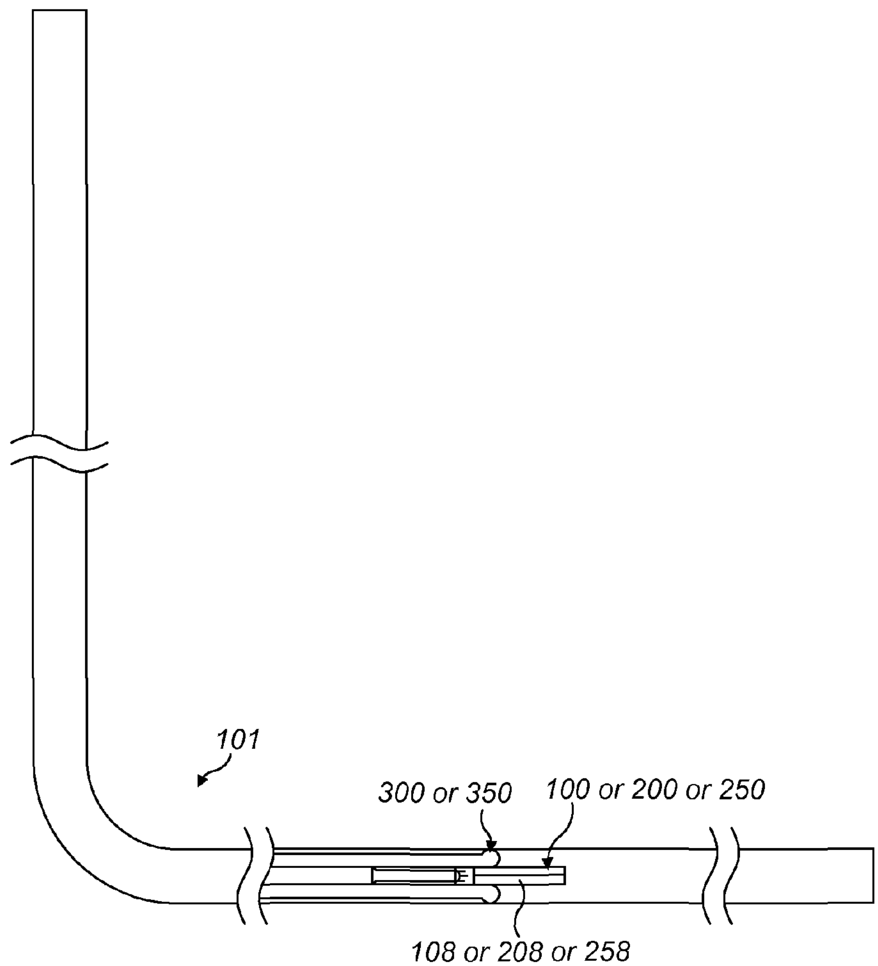


FIG. 12

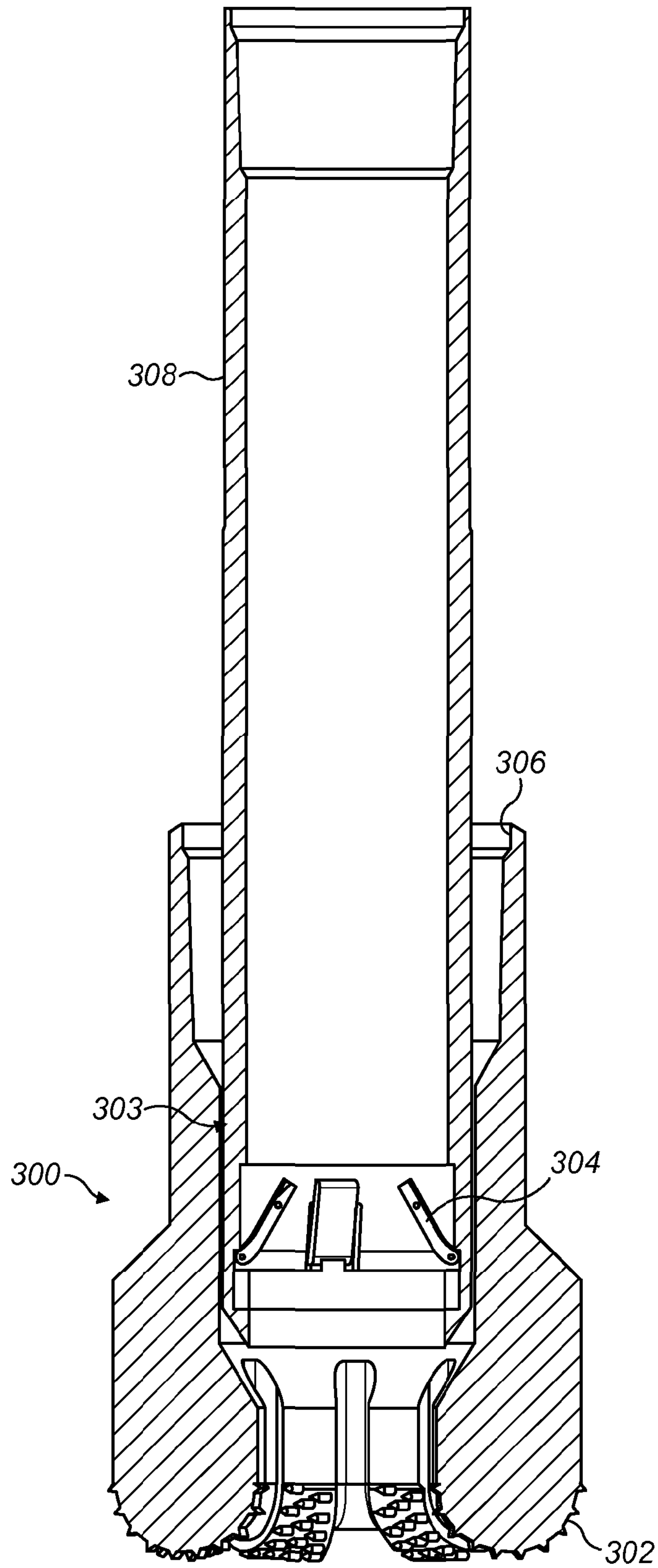


FIG. 13(a)

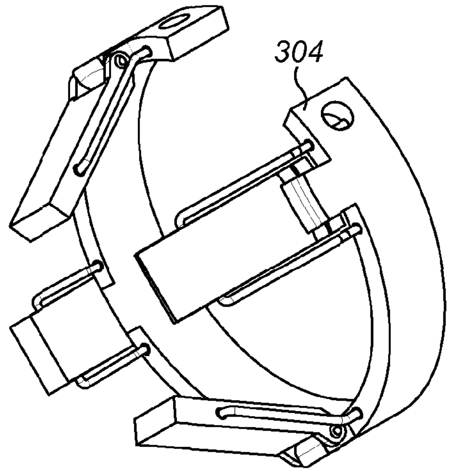


FIG. 13(b)

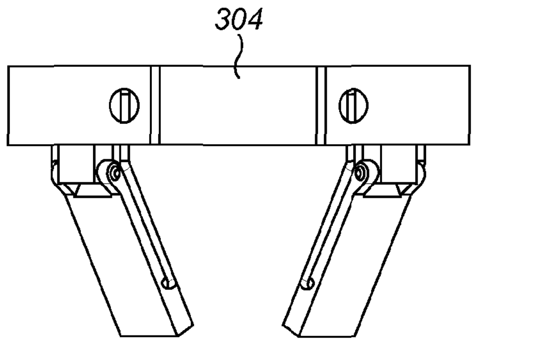
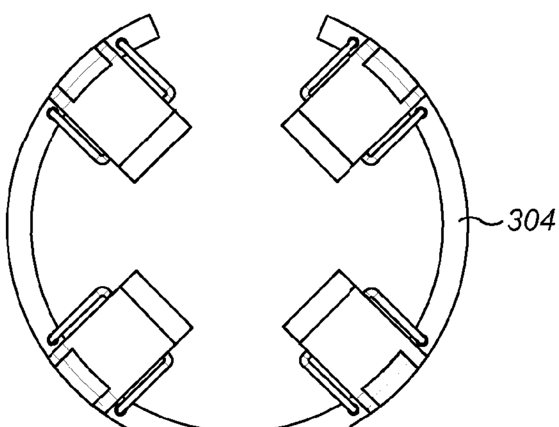


FIG. 13(c)



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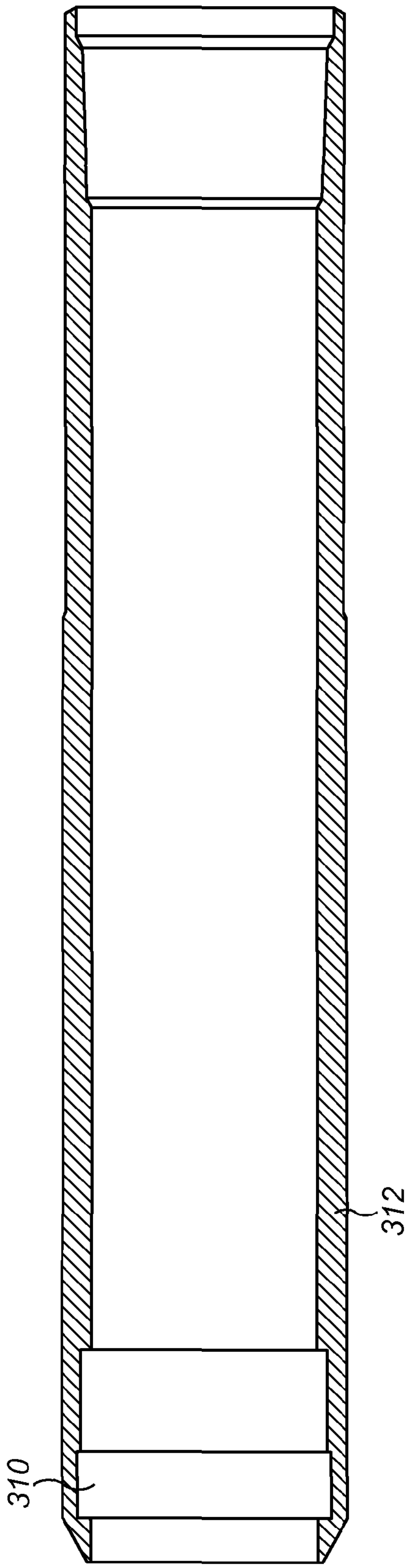


FIG. 14

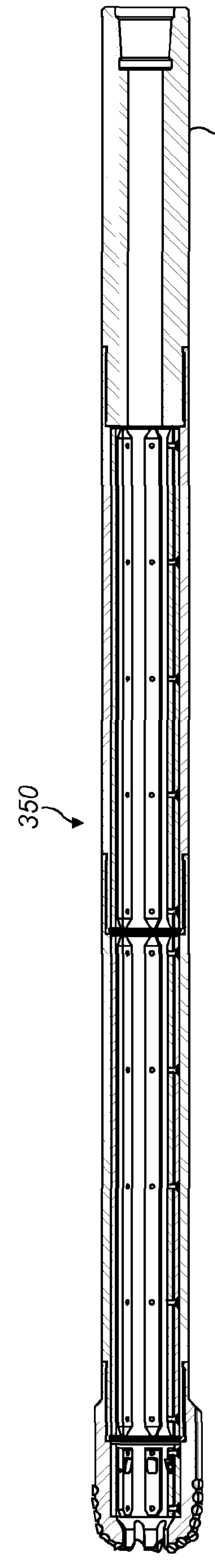


FIG. 15(a)

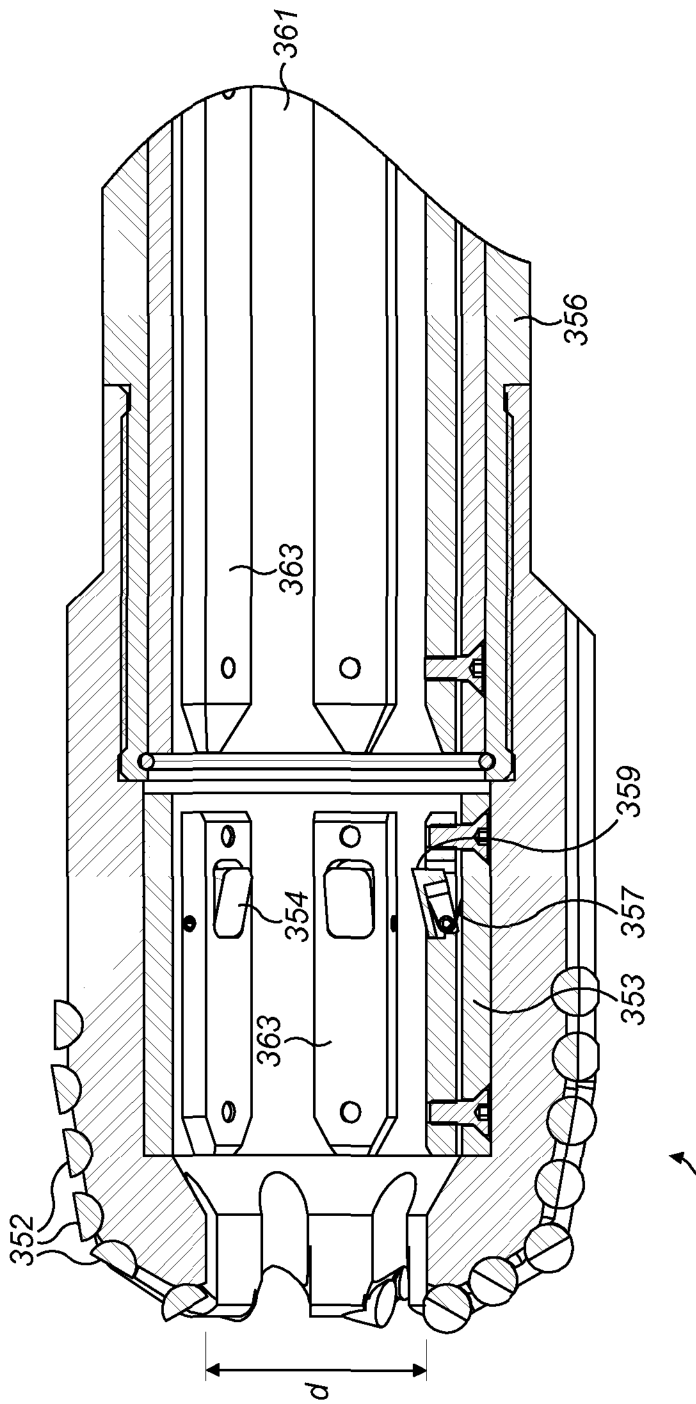


FIG. 15(b)

