



- (51) **International Patent Classification:**
E21B 49/10 (2006.01) *E21B 47/00* (2012.01)
- (21) **International Application Number:**
PCT/US2011/042631
- (22) **International Filing Date:**
30 June 2011 (30.06.2011)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (71) **Applicant (for all designated States except US):** HAL-LIBURTON ENERGY SERVICES, INC. [US/US]; 10200 Bellaire Boulevard, Houston, Texas 77072 (US).
- (72) **Inventors; and**
- (75) **Inventors/Applicants (for US only):** VAN ZUILEKOM, Anthony, Herman [AU/US]; 9130 Tepee Trail, Houston, Texas 77064 (US). WILSON, Jim, Randall [US/US]; 609 Edgewood Drive, Montgomery, Texas 77356 (US).
- (74) **Agent:** MOSCICKI, Matthew, R.; Conley Rose, P.C., P. O. Box 3267, Houston, TX 77253-3267 (US).

(81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) **Title:** DOWNHOLE SAMPLE MODULE WITH AN ACCESSIBLE CAPTURED VOLUME ADJACENT A SAMPLE BOTTLE

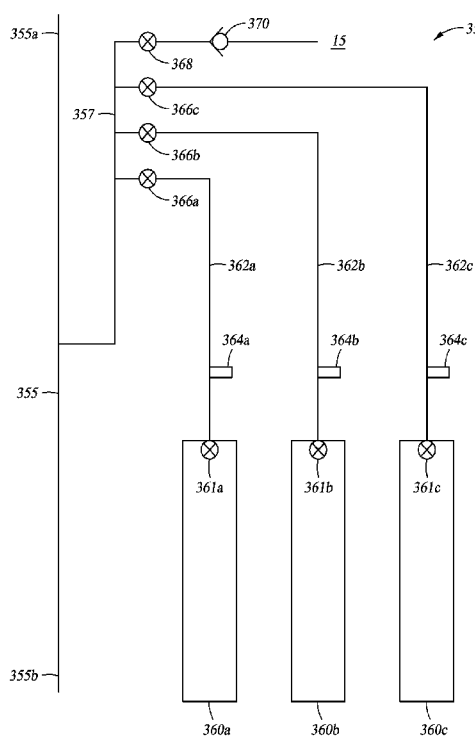


Fig. 7

(57) **Abstract:** Systems and methods for accessing a second or additional volume of sampled formation fluids identical to a first volume of formation fluids collected in a primary sample bottle during the downhole sampling process. The second volume can be accessed, extracted and analyzed without having to interfere with the first volume or the integrity of the primary sample. The second volume may be captured in a flowline coupled to the primary sample bottle and accessed using a secondary or mini-sample bottle.



Published:

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

DOWNHOLE SAMPLE MODULE WITH AN ACCESSIBLE CAPTURED VOLUME ADJACENT A SAMPLE BOTTLE

BACKGROUND

[0001] During the drilling and completion of oil and gas wells, it may be necessary to engage in ancillary operations, such as evaluating the production capabilities of formations intersected by the wellbore. For example, after a well or well interval has been drilled, zones of interest are often tested or sampled to determine various formation properties such as permeability, fluid type, fluid quality, formation temperature, formation pressure, bubblepoint and formation pressure gradient. When a formation is sampled, a formation fluid or other material is drawn into the formation tester and captured for later analysis. These tests are performed in order to determine whether commercial exploitation of the intersected formations is viable and how to optimize production. The acquisition of accurate data from the wellbore is critical to the optimization of hydrocarbon wells. This wellbore data can be used to determine the location and quality of hydrocarbon reserves, whether the reserves can be produced through the wellbore, and for well control during drilling operations.