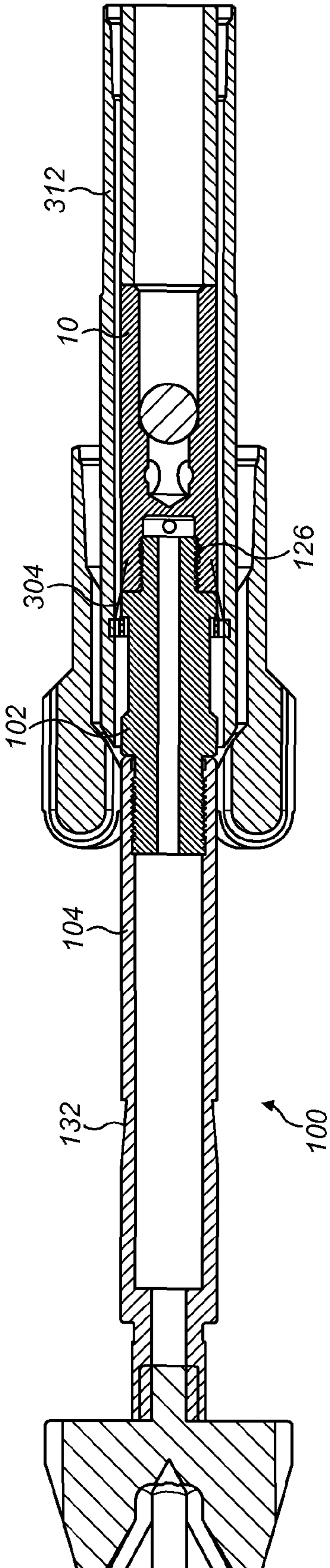


FIG. 16

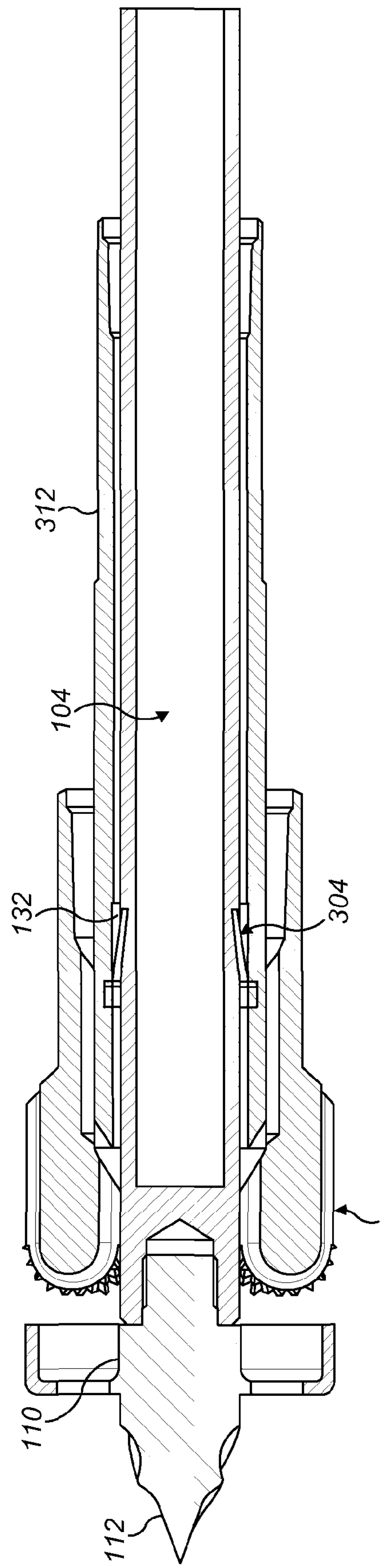


FIG. 17

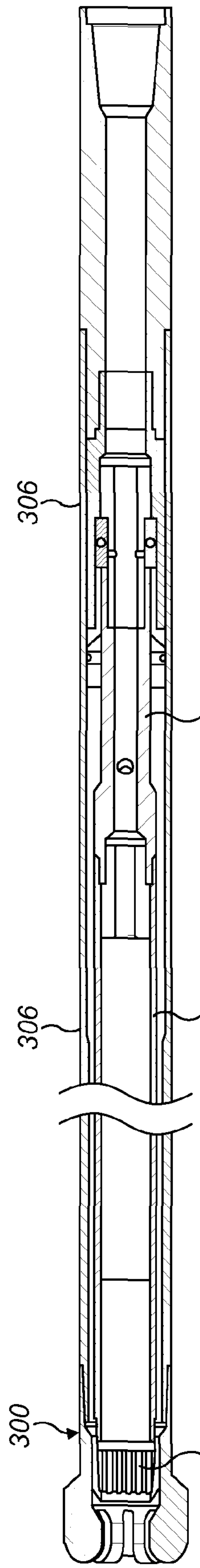


FIG. 18

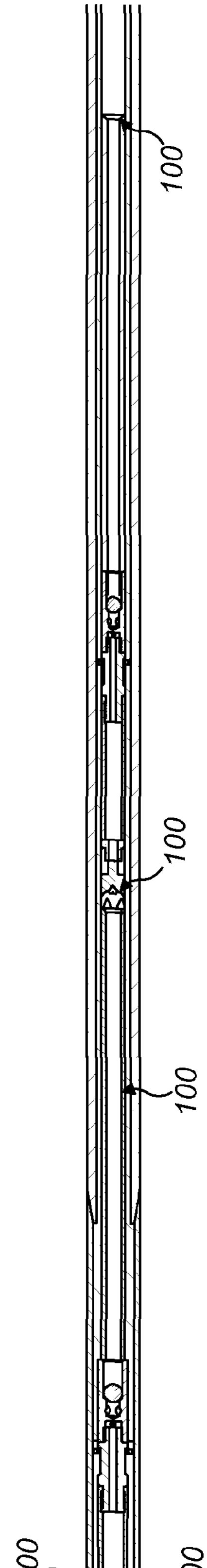


FIG. 19

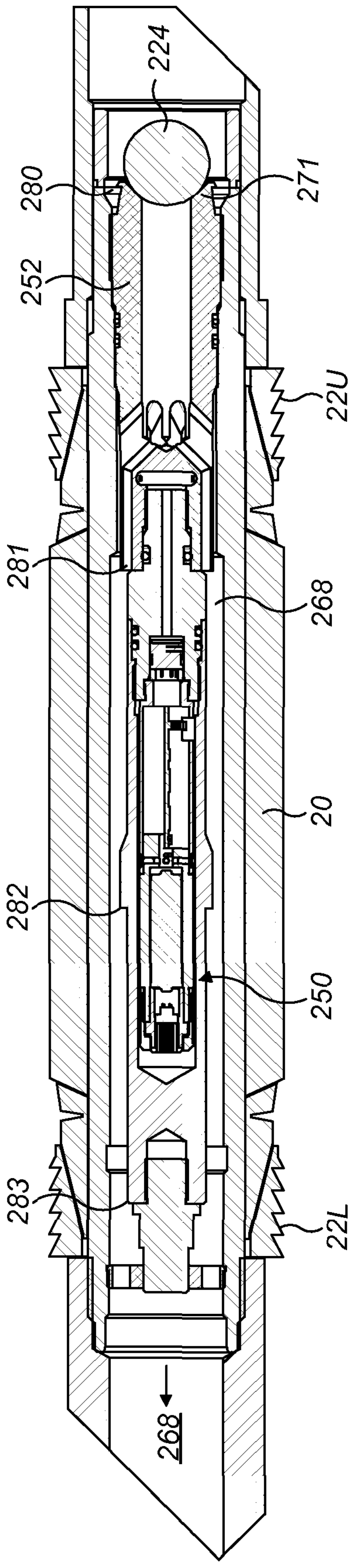
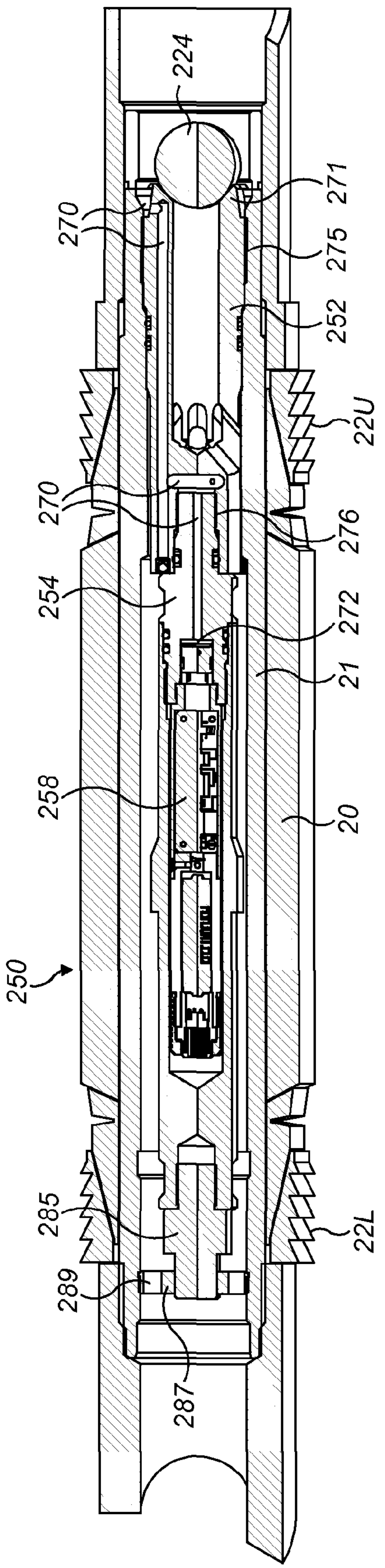


FIG. 20(a)


224
271
270
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258
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22L
289
287

FIG. 20(b)

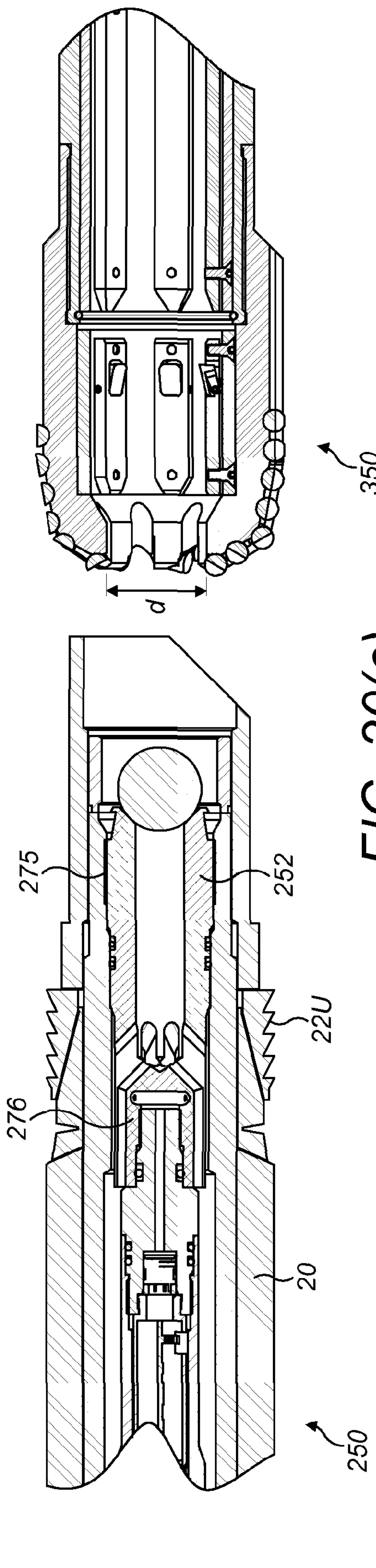

FIG. 20(c)

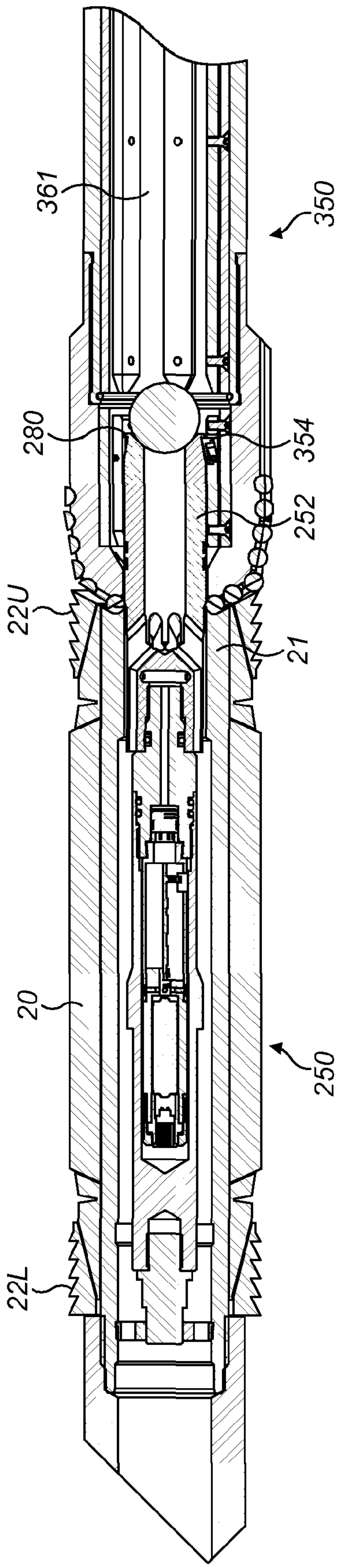

FIG. 20(d)

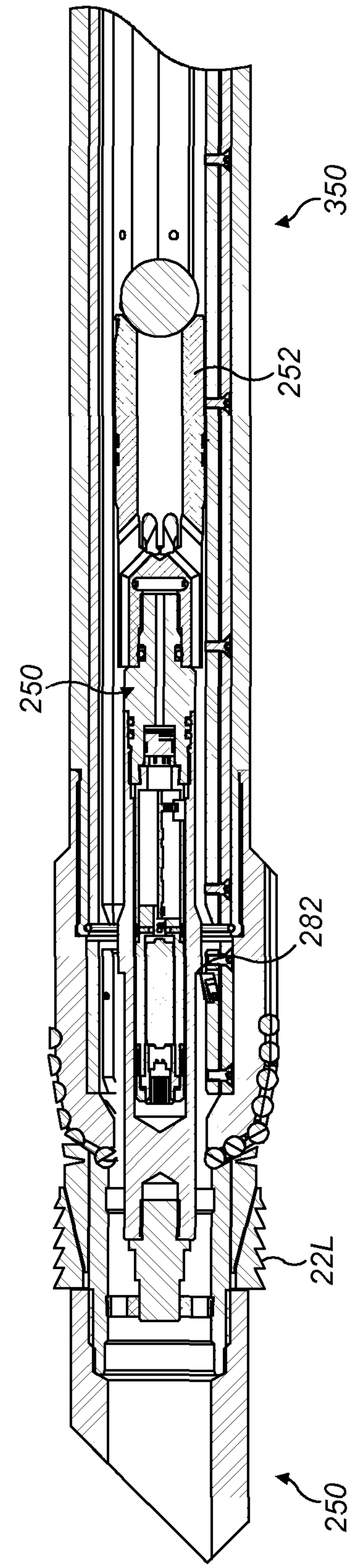

FIG. 20(e)

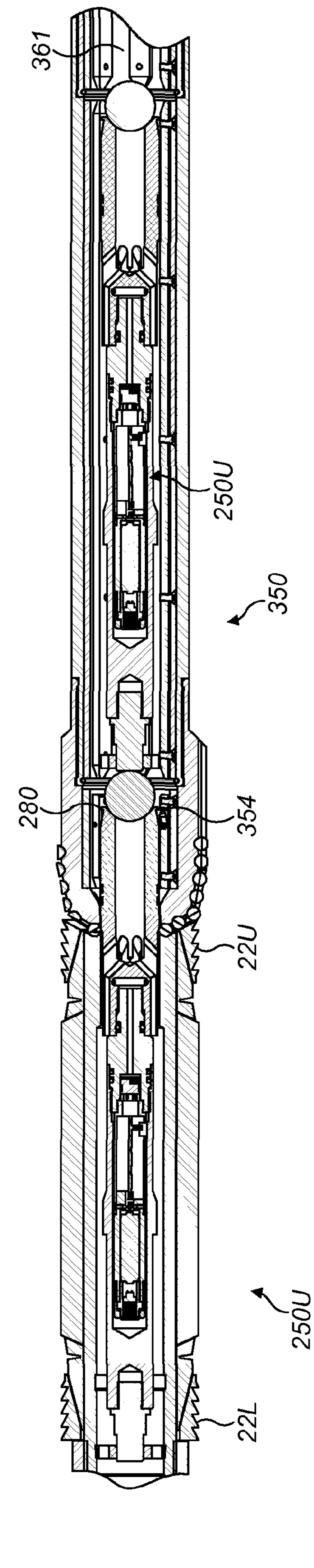

FIG. 20(f)

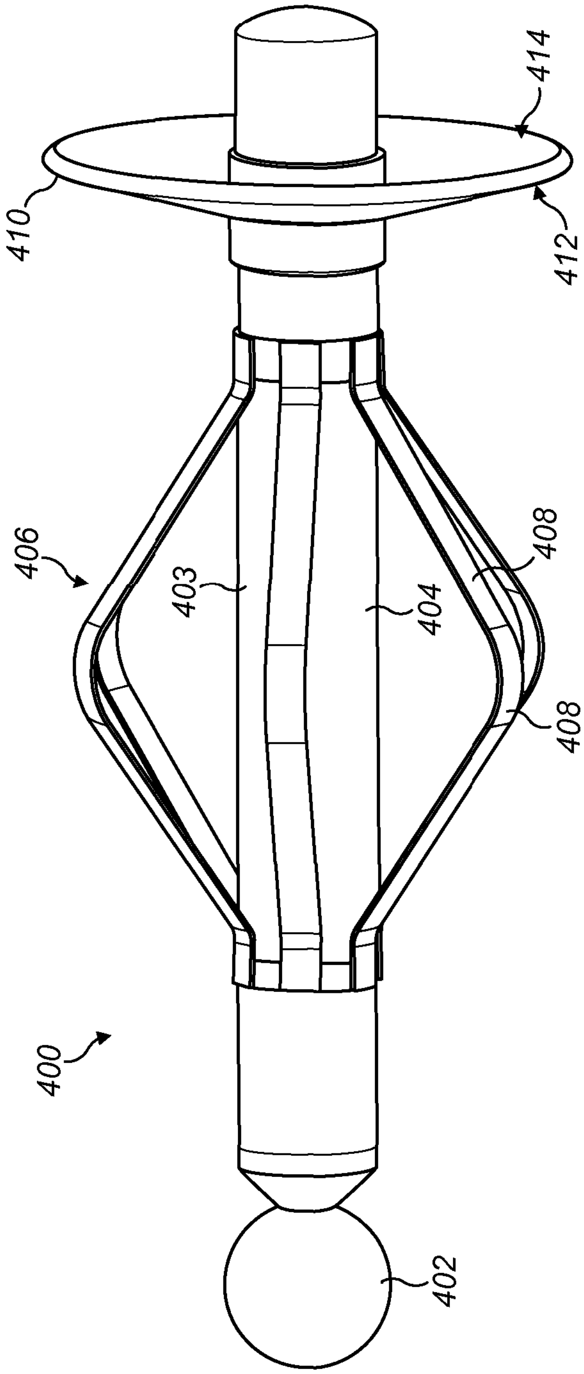

FIG. 21(a)

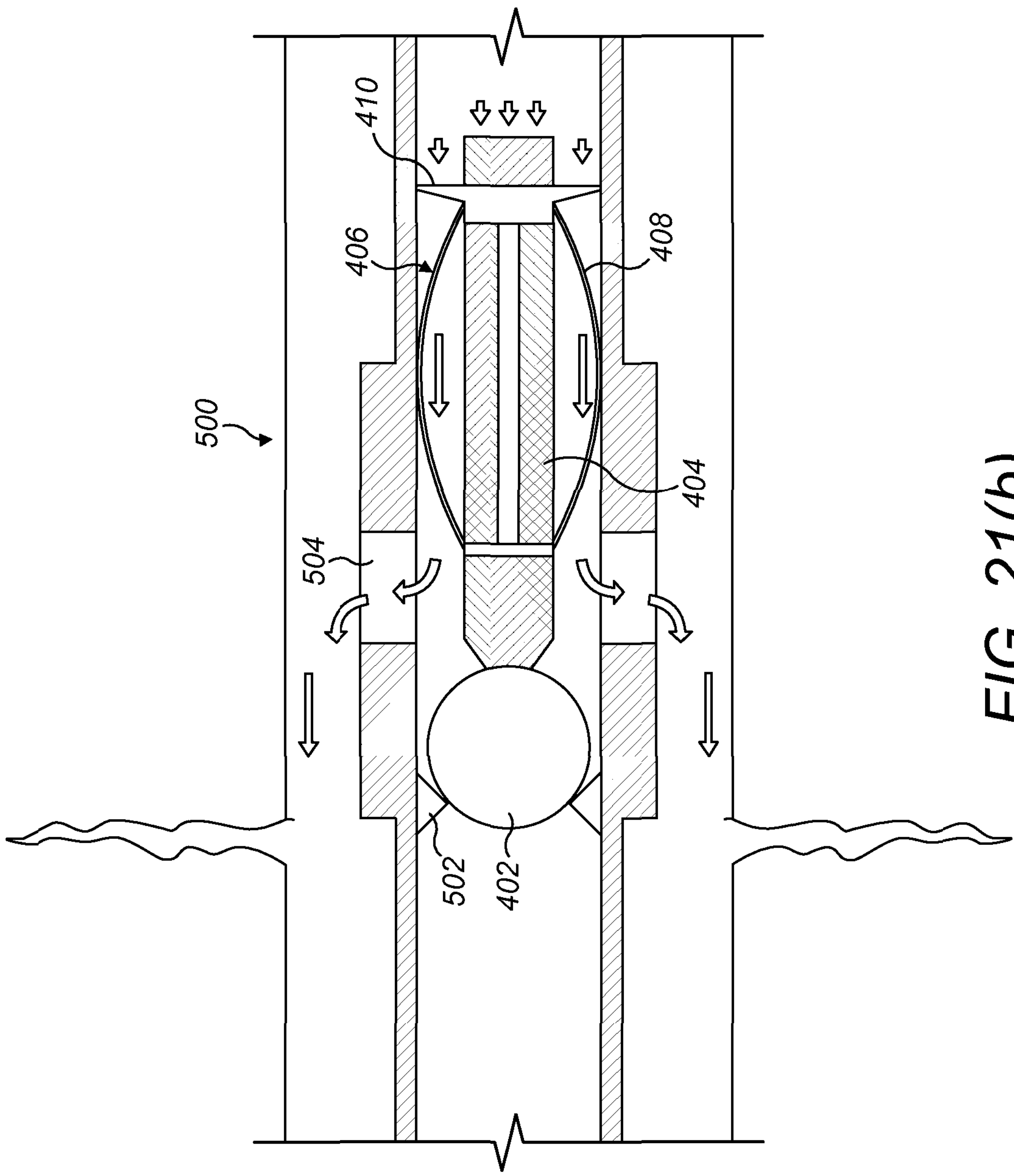

FIG. 21(b)

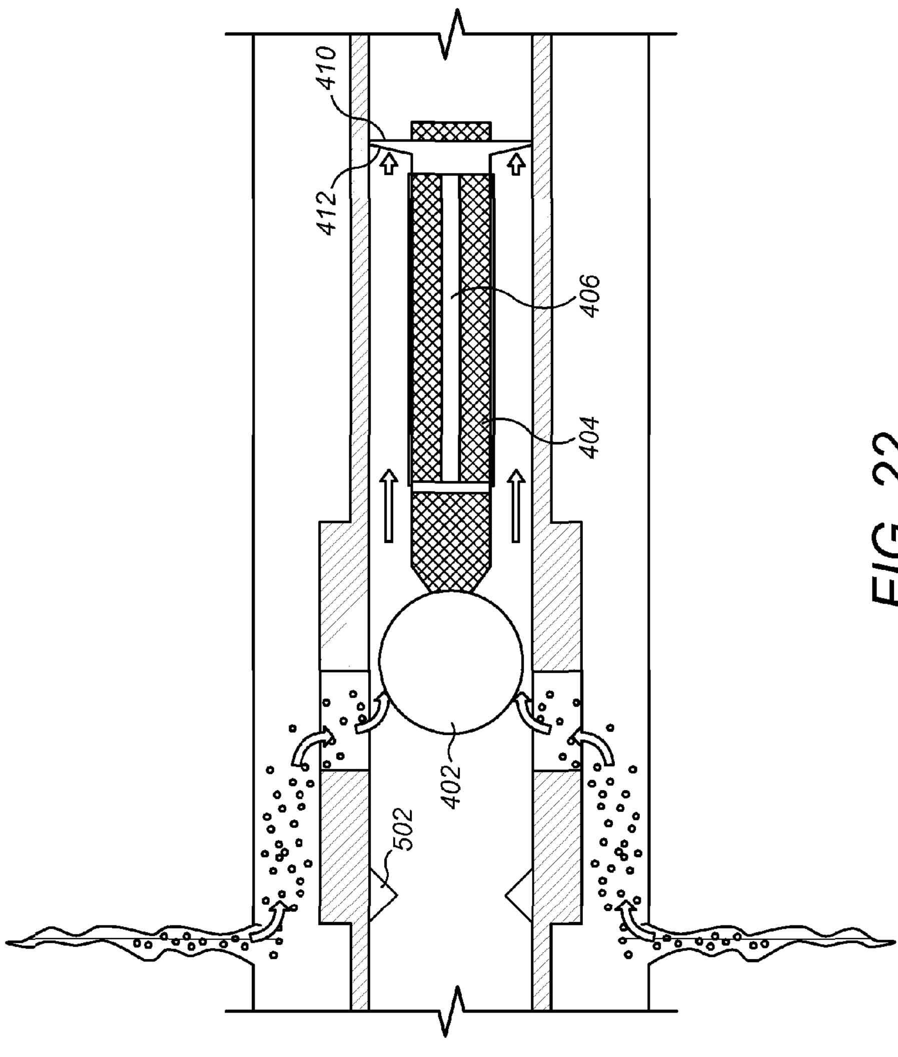

FIG. 22

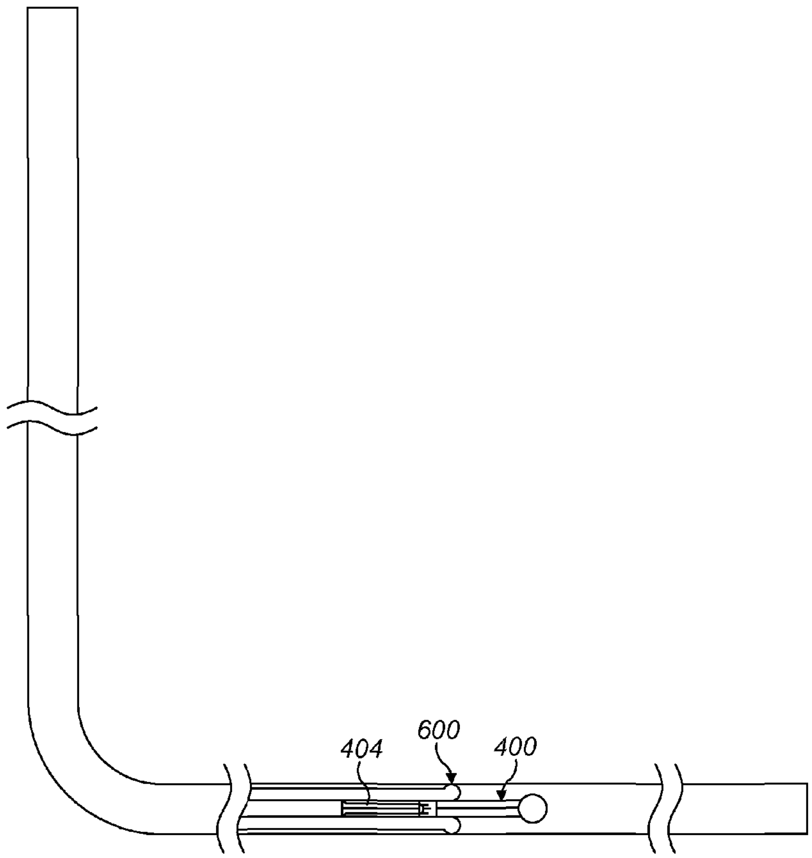

FIG. 23

DOWNHOLE DEVICE FOR DATA ACQUISITION DURING HYDRAULIC FRACTURING OPERATION AND METHOD THEREOF

[0001] The present invention relates to devices and processes used in well drilling. More specifically, the invention relates to a downhole device for data acquisition during a hydraulic fracturing operation and a method thereof. Another aspect of the invention relates to a drop device for data acquisition during a hydraulic fracturing operation and a method thereof.