[0002] Downhole fluid sampling is conducted to obtain representative fluid and gas samples in sample chambers of the downhole formation tester tool. Then, the samples can be removed to the surface and analyzed in Pressure-Volume-Temperature (PVT) laboratories to perform chemical and gas composition analysis. It is important that the formation fluid samples be stored in containers and maintained under conditions that retain the composition of the original sample over time. However, the time it takes to get a captured sample in a sample bottle chamber to the lab under the conditions the sample was taken is undesirably long. Therefore, there remains a need for a sample module including a readily available sample volume for efficient and flexible testing. The principles of the present disclosure overcome the limitations of the prior art.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] For a detailed description of exemplary embodiments of the invention, reference will now be made to the accompanying drawings in which:

[0004] Figure 1 is a schematic view, partly in cross-section, of a drilling apparatus with a formation tester;

[0005] Figure 2 is a schematic view, partly in cross-section, of a formation tester conveyed by wireline;

[0006] Figure 3 is a schematic view, partly in cross-section, of a formation tester disposed on a wired drill pipe connected to a telemetry network;

- [0007] Figure 4 is a cross-section view of a section of wired drill pipe including a wired tool;
- [0008] Figure 5 is a side view, partly in cross-section, of a drill collar including a formation probe assembly;
- [0009] Figure 6 is a schematic view of a formation fluid sampling assembly in accordance with principles disclosed herein;
- [0010] Figure 7 is a schematic view of a formation fluid sampling assembly with a captured volume of sample fluid in accordance with principles disclosed herein;
- [0011] Figure 8 is a schematic view of a captured sample volume adjacent a sample bottle in a first position in accordance with principles disclosed herein;
- [0012] Figure 9 is a schematic view of a captured sample volume adjacent a sample bottle in a second position in accordance with principles disclosed herein;
- [0013] Figure 10 is a flow chart of a method for analyzing a sample of formation fluid including directing a portion of the formation fluid flow into a secondary sample bottle removeable from the flowline separately from a primary sample bottle;
- [0014] Figure 11 is a flow chart of another method for analyzing a sample of formation fluid including directing a portion of the formation fluid flow into a secondary sample bottle for analysis independent of a primary sample bottle fluid analysis; and
- [0015] Figure 12 is a flow chart of further methods for capturing a secondary formation fluid volume to be tested and analyzed separate from a primary formation fluid volume.

DETAILED DESCRIPTION

[0016] In the drawings and description that follow, like parts are typically marked throughout the specification and drawings with the same reference numerals. The drawing figures are not necessarily to scale. Certain features of the disclosure may be shown exaggerated in scale or in somewhat schematic form and some details of conventional elements may not be shown in the interest of clarity and conciseness. The present disclosure is susceptible to embodiments of different forms. Specific embodiments are described in detail and are shown in the drawings, with the understanding that the present disclosure is to be considered an exemplification of the principles of the disclosure, and is not intended to limit the disclosure to that illustrated and described herein. It is to be fully recognized that the different teachings of the embodiments discussed below may be employed separately or in any suitable combination to produce desired results.

[0017] In the following discussion and in the claims, the terms “including” and “comprising” are used in an open-ended fashion, and thus should be interpreted to mean “including, but not limited to ...”. Unless otherwise specified, any use of any form of the terms “connect”,

“engage”, “couple”, “attach”, or any other term describing an interaction between elements is not meant to limit the interaction to direct interaction between the elements and may also include indirect interaction between the elements described. Reference to up or down will be made for purposes of description with “up”, “upper”, “upwardly” or “upstream” meaning toward the surface of the well and with “down”, “lower”, “downwardly” or “downstream” meaning toward the terminal end of the well, regardless of the well bore orientation. In addition, in the discussion and claims that follow, it may be sometimes stated that certain components or elements are in fluid communication. By this it is meant that the components are constructed and interrelated such that a fluid could be communicated between them, as via a passageway, tube, or conduit. Also, the designation “MWD” or “LWD” are used to mean all generic measurement while drilling or logging while drilling apparatus and systems. The various characteristics mentioned above, as well as other features and characteristics described in more detail below, will be readily apparent to those skilled in the art upon reading the following detailed description of the embodiments, and by referring to the accompanying drawings.