INTRODUCTION

[0002] In drilling operations for the production of oil and gas deposits, operators strive to maximize both the rate of flow and the overall quantity of hydrocarbon that can be recovered from the subsurface formation or reservoir to the surface. Therefore, various stimulation techniques have been developed and one of the most commercially successful techniques today is hydraulic fracturing, also referred to as "fracking" or "fracing".

[0003] The hydraulic fracturing process involves targeting a portion of the strata surrounding the wellbore and injecting a specialized fluid into the wellbore at pressures sufficient to initiate and extend a fracture into the formation. The fluid which is injected through the wellbore typically exits through holes which are formed in the cemented well casing using a special tool known as a perforating gun. As a result, a fracture zone, i.e. a zone having multiple fractures, or cracks in the formation, is created through which hydrocarbon fluids such as crude oil or, more commonly, gas can flow into the wellbore and be produced at the surface. These fractures are extended by continued pumping and are either propped open with sand or other propping agents, or the fracture faces are etched by a reactive fluid such as an acid, or both. These techniques allow hydrocarbons contained in the formation to more readily flow from the fractures into the well bore. The artificially created fractures may be complimented by naturally existing fractures, or by fractures caused by previous or simultaneous stimulation operations in the same or nearby formations. The quality of the fracturing operation obviously has a great effect on the overall success or failure of the well production.

[0004] In particular, horizontal oil and gas wells allow the extraction of valuable hydrocarbons at a minimum environmental "footprint", because more wellheads can be grouped together on one surface location requiring fewer rigs and less surface area disturbance, subsequently making it easier and cheaper to produce the wells.

[0005] One of the tools commonly used by some operators of hydraulic fracturing equipment includes specially sized "frac-balls" or "drop balls", which are injected into a well to block the passage of a previously installed frac plug and therefore close off portions of a well to allow pressure to build up and cause fracturing in a target section of the well above the location of the well blocked by the frac-ball. The frac-plug (or bridge plug) is a downhole tool that is located and set to isolate the lower part of the wellbore. Frac-plugs are usually retrievable so that the lower wellbore section can be temporarily isolated from a treatment conducted on the upper section of the frac-plug (i.e. during fracing operations). Frac-balls may be made of various materials, including G-10 (or other related phenolics), Torlon, PEEK, and other high-temperature thermosets or thermoplastics.

[0006] Typically, the material selected is based upon the operators' experience and the chemistry and temperatures within the well. Frac-ball sizes are selected specifically to fit within the well-bore or sliding sleeves of the downhole tools which vary in diameter as the well sections progress from upper to lower sections.

[0007] For example, one popular method for creating multiple fractures in a wellbore is the use of frac ports & sliding sleeves. Openhole packers isolate different sections of the horizontal well. A sliding sleeve is placed between each packer pair and is opened by injecting a properly sized frac-ball inside the borehole. Typically, a completion string is placed inside the well. The string includes frac ports and open hole packers spaced to specifications. The spacing between packers may be up to several hundred feet. The packers are actuated by mechanical, hydraulic or chemical mechanisms. In order to activate each sleeve, a properly sized frac-ball is pumped along with a fracturing fluid inside the well. Each ball is smaller than the opening of all of the previous sleeves, but larger than the sleeve it is intended to open. Seating of the frac-ball exerts pressure at the end of the sliding sleeve assembly, causing it to slide and open the frac ports. Once the port is opened, the fluid is diverted into the openhole space outside of the completion assembly, causing the formation to fracture.

[0008] At the completion of each fracturing stage, the next larger frac-ball is injected into the well, which opens the next sleeve, and so on, until all of the sleeves are opened and multiple fractures are created in the well. The main advantage of this completion technique is the speed of operation, because it allows activating multiple fractures with a single completion string.

[0009] In some alternative completions, the sleeves are sometimes cemented into the hole with acid soluble cement, such that the sleeves are opened by pumping down acid and the fracing operation can thereafter be performed. Also, occasionally, in some other wells, the sleeves can be run with out packers if the formation is of the type that it can be counted on to provide isolation between the sleeves.

[0010] In any event, in all completions, the quality of the fracturing operation obviously has a great effect on the overall success or failure of the well production. Therefore, knowing current formation and/or wellbore properties can be an important tool to optimize productivity of the hydrocarbon output and improve the quality and safety of fracing operations. In particular, knowing what was/is happening downhole at each of the perforations during the perforation and fracing process, may be invaluable information in order to improve the quality and safety of the fracing process.

[0011] Accordingly, it is an object of the present invention to provide a downhole device and method for data acquisition before, during and after fracing operations. It is a further object of the present invention to recover the downhole device and acquired data from the wellbore.

SUMMARY OF THE INVENTION

[0012] Preferred embodiments of the invention seek to overcome one or more of the above disadvantages of the prior art.

[0013] According to a first aspect of the present invention, there is provided a downhole device for data acquisition during fracing operations, comprising:

[0014] a bypass device operatively coupleable to a wellbore selective obturation member and adapted to provide a selectively closable first fluid path for fluid communication through said wellbore selective obturation member between a region inside the throughbore of the wellbore located uphole of said downhole device and a region inside the wellbore located downhole of said downhole device when in situ, and

[0015] at least one data acquisition device, adapted to detect at least one physical property and operatively coupled to said bypass device, wherein said bypass device is further adapted to provide at least one second fluid path for fluid communication between said at least one data acquisition device and said region inside the wellbore located uphole of said bypass device.

[0016] This provides the advantage that physical properties of the formation and wellbore environment can be measured and recorded before, during and after the fracing operation to provide important downhole information for evaluation. For example, the initial pressure increase after a perforation operation has been completed may provide important information about the structural integrity of the wellbore/casing and opened fractures.

[0017] Furthermore, frac pressure and temperature may be monitored during the fracing operation and/or pressure and temperature between different zones may be monitored during all subsequent fracing operations in the wellbore.

[0018] Preferably, the bypass device comprises a bypass sub device and the wellbore selective obturation member is typically a plug or packer suitable for use during a fracing operation.

[0019] Typically, the second fluid path communication allows fluid communication from an uphole region to a data acquisition device without compromising the frac plug operation for circulating fluid along the first fluid path between an uphole and downhole region in the wellbore until a drop member that is typically selectively introduced into the fluid flow at surface by an operator shuts the first flow path in order to initialize perforation. Preferably, the drop member is a drop ball, dart or the like. Alternatively, the first fluid flow path may be shut by means of a suitably located valve operable from the surface.

[0020] The compatible bypass sub device provides the advantage that it can be retro-fitted to any standard frac plug, minimizing cost and maximize ease of use.

[0021] The data acquisition device may be operatively coupled to said bypass sub device via a data acquisition device carrier housing mountable to said bypass sub device and may be adapted to accommodate said at least one data acquisition device. This provides the advantage that a plurality of data acquisition devices can simply be placed inside a data acquisition device carrier and be replaced according to current specific requirements.

[0022] Furthermore, since the data acquisition device carrier is operatively coupled to the bypass sub such as to provide a direct fluid communication with an uphole wellbore region, no alterations are necessary to the data acquisition devices in order to expose the data acquisition devices to the fluid communication and allow unperturbed measurements of the predetermined uphole wellbore environment. Advantageously, the bottom hole assembly may further comprise a centralising member operatively coupled to said data acquisition device or data acquisition device carrier housing and adapted to centralize and/or rotationally stabilize said data acquisition device within the wellbore. More advantageously, the centralizer member may comprise an anti-rotation element adapted to engage with a compatible uphole end of a second bottom hole assembly located immediately below the first bottom hole assembly in the wellbore so as to prevent rotational movement of said bottom hole assembly with respect to said second bottom hole assembly.

[0023] In addition, the centralizer member provides the advantage of centralizing the data acquisition device carrier housing and/or data acquisition device within the wellbore during recovery back to surface and whilst guiding the preceding data acquisition device carrier housing and/or data acquisition device over the top of the next lower bottom hole assembly within the wellbore. The anti-rotation element provides the additional advantage of anchoring the data acquisition device carrier housing and/or data acquisition device such as to prevent spinning during a milling process when recovering the data acquisition devices.

[0024] A seat member located within or at an end of the first fluid path may be adapted to engage with a drop member so as to at least unidirectionally selectively prevent fluid flow through said first fluid path. Advantageously, the second fluid communication path may be adapted to bypass said first fluid path.

[0025] This provides the advantage that both, the frac plug and the data acquisition device(s) can perform their function without compromising the function of the other. In particular, because the second fluid communication path to the at least one data acquisition device bypasses the first fluid path through the bore hole assembly, the first fluid path can be closed or opened as required during a fracing operation without blocking the fluid communication path to the at least one data acquisition device.

[0026] The at least one data acquisition device may comprise an integrated data storage device adapted to record a predetermined maximum amount of data. Advantageously, the data acquisition device may comprise a data interface adapted to permit download at least part of said predetermined amount of data to a remote data storage means. More advantageously, the data acquisition device may be adapted to transmit data to a remote location uphole of said bottom hole assembly within the wellbore.

[0027] This provides the advantage that the measured data can be recovered for evaluation either after recovering the at least one data acquisition device to the surface or while the bottom hole assembly is still downhole after or during fracing operations.

[0028] The at least one data acquisition device may be any one or all of a pressure data acquisition device and/or a temperature data acquisition device and/or a geophone and/or a micro seismic sensor.

[0029] The data acquisition device carrier may be adapted to telescopingly and slidingly irretractably engage with a data acquisition device catcher mechanism when moving along a longitudinal axis inside a pick-up device of the data acquisition device catcher mechanism. Advantageously, the data acquisition device carrier housing may comprise a recess and/or shoulder or other formation provided on or in the outer surface of the data acquisition device carrier housing or may alternatively and preferably comprise a groove located circumferentially around an outer surface of said data acquisition device carrier housing and adapted to cooperate with a spring loaded catcher ring mechanism located inside a pick-up device of the data acquisition device catcher mechanism.

[0030] This provides the advantage that the data acquisition device carrier housing and data acquisition device can be recovered using a milling or drilling device or the like (hereinafter simply referred to as "milling device") comprising a data acquisition device catcher device operable to drill over the bottom hole assembly removing any parts that exceed the inner diameter of the pick-up device but keeping the data acquisition device carrier housing and data acquisition device intact. Furthermore, the catcher ring mechanism ensures that the data acquisition device carrier housing does not fall out of the data acquisition device catcher mechanism during recovery of more than one data acquisition device carrier housing.

[0031] The bypass sub device may be located downhole of the frac plug when in situ. Preferably, the data acquisition device and/or data acquisition device carrier housing may be located downhole of said bypass sub device. Alternatively, the bypass sub device may be located uphole of the frac plug and the data acquisition device and/or data acquisition device carrier housing may be operatively located inside a mandrel of the frac plug.

[0032] The second fluid communication path may comprise an incompressible fluid sealingly encased within said second fluid communication path and said data acquisition device carrier housing by a membrane located at the uphole end of said second fluid path. The membrane is typically pressure sensitive such that it can transmit the pressure from one side to the other. This provides the advantage that the data acquisition device is safely enclosed in a protected environment, but is still in fluid communication with the uphole wellbore region. The membrane may be sufficiently flexible and diathermic to prevent distortion of the physical properties that are measured with the at least one data acquisition device.

[0033] According to a second aspect of the present invention, there is provided a method for acquiring data during fracing operations in a subterranean formation having a wellbore penetrating the formation, the method comprising the steps of:

[0034] (a) running in a downhole device having a data acquisition device into a wellbore along with a wellbore selective obturation member;

[0035] (b) placing said downhole device and wellbore selective obturation member at a location inside the wellbore;

[0036] (c) initiating at least one data acquisition device of said downhole device for monitoring at least one physical property;

[0037] (d) initiating a fracing operation while monitoring said at least one physical property, and

[0038] (e) recovering said monitored physical property after the fracing operation is completed.

[0039] Preferably, step (a) of the method comprises running in a downhole device according to the first aspect of the present invention.

[0040] Typically, step (b) comprises placing said downhole device and wellbore selective obturation member at a predetermined location inside the wellbore.

[0041] Preferably, there is an additional step in between steps c) and d) of:—

[0042] closing a first fluid path for fluid communication through the wellbore selective obturation member between a region inside the wellbore located uphole of said downhole device and a region inside the wellbore located downhole of said downhole device when in situ;

[0043] and where step (d) includes monitoring said at least one physical property through said at least one second fluid path.

[0044] This provides the advantage that important data can be determined before, after and during fracing operations and provided to an operator for evaluation to optimize production and/or improve quality and safety of fracing operations, therefore improving output and minimizing cost. Furthermore, recovering the data acquisition device carrier housing and/or data acquisition device instead of destroying or damaging it, provides the advantage that expensive data acquisition devices can be reused thus minimizing costs.

[0045] Advantageously, the at least one data acquisition device may be adapted to record a predetermined amount of data of said at least one physical parameter. More advantageously, the data acquisition device may be adapted to transmit said predetermined amount of data to a remote data storage means. Even more advantageously, the at least one monitored physical property may be recovered via a remotely located communication sub device operatively connectable to said at least one data acquisition device.

[0046] According to a third aspect of the present invention, there is provided a method for recovering at least one downhole device having a data acquisition device from a downhole location inside a wellbore typically after completing fracing operations, the method comprising the steps of:

[0047] (a) running a plug milling device, comprising at least one data acquisition device retrieval mechanism, downhole inside a wellbore;

[0048] (b) engaging a first of said at least one downhole device so as to irretrievably move a data acquisition device carrier and/or data acquisition device of said at least one downhole device into and along a longitudinal axis of said data acquisition device retrieval mechanism, milling away any parts of said at least one downhole device exceeding an inner diameter of said data acquisition device retrieval mechanism, and

[0049] (c) removing said plug mill including said at least one downhole device from said wellbore.

[0050] Preferably, the method of the third aspect of the present invention comprises recovering at least one downhole device according to the first aspect of the present invention.

[0051] Preferably, the method according to the third aspect may also include an additional step between steps (b) and (c) of engaging any subsequent second of said at least one downhole device so as to telescopingly and slidingly irretrievably move a data acquisition device carrier housing and/or data acquisition device of said second of said at least one downhole device into and along a longitudinal axis of said data acquisition device retrieval barrel, milling away any parts of said second of said at least one downhole device exceeding an inner diameter of said data acquisition device retrieval barrel.

[0052] This provides the advantage that at least one data acquisition device and/or data acquisition device carrier and be reusably recovered from its downhole location. Preferably, a plurality of data acquisition device carrier housings and/or data acquisition devices are recovered on a single downhole "trip". Furthermore, the recovering method of the third aspect of the present invention provides the advantage for embodiments thereof that the data acquisition device retrieval barrel protects the at least one data acquisition device carrier housing and/or data acquisition device while pulling them out of the wellbore.

[0053] The milling device and data acquisition device retrieval barrel may be adapted to be operated on coiled tubing or drill pipe or any other suitable work string.

[0054] The data acquisition device retrieval barrel may comprise at least one catcher means adapted to engage with said data acquisition device and/or data acquisition device carrier housing of said bottom hole assembly so as to prevent downhole movement of said data acquisition device and/or data acquisition device carrier housing with respect to said data acquisition device retrieval barrel in situ. Advantageously, the catcher mechanism may be at least one spring biased catcher member adapted to engage with at least one groove, recess of shoulder or the like located circumferentially around or on the outer surface of said data acquisition device and/or data acquisition device carrier housing.

[0055] According to a fourth aspect of the present invention, there is provided a drop device for data acquisition during fracing operations, comprising:

[0056] an obturation member adapted to actuatingly and/or sealingly engage with at least one downhole tool, and

[0057] at least one data acquisition device operatively coupled to said obturation member and adapted to detect at least one physical property.

[0058] Advantageously, the obturation member may be adapted to sealingly engage with a seat member of said downhole tool so as to prevent fluid communication through said downhole tool between a region inside the throughbore of the wellbore located uphole of said obturation member and a region inside the wellbore located downhole of said obturation member when in situ. Preferably, the data acquisition device may be located uphole of said obturation member when in situ.

[0059] This provides the advantage that physical properties of the formation and wellbore environment can be measured and recorded before, during and after the fracing operation to provide important downhole information for evaluation. For example, the initial pressure increase after a perforation operation has been completed may provide important information about the structural integrity of the wellbore/casing and opened fractures.

[0060] Furthermore, frac pressure and temperature may be monitored during the fracing operation and/or pressure and temperature between different zones may be monitored during all subsequent fracing operations in the wellbore. Also, a drop device provides the advantage of improved ease of use and minimized cost, since the drop device is simply pumped down to the required location where the obturation member engages with the determined downhole tool automatically locating the data acquisition tool in the required position within the throughbore.

[0061] The data acquisition device may be operatively coupled to said obturation member via a data acquisition device carrier housing that may be removably mountable to said obturation member and adapted to accommodate said at least one data acquisition device.

[0062] This provides the advantage that a plurality of data acquisition devices can simply be placed inside a data acquisition device carrier and be replaced according to current specific requirements. Furthermore, since the data acquisition device carrier is operatively coupled to the obturation member such as to provide a direct fluid communication with an uphole wellbore region, no alterations are necessary to the data acquisition devices in order to expose the data acquisition devices to the fluid communication and allow unperturbed measurements of the predetermined uphole wellbore environment.

[0063] The drop device may further comprise a centralizing member operatively coupled to said data acquisition device and adapted to centralize and/or fixate and/or rotationally stabilize said data acquisition device within the wellbore. Advantageously, the centralizing member may be operatively coupled to said data acquisition device via said data acquisition device carrier housing. Even more advantageously, the centralizer member may comprise a plurality of spreading elements adapted to spread radially towards and in engagement with the inner wall of the wellbore.

[0064] This provides the advantage that the data acquisition tool is securely fixed within the wellbore region that is measured during fracing operation, minimizing the risk that the data acquisition tool is dislodged or tilted, twisted or wedged within the throughbore when exposed to the substantial hydraulic pressures during fracing operation. A data acquisition tool tilted or wedged within the throughbore would also make it more difficult or even impossible to recover. In addition, a data acquisition tool that is not optimally placed within the throughbore may provide biased or falsified measurements.

[0065] The drop device may further comprise a flange member operatively coupled to said data acquisition device and adapted to provide a contact surface for fluid flowing through the wellbore. Advantageously, the contact surface may comprise an uphole contact surface adapted to operatively engage with fluid flowing in an uphole direction, and a downhole surface adapted to operatively engage with fluid flowing in a downhole direction when in situ. Advantageously, the flange member may be adapted to actuate said centralizing member and preferably may be adapted to slidingly actuate said centralizing member.

[0066] This provides the advantage that the hydraulic energy provided by fluid flowing uphole or downhole can be used to move or remove the drop device to or from a desired location within the wellbore and/or actuate the centralizing member. For example, the hydraulic energy of the fluid flowing downhole may be used to slidingly move the flange member along a longitudinal axis and with respect to the data acquisition tool and/or data acquisition tool carrier housing, compressing and subsequently spreading the plurality of spreading elements into engagement with the interior wall of the throughbore, thus centrally fixating the data acquisition tool within the throughbore. During recovery of the drop device, the hydraulic energy of the fluid flowing uphole may be used to slidingly move the flange member back along the longitudinal axis and with respect to the data acquisition tool and/or data acquisition tool carrier housing expanding and disengaging the plurality of spreading elements from the interior wall of the throughbore so that the drop device can be pushed uphole through the throughbore of the wellbore.

[0067] The at least one data acquisition device may comprise an integrated data storage device adapted to record a predetermined maximum amount of data. Advantageously, the data acquisition device may comprise a data interface adapted to permit download of at least part of said predetermined amount of data to a remote data storage means. Even more advantageously, the data acquisition device may be further adapted to transmit data to a remote location uphole of said downhole tool within the wellbore.

[0068] This provides the advantage that the measured data can be recovered for evaluation either after recovering the at least one data acquisition device to the surface or while the bottom hole assembly is still downhole after or during fracing operations.

[0069] Preferably, the at least one data acquisition device may be any one or all of a pressure data acquisition device and/or a temperature data acquisition device and/or a geophone and/or a micro seismic sensor. Even more preferably, the obturation member may be a drop ball, dart or the like.

[0070] According to a fifth aspect of the present invention, there is provided a method for acquiring data during fracing operations in a subterranean formation having a wellbore penetrating the formation, the method comprising the steps of:

(a) providing a drop device according to the fourth aspect of the present invention at a predetermined location and in engagement with a predetermined downhole tool;

(b) initiating at least one data acquisition device for monitoring at least one physical property;

(c) closing a first fluid path for fluid communication through the downhole tool between a region inside the wellbore located uphole of said drop device and a region inside the wellbore located downhole of said drop device when in situ;

(d) initiating a fracing operation while monitoring said at least one physical property through at least one data acquisition device of said drop device, and

(e) recovering said monitored physical property after the fracing operation is completed.

[0071] This provides the advantage that important data can be determined before, after and during fracing operations and provided to an operator for evaluation to optimize production and/or improve quality and safety of fracing operations, therefore improving output and minimizing cost. Furthermore, being able to fully recovering the data acquisition device instead of destroying or damaging it, provides the advantage that expensive data acquisition devices can be reused thus minimizing costs.

[0072] The drop device may be recovered by fluid flowing uphole through the wellbore and/or drill string and engaging with a contact surface of a flange member of said drop device.

[0073] This provides the advantage that there is no need for additional equipment and/or energy to recover the drop device and data acquisition tool thus minimizing cost.

[0074] Alternatively, the drop device may be recovered by running a milling device, comprising at least one data acquisition device retrieval barrel, downhole inside a wellbore. In particular, during recovery of the drop device, the milling device engages said drop device so as to, for example, telescopingly and slidingly irretrievably move a data acquisition device carrier housing and/or data acquisition device of said drop device into and along a longitudinal axis of said data acquisition device retrieval barrel, milling away any parts of said drop device and/or downhole tool exceeding an inner diameter of said data acquisition device retrieval barrel, and subsequently removes said milling device including said data acquisition device from said wellbore. However, it is understood by the skilled person in the art that any other suitable retrieval barrel and retrieval mechanism may be used to recover and store the drop device and/or at least one data acquisition device when using a milling device.

[0075] Alternatively, the drop device may be recovered by securing it with an alternative retrieval device such as a fishing tool or the like on the end of an elongate member such as a wireline or slick line and pulling it out of the hole.

[0076] This provides the advantage that at least one data acquisition device and/or data acquisition device carrier can be reusably recovered from its downhole location. Preferably, a plurality of data acquisition device carrier housings and/or data acquisition devices are recovered on a single downhole "trip". Furthermore, the recovering method of the fifth aspect of the present invention provides the advantage for embodiments thereof that the data acquisition device retrieval barrel protects the at least one data acquisition device carrier housing and/or data acquisition device while pulling them out of the wellbore.

[0077] According to a sixth aspect the present invention provides a frac plug comprising a downhole device according to the first aspect of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0078] Preferred embodiments of the present invention will now be described, by way of example only and not in any limitative sense, with reference to the accompanying drawings, in which:

[0079] FIG. **1** shows a perspective view of a first but less preferred embodiment of a downhole device according to the present invention as including a bypass sub, a data acquisition device carrier and data acquisition device (inside the data acquisition device carrier and therefore not seen in FIG. **1**) and a centralizer;

[0080] FIG. **2** shows a cross sectional side view of the downhole device of FIG. **1**, but with an alternative centralizer;

[0081] FIG. **3** shows a perspective sectional view of the bypass sub of FIG. **1** having a first flow path selectively closed by a drop ball;

[0082] FIG. **4** shows a sectional side view of the bypass sub of FIG. **3** indicating a (fully open) flow path of the fluid from an uphole wellbore region to a downhole wellbore region;

[0083] FIG. **5** shows a sectional side view of the bypass sub of FIG. **3** indicating a (restricted) pressure bypass path of the fluid from an uphole wellbore region to a data acquisition device and/or data acquisition device carrier when the first flow path is selectively closed by a drop ball;

[0084] FIG. **6** shows (a) a close up sectional side view of the data acquisition device carrier of FIG. **1** and a data acquisition device (Micro Automatic Gauge) placed inside the data acquisition device carrier, (b) a close up sectional view of the interface port of the data acquisition device, and (c) a close up view of the pressure transducer;

[0085] FIG. **7** shows a sectional side view of a second and more preferred embodiment of a downhole device according to the present invention, with the bypass sub mounted to the uphole end of a frac plug and two data acquisition devices placed in series one above the other inside the mandrel of the frac plug;

[0086] FIG. **8** shows a sectional side view of the downhole device of FIG. **7** (but with the outer most parts of the frac plug and the data acquisition device not shown), where the bypass sub is mounted to the uphole end of an inner mandrel of a frac plug, where (a) shows the fluid flow from an uphole wellbore region through to a downhole wellbore region when the first flow path is open, (b) shows the fluid pressure path along a second fluid communication path, bypassing the first flow path, from an uphole wellbore region into a data acquisition device carrier (data acquisition device not shown), and (c) shows a front view and section lines of (a) and (b);

[0087] FIG. **9** shows (a) a top view, (b) a bottom view, (c) a sectional side view along C-C, and (d) a sectional side view along A-A of the bypass sub of FIG. **8**;

[0088] FIG. **10** shows a simplified schematic side view of the step of pumping the downhole device of the first aspect of the present invention downhole inside the wellbore in accordance with the second aspect of the present invention;

[0089] FIG. **11** shows a simplified schematic side view of the step of closing the first flow path of the downhole device of the present invention by dropping a drop ball into place;

[0090] FIG. **12** shows a simplified schematic side view of the step of recovering the downhole device in accordance with the first aspect of the present invention from the wellbore using a milling device (e.g. plug mill) and data acquisition device retrieval mechanism in accordance with a third aspect of the present invention;

[0091] FIG. **13** (*a*) shows a sectional side view of a first (less preferred) embodiment of a milling device and data acquisition device retrieval mechanism of FIG. **12** including spring loaded catching slips and centralising pads;

[0092] FIG. **13**(*b*) shows a perspective view; **13**(*c*) a side view and **13**(*d*) a bottom view of the spring based catcher ring of the less preferred embodiment of milling device and retrieval mechanism of FIG. **13**(*a*)

[0093] FIG. **14** shows a sectional side view of the pick-up shoe of the data acquisition device retrieval barrel of the less preferred milling device shown in FIG. **13**(*a*);

[0094] FIG. **15**(*a*) shows a cross-sectional side view of a second and most preferred embodiment of a milling device and data acquisition device retrieval mechanism in accordance with the third aspect of the present invention;

[0095] FIG. **15**(*b*) shows a close up more detailed view of the milling device and part of the retrieval mechanism of FIG. **15**(*a*), particularly showing springloaded catching slips and centralising pads;

[0096] FIG. **16** shows a sectional side view of the less preferred milling device and data acquisition device retrieval barrel of FIG. **13**(*a*) at the entry stage when milling over a downhole device of FIG. **1** during recovery of the data acquisition device carrier and data acquisition device, in accordance with the third aspect of the present invention;

[0097] FIG. **17** shows a sectional side view of the less preferred milling device and data acquisition device retrieval barrel of FIG. **16**, but at the end stage when milling over the downhole device during recovery of the data acquisition device carrier and data acquisition device;

[0098] FIG. **18** shows the less preferred milling device and data acquisition device retrieval barrel of FIG. **17**, but filled with a recovered downhole device;

[0099] FIG. **19** shows the less preferred milling device and data acquisition device retrieval barrel of FIG. **18**, but filled with a plurality of recovered bottom hole assemblies that are interlocked via the centralizer of the downhole device;

[0100] FIG. **20**(*a*) shows a cross-sectional side view of a third and most preferred embodiment of a downhole device according to the present invention, with the bypass sub mounted within and just below the uphole end of a frac plug and one data acquisition device located inside the mandrel of the frac plug;

[0101] FIG. **20**(*b*) shows a different cross-sectional side view of the downhole device of FIG. **20**(*a*) but on a different cross-section plane and FIG. **20**(*b*) therefore shows the second fluid communication pressure path;

[0102] FIG. **20**(*c*) shows a cross-sectional side view of the most preferred embodiment of a milling device and data acquisition device retrieval mechanism as shown in FIGS. **15**(*a*) and **15**(*b*), approaching the upper end of the most preferred downhole device of FIGS. **20**(*a*) and **20**(*b*);

[0103] FIG. **20**(*d*) shows the milling device and retrieval mechanism of FIG. **20**(*c*) as having milled away the uppermost outermost section of the frac plug of FIGS. **20**(*a*) and (*b*) and also shows the upper end and also the drop ball of the downhole device of FIGS. **20**(*a*) and (*b*) as having entered the retrieval mechanism;

[0104] FIG. **20**(*e*) shows the milling device and retrieval mechanism of FIG. **20**(*d*) as having further milled away most of the outermost part of the frac plug of FIGS. **20**(*a*) and (*b*) and also shows the majority of the downhole device as having entered the retrieval mechanism; FIG. **20**(*f*) shows the milling device and retrieval barrel of FIG. **20**(*e*) but now with the downhole device of FIG. **20**(*e*) as having fully entered the retrieval mechanism and also showing the milling device starting to mill the upper and outermost section of a second and lower frac plug such that the uppermost end of the downhole device of the second frac plug is now starting to enter the retrieval barrel;

[0105] FIG. **21**(*a*) shows a perspective view of a drop device in accordance with a fourth aspect of the present invention, the drop device including a obturation member (drop ball), a data acquisition tool (logging tool) that is mounted to the drop ball, and a centralizing member that is actuatable by a flange member;

[0106] FIG. **21**(*b*) shows a cross sectional side view of the drop device of FIG. **21**(*a*) when engaged with a downhole tool and fixated to the throughbore;

[0107] FIG. **22** shows a cross sectional side view of the drop device of FIG. **21** during recovery when disengaged and pushed up by fluid flowing uphole, and

[0108] FIG. **23** shows a simplified schematic side view of an alternative recovery method of the drop device in FIG. **21**(*a*) from the wellbore using a milling device and data acquisition device retrieval barrel similar to the one shown in FIG. **12** used for the third aspect of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0109] The following definitions will be followed in the specification. As used herein, the term "wellbore" refers to a wellbore or borehole being provided or drilled in a manner known to those skilled in the art. The wellbore may be 'open hole' or 'cased', being lined with a tubular string. Reference to up or down will be made for purposes of description with the terms "above", "up", "upward", "upper", or "upstream" meaning away from the bottom of the wellbore along the longitudinal axis of a work string and "below", "down", "downward", "lower", or "downstream" meaning toward the bottom of the wellbore along the longitudinal axis of the work string. Similarly 'work string' refers to any tubular arrangement for conveying fluids and/or tools from a surface into a wellbore. In the present invention, a coiled tubing string or a drill pipe string is the preferred work string.

[0110] Referring to FIGS. **1** to **6**, a downhole device **100** is shown comprising a bypass sub tool **102**, a data acquisition device carrier **104** and a centralizer **106**. The downhole device **100** is less preferred when compared to the more preferred downhole device **200** of FIG. **7** and particularly the most preferred downhole device **250** for reasons to be detailed subsequently. The upper end of the less preferred bypass sub **102** of FIG. **1** is adapted to be mounted to the lower end of any standard frac plug **10** and/or on any manufacturers frac plug. The data acquisition device carrier **104** of FIG. **1** is operatively coupleable to the in use lower or downhole end of the bypass sub **102** and is adapted to provide a housing for at least one data acquisition device **108**. The centralizer **106** is mounted to the lower or downhole end **107** of the downhole device **100** and comprises, for example, a centralizer disc **110** and an anti rotation stab **112**.

[0111] Alternatively, and as shown in FIG. **2**, the centralizer **106** may comprise a flange-type member **114** having a depression **116** at the downhole end that is adapted to cooperatively engage with a matching counter part (not shown) coupled to the uphole end **109** of another downhole device **100**. The centralizer **106** and matching counter part (not shown) engage such as to guide the downhole end **107** of an upper downhole device **100** into the uphole end **109** of a lower downhole device **100** during recovery of a plurality of bottom hole assemblies **100** placed within a wellbore as will be subsequently described in more detail.

[0112] As shown in FIG. **2**, the bypass sub **102** comprises a first fluid path **118** which in use is in fluid communication with the fluid flow through path of the frac plug **10** such as to provide a fluid path between an uphole region of the wellbore (that is, the wellbore located above the plug **10**) and a downhole region of the wellbore located below the plug **10**. The first fluid path is selectively blockable by a drop ball **124** landing on a drop ball seat **121** (see FIG. **3**). The bypass sub **102** comprises a second fluid pressure path **120** bypassing the dropball **124** such as to provide fluid communication (particularly to transmit pressure) between the uphole region of the wellbore and the interior cavity **122** of the data acquisition device carrier **104** even in the event the first fluid path **118** is blocked by the drop ball **124**, thus allowing measurements of physical parameters of the uphole wellbore environment located above the frac plug **10** at all times during the fracing operation. FIG. **3** shows a detailed perspective section view of the bypass sub **102**, the first fluid path **118**, the bypassing second fluid pressure path **120** and drop ball **124**. It is understood that the bypass sub **102** may comprise more than one first fluid path **118**. Similarly, the bypass sub **102** may comprise more than one fluid pressure path bypass path **120**. The upper end of the bypass sub **102** of the less preferred downhole device **100** is coupled to the lower end of the frac plug **10** via a fluid tight screwthread **125** having a relatively large diameter and which is preferably larger than the inner cutting diameter "d" of a milling tool **300** or **350** to be detailed subsequently. The upper end of the data acquisition device carrier **104** is coupled to the lower end of the bypass sub **102** via a fluid tight screw thread **126** having a relatively smaller diameter than thread **125** and preferably a smaller diameter than the inner cutting diameter "d" of the milling tool **300** or **350** for reasons which will be discussed subsequently. However, it is understood by the skilled person in the art that any other suitable connection may be used to mount the bypass sub **102** to the data acquisition device carrier **104** and to the plug **10**. The data acquisition device carrier **104** and/or the plug **10** may be removably or permanently fixed to the bypass sub **102**.

[0113] Referring to FIG. **4**, the first fluid path **118** through the bypass sub is shown in greater detail when there is no drop ball **124** blocking the first fluid path **118**. FIG. **5**, shows the second fluid pressure path **120** through into the interior cavity **122** of the data acquisition device carrier **104** when the drop ball **124** blocks the first fluid path **118**; as can be seen in FIG. **5**, no fluid can flow along or through the second fluid pressure path **120** because the lower end of the cavity **122** is blocked.

[0114] FIG. **6** shows a particular and preferred example of a data acquisition device in the form of a Micro Automatic Gauge **108** placed inside the data acquisition device carrier **104**. The interface port **128** of the Micro Automatic Gauge **108** is located at the downhole end of the data acquisition device carrier **104** and the pressure transducer **130** is located towards the uphole end of the data acquisition device carrier **104**. This particular Micro Automatic Gauge **108** requires no input to acquire data since the sensor of the Micro Automatic Gauge **108** is in monitor mode checking for pressure and temperature changes after a pre-determined period has lapsed for instance in between a second and some minutes such as every 2 minutes. Once a temperature or pressure threshold have been exceeded, the Micro Automatic Gauge **108** automatically switches into record mode sending the acquired data to a memory at a pre-set sample rate. At the end of the acquisition, the Micro Automatic Gauge **108** automatically switches off and goes back into its monitor mode. The Micro Automatic Gauge **108** is available from the applicant, Omega Well Monitoring Limited of Aberdeen, United Kingdom.

[0115] FIGS. **7** to **9** show an alternative downhole device **200**, where the bypass sub **202** is located vertically above the frac plug **20** such that the in use lower (downhole) end of the bypass sub **202** is mounted to the in use uphole end of the frac plug **20** such that the at least one data acquisition device carrier **204** and/or data acquisition device **208** is located inside the mandrel **22** of the frac plug **20**. The downhole device **200** of FIG. **7** is not as preferred as the downhole device **250** of FIG. **20**(*a*) though because the downhole device **200** may impede the setting of the frac plug **20** (which is set with a special setting tool (not shown)) that connects at the top of each frac plug **20** and which is not a problem experienced with the most preferred downhole device **250**. In the example shown in FIG. **7**, two data acquisition devices **208** are placed inside a data acquisition device carrier **204** that is in fluid communication with a second fluid pressure path **220** (see FIGS. **8** and **9**) from an uphole region of the wellbore above the plug **20** to the data acquisition devices **208** (not shown in FIG. **8**). A first fluid path **218** runs through the bypass sub **202** and the frac plug **20** between an uphole region of the wellbore located above the plug **20** and a downhole region of the wellbore located below the plug **20** allowing fluid communication between the uphole and downhole region of the wellbore in the absence of a drop ball **224** blocking the first fluid path **218**. If a suitably sized drop ball **224** is dropped into the fluid flow at surface, it will come to rest against the upper most end **221** or seat **221** of the bypass sub **202**, in which case the first fluid path **218** is blocked, but the data acquisition devices **208** can still experience the parameters of the fluid (such as pressure and/or temperature) via the bypass path **220**.

[0116] Note that FIG. **8** omits to show a data acquisition device carrier located below the bypass sub **202**.

[0117] FIGS. **10** to **12** show the placement, operation and recovery of the downhole device **100** step-by-step. In particular, as shown in FIG. **10**, the downhole device **100** is mounted to the downhole end of a frac plug **10** (although the downhole device **200** of FIG. **7** would be mounted to the uphole end of a frac plug **20** and the downhole device **250** or FIG. **20**(*a*) would be mounted within frac plug **20**) and placed downhole into the wellbore in a region that is determined for perforation and a fracing operation by running them into the wellbore **101** by conventional methods such as lowering on wireline (not shown) or a tubing string such as coiled tubing (not shown) or pumped into the wellbore **101**, wherein a plurality of downhole devices **100** may be placed in the required respective zone in a plurality of dedicated regions. The plug(s) **10** (or **20**) are then set in the conventional manner to seal against the inner surface of the wellbore **101**. Perforation guns (not shown) associated with each downhole device **100** are then detonated in the conventional manner to create fractures within the formation. The pressure and temperature changes caused by the detonation may initiate the data acquisition of the data acquisition device **108**, which also starts to record the data. Alternatively, the data acquisition devices **108** may be operated from the surface remotely, or may be on a timer to operate after a period of time has elapsed.

[0118] In the event that the perforation is unsuccessful, a second perforation gun is pumped downhole to the first downhole device **100**, before blocking the first fluid path with a drop ball **124**.

[0119] After a successful perforation, as shown in FIG. **11**, a first drop ball **124** is pumped downhole such as to engage with the seat **221** provided in the bypass sub **102** or **202** or **252** of a first downhole device **100** or **200** or **250** and block the first fluid path **118** or **218** or **268**. Subsequently, fracing fluid including proppants is then pumped downhole and into the fractures of the formation at extremely high pressure, while determining, for example, wellbore pressure and temperature using the data acquisition devices **108** or **208** or **258** by means of being in fluid communication via the second fluid pressure path **120** or **220** or **270**. After completing the fracing operation of the first downhole device **100** or **200** or **250**, a communication sub tool (not shown) may be moved downhole to connect to the data acquisition device **108** or **208** or **258** and recover the recorded data via a near field transmission means such as RFID or other suitable means. Alternatively, the data may be recovered after physically retrieving the data acquisition device **108** or **208** or **258** to the surface (and this method and apparatus therefore will be described subsequently), or the data may be transmitted uphole via a signal path established, for example, through a wireline or a transceiver (not shown).

[0120] A second smaller diameter "d" rop ball **124** or **224**, which is adapted to engage with the seat **121** or **221** or **271** of a second, subsequently run in downhole device **100** or **200** or **250**, is then pumped downhole to block the first fluid path **118** or **218** or **268** of the second upper most downhole device **100** or **200** or **250** before repeating the fracing operation for that upper most downhole device **100** or **200** or **250** while recording, for example, well pressure and temperature for evaluation. These steps are repeated with further bottom hole assemblies **100** or **200** or **250** until all dedicated formation regions are perforated and fraced.

[0121] Once the fracing operations have been completed, as shown in FIG. **12**, a tool to mill away the bottom hole assemblies **100**, **200** or **250** for example a milling device (i.e. a mill plug) **300**, is sent downhole, for example, on coiled tubing or a drill pipe string to recover the data acquisition devices **108**, **208** or **258** and pick-up each downhole device **100** or **200** or **250** in turn starting with the uppermost one closest to the surface.

[0122] FIG. **13**(*a*) shows a first but less preferred embodiment of a part of a coring-style bit mill **300** in accordance with the present invention as comprising TSP cutters **302**, a data acquisition device catcher lower shoe **303** and its data acquisition device catcher **304**, an outer barrel **306** and an inner barrel **308**. The data acquisition device catcher **304** is, for example, a spring biased catcher ring **304** mounted within the shoe **303** as shown in FIGS. **13**(*b*), **13**(*c*) and **13**(*d*). Alternatively, the two piece shoe **303** and inner barrel **308** can be replaced by a one piece pick-up shoe **312** as shown in FIG. **14** in which case the catcher ring **304** is mounted within a cavity **310** of the pick-up shoe **312**. In either case, the catcher ring **304** is adapted to engage with a groove **132** located circumferentially around the data acquisition device carrier **104** or data acquisition device **108**, as shown in FIGS. **16** and **17**, once the ring **304** has traveled down the outside of the data acquisition device carrier **104** to prevent the data acquisition device carrier **104** from otherwise falling out.

[0123] FIGS. **15**(*a*) and **15**(*b*) show the most preferred embodiment of mill **350** and will be detailed subsequently.

[0124] FIG. **16** shows the mill **300** of FIG. **13**(*a*) during operation at the stage when the downhole device **100** is just entering the inner barrel **308** or pick-up shoe **312**. The mill **300** has milled away and thus removed the outer part of the frac plug **10**, **20** and the bypass sub **102**, **202** including the relatively large diameter threaded connection **125** (but has not milled the relatively small diameter threaded connection **126**). FIG. **17** shows an advanced stage after the data acquisition device carrier **104** has entered the pick-up shoe **312** and the data acquisition device catcher **304** has engaged with the groove **132** of the data acquisition device carrier **104** preventing any unwanted downhole movement of the data acquisition device carrier **104** with respect to the mill **300** than the point shown in FIG. **17**.

[0125] FIG. **18** shows substantially the whole length of the mill **300** including its upper end and its inner bearing assembly **305** and its inner barrel **308** into which is recovered the data acquisition device carrier **104** and data acquisition device **108** of a downhole device **100** (not shown in FIG. **18**). Sections of the frac plug **10**, bypass sub **102** and centralizer **106** will be milled away and thus removed such that the downhole device **100** fits into the inner barrel **308** or pick-up shoe **312**. The data acquisition device catcher lower shoe **303** may be modified to allow the additional option of taking samples of the wellbore reservoir for analysis.

[0126] FIG. **19** shows a mill **300** after retrieval of a plurality of bottom hole assemblies **100**. During retrieval each anti rotation stab **112** of a preceding (upper) downhole device **100** engages with a complementary section at the uphole end of the frac plug **10**, **20** of a subsequent (immediately lower) downhole device **100** to guide the mill **300** over the next downhole device **100** and prevent rotation of the downhole device **100** with the drill bit **302** of the mill **300** and with respect to the wellbore **101**, thus allowing to mill away the outer section of the downhole device **100** that does not fit inside the inner barrel **308** or pick-up shoe **312**.

[0127] The mill **300** with bottom hole assemblies **100** located therein is then pulled out of the wellbore **101** to the surface, where the data acquisition device carriers can be removed and recovered from the inner barrel **308**/pick-up shoe **312** and the data stored therein can be downloaded or otherwise retrieved and analysed.

[0128] FIGS. **20**(*a*) and **20**(*b*) show an alternative and indeed most preferred embodiment of a downhole device **250** in accordance with the present invention, where the bypass sub **252** and the data acquisition device **258** are mounted within the throughbore of the frac plug **20** (rather than being mounted below the frac plug **10** as shown in FIG. **2** or respectively above and within the frac plug **20** as shown in FIG. **7** for that embodiment of the downhole device **200**). The downhole device **250** is most preferred because it is wholly located within the frac plug **20** and therefore will not impede the setting of the frac plug **20** which typically is set with a special setting tool (not shown) that connects at the top of each frac plug **20**.

[0129] The bypass sub **252** is coupled via a screwthread **275** provided on its outer surface to a similarly shaped screwthread surface formed on the inner throughbore **21** of the frac plug **20**, where the screwthread **275** is a relatively large diameter and which is preferably larger than the inner cutting diameter "d" of a milling tool **350** to be detailed subsequently. The lower end of the bypass sub **252** is coupled to the upper end of the data acquisition device carrier **254** via a fluid tight screwthread **276** having a relatively smaller diameter than thread **275** and preferably a smaller diameter than the inner cutting diameter "d" of the milling tool **350**, for reasons which will be discussed subsequently. FIG. **20**(*a*) shows frac ball or drop ball **224** as being seated on ball seat **271** but were the frac ball **224** not present, the first fluid path **268** through the bypass sub **252** can be seen in FIG. **20**(*a*). FIG. **20**(*b*) shows the second fluid pressure path **270** as being present when the frac ball **224** is seated on the ball seat **271** where the second fluid pressure path **270** leads from the throughbore portion of the frac plug **20** located above the frac ball **224** and into the interior cavity **272** of the data acquisition device carrier **254**. As can be seen in FIG. **20**(*b*), no fluid can flow along or through the second fluid pressure path **270** because the lower end of the interior cavity **272** is blocked. A membrane (not shown) is typically provided across the second fluid pressure path **270** at some point, where the cavity **272** is filled with clean hydraulic fluid and the membrane acts to seal that cavity **272** but also acts to communicate the pressure of the downhole fluid to the sealed hydraulic fluid.

[0130] FIGS. **20**(*a*) and **20**(*b*) also show the data acquisition device such as sensors or gauges **258** as being housed within the interior cavity **272**. The data acquisition device **258** is similar in form to the data acquisition device **108** as described above.

[0131] The downhole device **250** has a first shoulder **280** formed at its very upper end around the outer circumference of its very upper end such that the shoulder **280** projects outwardly, and a second outwardly projecting shoulder **281** approximately one quarter of the way down the length of the tunnel device **250** and just below the thread **276**, and a third outwardly projecting shoulder **282** approximately three quarters of the length down the downhole device **250** and a fourth outwardly projecting shoulder **283** provided at its lower most end where the functions of the first **280**, second **281**, third **282** and fourth **283** shoulders will be discussed in detail subsequently.

[0132] The upper end of the downhole device **250** is secured by means of the screwthread **275** to the inner bore **21** of the plug **20** as described above. The lower end of the downhole device **250** is provided with a downwardly projecting insert **285** and which projects downwardly through an aperture formed in an annular ring centraliser **287** where the centraliser **287** is secured via a left hand thread to the inner bore **21** of the frac plug **20**, the left hand thread ensuring that the centraliser **287** can not be rotated out of secure connection with the inner bore **21** if the rest of the downhole device **250** were to rotate or to be caused to rotate in the right hand direction within the inner bore **21**. The insert **285** is however not in threaded coupling with the inner bore of the centraliser **287** and therefore it would be possible for the downhole device **250** to rotate within the centraliser **287** if it were caused to do so and the centraliser **287** prevents the insert **285** and therefore the downhole device **250** from moving downwardly through the centraliser **287** and therefore the centraliser axially locks the downhole device **250** in a downwards direction. However, the centraliser **287** does not prevent the insert **285** from moving upwardly through it if for instance the downhole device **250** were pulled upwards with respect to the inner bore **21** of the frac plug **20** and that possibility will be described subsequently. Consequently, the centraliser **287** centralises the lower end of the downhole device **250** within the throughbore **21** of the frac plug **20** and in doing so prevents the insert **285** and therefore the downhole device **250** from moving in a radial direction with respect to the longitudinal access of the frac plug **20** and further prevents the downhole device **250** from moving downwards through the centraliser **287** but does not prevent the downhole device **250** from being moved upwards out of the frac plug **20** were that to be possible for instance were the screwthread **275** to be milled away. As can be seen in FIGS. **20**(*a*) and **20**(*b*) the centraliser **287** has some apertures **289** formed around its annular ring such that when the drop ball **224** is not present and fluid can flow through the first fluid path **268**, the fluid can exit the throughbore at the bottom of the frac plug **20** through the apertures **289**.

[0133] Once the fracing operation with frac plug **20** and downhole device **250** have been completed, as shown in FIG. **20**(*c*), the milling device **350** of FIGS. **15**(*a*) and **15**(*b*) is run into the wellbore for instance on coiled tubing or a drillpipe string to recover the data acquisition device **258** from each downhole device **250** in turn starting with the uppermost one closest to the surface of the wellbore.

[0134] The most preferred coring style bit mill or milling device **350** is shown in FIGS. **15**(*a*) and **15**(*b*) as comprising PDC cutting elements **352** (but these could be TSP cutting elements or Tungsten Carbide cutting elements etc,), a data acquisition device catcher lower shoe **353** and its data acquisition device catcher **354** and an outer barrel **356** (the most preferred coring style bit mill **350** not requiring an inner barrel like the other embodiments). As can be most clearly seen in FIG. **15**(*b*) the data acquisition device catcher **354** is a plurality of individual spring loaded catching slips **354** which are normally biased to project into the bore of the bit mill **350** by respective individual springs **357** such that the slips **354** provide an upwardly facing catching surface **359** which as will be described in more detail subsequently, will cooperate with the shoulders **280**, **281**, **282** and **283** of the downhole device **250** to prevent the downhole device **250** from falling out of the retrieval barrel **361** once the respective shoulder **280**, **281**, **282**, **283** has cleared the slips **354** and therefore the slips **354** secure the data acquisition carrier **254** inside the retrieval barrel **361**.

[0135] Both the shoe **353** and the outer barrel **356** contain longitudinally extending centralising pads **363** which will act to prevent lateral movement of the data acquisition device carrier **354** as it enters the retrieval barrel **361**. As shown in FIG. **15**(*a*) the mill **350** is provided with a crossover sub **351** at its uppermost end to connect the mill **350** to the lower end of a bottom hole assembly on which the mill **350** is run into the wellbore.

[0136] FIG. **20**(*c*) shows the mill **350** of FIG. **15**(*a*) during operation at the stage where the mill **350** is approaching the upper end of the frac plug **20** and therefore the upper end of the downhole device **250** and, as can be seen in FIG. **20**(*c*), the mill **350** will shortly start to mill away the upper end of the frac plug **20**. The inner diameter (d) of the mill cutting head **350** is chosen such that it is smaller in diameter than the diameter of the relatively large diameter threaded connection **275** but is larger in diameter than the relatively small diameter threaded connection **276** and therefore the mill **350** will mill away the threaded connection **275** such that the rest of the upper end of the bypass sub **252** with a diameter smaller than diameter "d" starts to enter the retrieval barrel **361**. The mill **350** is now at the position shown in FIG. **20**(*d*) as having milled away part of the outside of the bypass sub **252** and particularly in FIG. **20**(*d*) the bypass sub **252** has entered the retrieval barrel **361** sufficiently such that the shoulder **280** has just moved past the slips **354** such that the slips **354** have been moved into the groove that is immediately below the shoulder **280** under the action of the springs **357** such that the bypass sub **252** and therefore the downhole device **250** cannot now exit the retrieval barrel **361**. Continued downward movement of the mill **350** will continue to mill away the rest of the frac plug **20** such that the second shoulder **281** will move past the slips **354** and further continued downward movement of the mill **350** will result in the slips **354** moving past the third shoulder **282** and subsequently the fourth shoulder **283**. By the time slips **354** have moved past the third shoulder **282**, the plug **20** is no longer attached to the wellbore via its slips **22**U as they have been milled away and that is the position shown in FIG. **20**(*d*). Furthermore, by the time the shoulder **283** passes the slips **354**, the lower frac plug slips **22**L will have been milled way as well. FIG. **20**(*f*) shows that as having incurred with a first downhole device **250**U and also shows that a second lower downhole device **250**L has started to enter the retrieval barrel **361** of the mill **350**.

[0137] Importantly, once the first shoulder **280** of a downhole device **250** has passed the slips **354**, the relatively large diameter threads **275** will have been milled away and therefore it would be possible for the mill **350** to pick up the downhole device **250** at any point thereafter because the slips **354** will prevent the first shoulder **280** from passing back through the slips **354** but the downhole device **250** would only be pulled out of the well in that configuration as a last resort because the rest of the downhole device **250** would be protruding out of the lower end of the mill **350** and therefore would be more susceptible to damage as it was pulled out of the wellbore and therefore it is much preferred that the mill **350** does mill away all of the frac plug **20** so that the downhole device **250** fully enters the retrievable barrel **361** and is retained therein by its fourth shoulder **283**. The third **282** and fourth **283** shoulders are therefore beneficial particularly when there are at least two downhole devices **250** to recover from the wellbore.

[0138] Referring now to FIGS. **21** to **23**, an alternative to the downhole devices **100** or **200** or **250** is shown in the form of a drop device **400**. The drop device **400** comprises an obturation member, such as a drop ball **402**, and a data acquisition device **404** removably and operatively coupled to the drop ball **402**. Preferably, a data acquisition device **404** is coupled to the drop ball **402** via a data acquisition device carrier housing **403** that is mounted to the drop ball **402**. The data acquisition device carrier housing **403** is adapted to accommodate at least one data acquisition device **404**, such as a logging tool. The at least one logging tool may be suitable to determine any one or both of temperature or pressure. Alternatively or additionally, the logging tool may include a geophone and/or micro seismic sensor. Preferably, the data acquisition device **404** and/or data acquisition device carrier housing **403** is located uphole of the drop ball **402** when in use so that the data acquisition device **404** is located within the isolated fracing region. However, a second data acquisition device (not shown) may be secured to (but be located downhole of) the drop ball **402** when in use.

[0139] A centralizing member **406** is operatively mounted to the data acquisition device **404** or data acquisition device carrier housing **403**. The centralizing member **406** comprises a plurality of spreading elements **408** adapted to engage with an interior wall of the throughbore of the wellbore so as to fixate and centralize the drop device **400** within the throughbore. In particular, the centralizing member **406** is actuated by slidingly compressing the spreading elements **408** until the spreading elements **408** bend towards and engage with the interior wall of the throughbore. The centralizing member **406** is actuated by a flange member **410** that is operatively coupled to the data acquisition device **404** or data acquisition device carrier housing **403**. The flange member **410** is adapted to slide along a longitudinal axis of the drop device **400**, but is prevented from sliding off the data acquisition device **404** or data acquisition device carrier housing **403**. The flange member **410** provides an uphole contact surface **412** and a downhole contact surface **414**, both of which are adapted to engage with fluid flowing uphole or downhole, respectively.

[0140] It is understood by the skilled person in the art that any other suitable obturation member may be used. In particular, alternatively to the drop ball, the obturation member may be a dart or plug or other device suitable for obturating a packer or shifting a sleeve.

[0141] Referring now to FIGS. **21**(*a*) and (*b*) and **22**, during operation, the drop device **400** (having a suitably sized drop ball **402**) is injected into the wellbore and pumped down to a predetermined downhole tool **500**. The drop ball **402** is sized so as to only sealingly engage with the predetermined downhole tool **500**. For example, the drop ball **402** may seal off fluid communication when engaging with a suitably sized seat **502** of the predetermined downhole tool **500**. The drop device **400** may actuate other downhole tools (not shown) while on the way.

[0142] For example, in a multi stage fracturing system, the drop ball **402** may actuate a hydraulically-activated flow port **504** that is run in conjunction with a fracture port sleeve (not shown), thus allowing specific zones of the wellbore to be isolated and selectively fractured. In particular, the multiple hydraulically-activated flow ports can be successively activated by locating the ball seat **502** with the largest diameter at the top (most uphole) of the line. Starting with the smallest diameter "d" rop ball **402**, the flow ports and fracture port sleeves can be isolated and activated one by one.

[0143] As shown in FIG. **21**(*b*), the drop ball **402** of the drop device **400** has activated the flow port **504** and is sealingly engaged with the seat **502** of the downhole tool **500**. As soon as the drop ball **402** sealingly engages with the seat **502**, the hydraulic pressure of the fluid pushes the flange member **410** towards the drop ball **402** simultaneously actuating the centralizing member **406** so as to bend and engage the spreading elements **408** with the interior wall of the throughbore. The increasing hydraulic pressure opens the flow port **504** so that fracing fluid flows into the wellbore. The fracing fluid props open any fractures within the isolated region of the wellbore so that hydrocarbons can flow freely into the wellbore. Temperature and pressure changes during the fracing operation may initiate data acquisition of the data acquisition device **404**, which also starts to record the data. Alternatively, the data acquisition device **404** may be operated from the surface remotely, or may be on a timer to operate after a period of time has elapsed.

[0144] When the fracing operation is completed and hydrocarbons flow into the wellbore, the production fluid is pumped uphole (see FIG. **22**). The fluid flowing uphole engages with the uphole surface **412** of the flange member **410** which slides in a direction away from the drop ball **402** thus disengaging the spreading elements **408** from the interior wall of the throughbore so that the drop device **400** is pumped uphole with the fluid flow. Once recovered, the data stored on the drop device **400** can be downloaded for assessment before reusing the drop device **400**. Alternatively, the data acquisition device **404** and centralizing member **406** may be coupled to a different sized drop ball **402** for engagement with a different downhole tool.

[0145] In an alternative method for recovering the drop device **400**, a milling device (e.g. mill plug) **600**, similar in design to the milling device **300** described with the third aspect of the invention and shown in FIG. **13**, may be used in the same way as described for the third aspect of the invention. In particular, as shown in FIG. **23**, once the fracing operation has been completed, the milling device tool **600** is sent downhole, for example, on coiled tubing or a drill pipe string to recover the data acquisition device **404** and pick-up each downhole tool **500** in turn starting with the uppermost one closest to the surface.

[0146] The procedure described for the drop device **400** may be repeated for each of the isolated regions covered by the multi stage fracturing system.

[0147] It will be appreciated by persons skilled in the art that the above embodiments have been described by way of example only and not in any limitative sense, and that various alterations and modifications are possible without departing from the scope of the invention.

1. A downhole device for data acquisition during fracing operations, the device comprising:

a bypass device operatively coupleable to a wellbore selective obturation member and adapted to provide a selectively closable first fluid path for fluid communication through said wellbore selective obturation member between a region inside the throughbore of the wellbore located uphole of said downhole device and a region inside the wellbore located downhole of said downhole device when in situ; and

at least one data acquisition device, adapted to detect at least one physical property and operatively coupled to said bypass device, wherein said bypass device is further adapted to provide at least one second fluid path for fluid communication between said at least one data acquisition device and said region inside the wellbore located uphole of said bypass device.

2. The downhole device according to claim **1**, wherein said at least one data acquisition device is operatively coupled to said bypass device directly or via a data acquisition device carrier mountable to said bypass device and adapted to accommodate said at least one data acquisition device.

3. The downhole device according to claim **1**, further comprising a centralizing member operatively coupled to said at least one data acquisition device and adapted to centralize and/or rotationally stabilize said at least one data acquisition device within the wellbore.

4. The downhole device according to claim **2**, further comprising a centralizing member operatively coupled to said data acquisition device carrier and adapted to centralize and/or rotationally stabilize said data acquisition device carrier within said wellbore.

5. The downhole device according to claim **1**, wherein a seat member located within or at an end of said first fluid path is adapted to engage with a drop member so as to at least unidirectionally selectively prevent fluid flow through said first fluid path.

6. The downhole device adapted according to claim **1**, wherein said second fluid path is adapted to bypass said first fluid path.

7. The downhole device according to claim **1**, wherein said at least one data acquisition device comprises an integrated data storage device adapted to record a predetermined maximum amount of data.

8. The downhole device according to claim **7**, wherein said at least one data acquisition device comprises a data interface adapted to permit download of at least part of said predetermined maximum amount of data to a remote data storage means.

9. The downhole device according to claim **1**, wherein said at least one data acquisition device is adapted to transmit data to a remote location uphole of said downhole device within the wellbore.

10. The downhole device according to claim **1**, wherein said at least one data acquisition device is any one or all of a pressure data acquisition device and/or a temperature data acquisition device and/or a geophone and/or a micro seismic sensor.

11. The downhole device according to claim **2**, wherein said data acquisition device carrier is adapted to irretractably engage with a data acquisition device catcher mechanism when moving along a longitudinal axis inside a pick-up device of said data acquisition device catcher mechanism.

12. The downhole device according to claim **11**, wherein said data acquisition device carrier comprises at least one recess or shoulder or other formation provided on or in the outer surface of said data acquisition device carrier and is adapted to cooperate with said data acquisition device catcher mechanism.

13. The downhole device according to claim **12**, wherein said data acquisition device catcher mechanism comprises at least one spring loaded catcher member.

14. The downhole device according to claim **1**, wherein said bypass device is located inside a mandrel of said wellbore selective obturation member when in situ.

15. The downhole device according to claim **14**, wherein at least one of said data acquisition device and the data acquisition device carrier is located downhole of said bypass device.

16. The downhole device according to claim **1**, wherein said bypass device is located uphole of said wellbore selective obturation member when in situ.

17. The downhole device according to claim **16**, wherein said at least one data acquisition device and the data acquisition device carrier is operatively located inside a mandrel of said wellbore selective obturation member.

18. The downhole device according to claim **1**, wherein said bypass device is located downhole of said wellbore selective opturation member when in situ.

19. The downhole device according to claim **18**, wherein said at least one data acquisition device and the data acquisition device carrier is located downhole of said bypass device.

20. The downhole device according to claim **2**, wherein said second fluid path comprises an incompressible fluid sealingly encased within said second fluid path and said data acquisition device carrier by a membrane located at the uphole end of said second fluid path.

21. The downhole device according to claim **20**, wherein said membrane is typically pressure sensitive such that it can transmit pressure from one side to the other side of said membrane.

22. The downhole device according to claim **20**, wherein said membrane is sufficiently flexible and diathermic to prevent distortion of said physical properties that are measured with said at least one data acquisition device.

23. A method for acquiring data during fracing operations in a subterranean formation having a wellbore penetrating the formation, the method comprising:

(a) running in a downhole device having a data acquisition device into a wellbore along with a wellbore selective obturation member;

(b) placing said downhole device and wellbore selective obturation member at a location inside the wellbore;

(c) initiating at least one data acquisition device of said downhole device for monitoring at least one physical property;

(d) initiating a fracing operation while monitoring said at least one physical property; and

(e) recovering said monitored physical property after the fracing operation is completed.

24. The method according to claim **23** wherein the downhole device comprises:

a bypass device operatively coupleable to a wellbore selective obturation member and adapted to provide a selectively closable first fluid path for fluid communication through said wellbore selective obturation member between a region inside the throughbore of the wellbore located uphole of said downhole device and a region inside the wellbore located downhole of said downhole device when in situ; and

at least one data acquisition device, adapted to detect at least one physical property and operatively coupled to said bypass device, wherein said bypass device is further adapted to provide at least one second fluid path for fluid communication between said at least one data acquisition device and said region inside the wellbore located uphole of said bypass device.

25. The method according to claim **24**, wherein there is an additional step in between steps c) and d) of:—

closing a first fluid path for fluid communication through the wellbore selective obturation member between a region inside the wellbore located uphole of said downhole device and a region inside the wellbore located downhole of said downhole device when in situ; and

wherein step (d) includes monitoring said at least one physical property through said at least one second fluid path.

26. The method according to claim **23**, wherein said at least one data acquisition device is adapted to record a predetermined amount of data of said at least one physical parameter.

27. The method according to claim **23**, wherein said at least one data acquisition device is adapted to transmit said predetermined amount of data to a remote data storage means.

28. The method according to claim **23**, wherein said at least one monitored physical property is recovered via a remotely located communication device operatively connectable to said at least one data acquisition device.

29. A method for recovering at least one downhole device having a data acquisition device from a downhole location inside a wellbore typically after completing fracing operations, the method comprising:

(a) running a plug milling device, comprising at least one data acquisition device retrieval mechanism, downhole inside a wellbore;

(b) engaging a first of said at least one downhole device so as to irretrievably move a data acquisition device carrier and/or data acquisition device of said at least one downhole device into and along a longitudinal axis of said data acquisition device retrieval mechanism, milling away any parts of said at least one downhole device exceeding an inner diameter of said data acquisition device retrieval mechanism; and

(c) removing said plug mill including said at least one downhole device from said wellbore.

30. A method according to claim **29**, wherein the downhole device comprises:

a bypass device operatively coupleable to a wellbore selective obturation member and adapted to provide a selectively closable first fluid path for fluid communication through said wellbore selective obturation member between a region inside the throughbore of the wellbore located uphole of said downhole device and a region inside the wellbore located downhole of said downhole device when in situ; and

at least one data acquisition device, adapted to detect at least one physical property and operatively coupled to said bypass device, wherein said bypass device is further adapted to provide at least one second fluid path for fluid communication between said at least one data acquisition device and said region inside the wellbore located uphole of said bypass device.

31. The method according to claim **29**, further comprising a step between steps (b) and (c) of engaging any subsequent second of said at least one downhole device so as to irretrievably move at least one of a data acquisition device carrier and a data acquisition device of said second of said at least one downhole device into and along a longitudinal axis of said data acquisition device retrieval mechanism, milling away any parts of said second of said at least one downhole device exceeding an inner diameter of said data acquisition device retrieval mechanism.

32. The method according to claim **29**, wherein said plug milling device and data acquisition device retrieval mechanism is adapted to be operated on coiled tubing or drill pipe or any other suitable work string.

33. The method according to claim **29**, wherein said data acquisition device retrieval mechanism comprises at least one catcher mechanism adapted to engage with said at least one of the at least one data acquisition device and the data acquisition device carrier of said downhole device so as to prevent downhole movement of said data acquisition device and/or data acquisition device carrier with respect to said data acquisition device retrieval mechanism in situ.

34. The method according to claim **33**, wherein said catcher mechanism is at least one spring loaded catcher member adapted to engage with at least one recess or shoulder located on the outer surface of said at least one data acquisition device and the data acquisition device carrier.

35. A drop device for data acquisition during fracing operations, the drop device comprising:

an obturation member adapted to at least one of actuatingly and sealingly engage with at least one downhole tool; and

at least one data acquisition device operatively coupled to said obturation member and adapted to detect at least one physical property.

36. The drop device according to claim **35**, wherein said obturation member is adapted to sealingly engage with a seat member of said downhole tool so as to prevent fluid communication through said downhole tool between a region inside the throughbore of the wellbore located uphole of said obturation member and a region inside the wellbore located downhole of said obturation member when in situ.

37. The drop device according to claim **35**, wherein said at least one data acquisition device is located uphole of said obturation member when in situ.

38. The drop device according to claim **35**, wherein said at least one data acquisition device is operatively coupled to said obturation member via a data acquisition device carrier removably mountable to said obturation member and adapted to accommodate said at least one data acquisition device.

39. The drop device according to claim **35**, further comprising a centralizing member operatively coupled to said at least one data acquisition device and adapted to at least one of centralize, fixate, and rotationally stabilize said at least one data acquisition device within the wellbore.

40. The drop device according to claim **39**, wherein said centralizing member is operatively coupled to said at least one data acquisition device via said data acquisition device carrier.

41. The drop device according to claim **39**, wherein said centralizer member comprises a plurality of spreading elements adapted to spread radially towards and in engagement with the inner wall of at least one of the wellbore and the drill string.

42. The drop device according to claim **35**, further comprising a flange member operatively coupled to said at least one data acquisition device and adapted to provide a contact surface for fluid flowing through the wellbore.

43. The drop device according to claim **42**, wherein said contact surface is selectively retractable so as to allow fluid flow between a region located uphole of said contact surface and a region located downhole of said contact surface.

44. The drop device according to claim **43**, wherein said contact surface comprises an uphole contact surface adapted to operatively engage with fluid flowing in an uphole direction, and a downhole surface adapted to operatively engage with fluid flowing in a downhole direction when in situ.

45. The drop device according to claim **42**, wherein said flange member is adapted to actuate said centralizing member.

46. The drop device according to claim **42**, wherein said flange member is adapted to slidingly actuate said centralizing member.

47. The drop device according to claim **35**, wherein said at least one data acquisition device comprises an integrated data storage device adapted to record a predetermined maximum amount of data.

48. The drop device according to claim **47**, wherein the at least one data acquisition device comprises a data interface adapted to permit download of at least part of said predetermined maximum amount of data to a remote data storage means.

49. The drop device according to claim **35**, wherein said data acquisition device is further adapted to transmit data to a remote location uphole of said downhole tool within the wellbore.

50. The drop device according to claim **35**, wherein said at least one data acquisition device is any one or all of a pressure data acquisition device, a temperature data acquisition device, a geophone, and a micro seismic sensor.

51. The drop device according to claim **42**, wherein said flange member is a wiper.

52. A method for acquiring data during fracing operations in a subterranean formation having a wellbore penetrating the formation, the method comprising:

(a) providing the drop device according to claim **35** at a predetermined location and in engagement with a predetermined downhole tool;

(b) initiating at least one data acquisition device of said downhole device for monitoring at least one physical property;

(c) closing a first fluid path for fluid communication through the downhole tool between a region inside the wellbore located uphole of said drop device and a region inside the wellbore located downhole of said drop device when in situ;

(d) initiating a fracing operation while monitoring said at least one physical property through at least one data acquisition device of said drop device; and

(e) recovering said monitored physical property after the fracing operation is completed.

53. The method according to claim **52**, wherein said drop device is recovered by fluid flowing uphole through at least one of the wellbore and the drill string and engaging with a contact surface of a flange member of said drop device.

54. The method according to claim **52**, wherein said drop device is recovered by running a milling device comprising at least one data acquisition device retrieval mechanism downhole inside a wellbore.

55. A frac plug comprising a downhole device according to claim **1**.

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