[0018] Referring initially to Figure 1, a drilling apparatus including a formation tester is shown. A formation tester 10 is shown enlarged and schematically as a part of a bottom hole assembly 6 including a sub 13 and a drill bit 7 at its distal most end. The bottom hole assembly 6 is lowered from a drilling platform 2, such as a ship or other conventional land platform, via a drill string 5. The drill string 5 is disposed through a riser 3 and a well head 4. Conventional drilling equipment (not shown) is supported within a derrick 1 and rotates the drill string 5 and the drill bit 7, causing the bit 7 to form a borehole 8 through formation material 9. The drill bit 7 may also be rotated using other means, such as a downhole motor. The borehole 8 penetrates subterranean zones or reservoirs, such as reservoir 11, that are believed to contain hydrocarbons in a commercially viable quantity. An annulus 15 is formed thereby. In addition to the formation tester 10, the bottom hole assembly 6 contains various conventional apparatus and systems, such as a down hole drill motor, a rotary steerable tool, a mud pulse telemetry system, MWD or LWD sensors and systems, and others known in the art.

[0019] In some embodiments, and with reference to Figure 2, a formation testing tool 60 is disposed on a tool string 50 conveyed into the borehole 8 by a cable 52 and a winch 54. The testing tool includes a body 62, a sampling assembly 64, a backup assembly 66, analysis modules 68, 84 including electronic devices, a flowline 82, a battery module 65, and an electronics module 67. The formation tester 60 is coupled to a surface unit 70 that may include an electrical control system 72 having an electronic storage medium 74 and a control processor

76. In other embodiments, the tool 60 may alternatively or additionally include an electrical control system, an electronic storage medium and a processor.

[0020] Referring to Figure 3, a telemetry network 100 is shown. A formation tester 120 is coupled to a drill string 101 formed by a series of wired drill pipes 103 connected for communication across junctions using communication elements. It will be appreciated that work string 101 can be other forms of conveyance, such as wired coiled tubing. The downhole drilling and control operations are interfaced with the rest of the world in the network 100 via a top-hole repeater unit 102, a kelly 104 or top-hole drive (or, a transition sub with two communication elements), a computer 106 in the rig control center, and an uplink 108. The computer 106 can act as a server, controlling access to network 100 transmissions, sending control and command signals downhole, and receiving and processing information sent up-hole. The software running the server can control access to the network 100 and can communicate this information via dedicated land lines, satellite uplink 108), Internet, or other means to a central server accessible from anywhere in the world. The formation tester 120 is shown linked into the network 100 just above the drill bit 110 for communication along its conductor path and along the wired drill string 101.

[0021] The formation tester 120 may include a plurality of transducers 115 disposed on the formation tester 120 to relay downhole information to the operator at surface or to a remote site. The transducers 115 may include any conventional source/sensor (e.g., pressure, temperature, gravity, etc.) to provide the operator with formation and/or borehole parameters, as well as diagnostics or position indication relating to the tool. The telemetry network 100 may combine multiple signal conveyance formats (e.g., mud pulse, fiber-optics, acoustic, EM hops, etc.). It will also be appreciated that software/firmware may be configured into the formation tester 120 and/or the network 100 (e.g., at surface, downhole, in combination, and/or remotely via wireless links tied to the network).

[0022] Referring briefly to Figure 4, sections of wired drill pipe 103 are enlarged for clarity. The wired drill pipe 103 includes conductors 150 that traverse the entire length of the pipe sections. Communication elements 155 allow the transfer of power and/or data between the pipe sections 103. A data/power signal may be transmitted along a pipe section of the wired drill string, such as the pipe section with formation tester 120 (Figure 3), from one end through the conductor(s) 150 to the other end across the communication elements 155. In some embodiments, the conductor(s) 150 comprise coaxial cables, copper wires, optical fiber cables, triaxial cables, and twisted pairs of wire. The conductor(s) 150 may be disposed through a hole formed in the walls of the outer tubular members of the pipes 103. The communication

elements 155 may comprise inductive couplers, direct electrical contacts, optical couplers, and combinations thereof. Portions of the wired drill pipes 103 may be subs or other connections means. The ends of subs or connections means of the wired subs 103 are configured to communicate within the downhole telemetry network 100.

[0023] Referring next to Figure 5, an embodiment of an MWD formation probe collar section 200 is shown in detail, which may be used as the tool 10 in Figure 1 or the tool 120 in Figure 3. A drill collar 202 houses the formation tester or probe assembly 210. The probe assembly 210 includes various components for operation of the probe assembly 210 to receive and analyze formation fluids from the earth formation 9 and the reservoir 11. An extendable probe member 220 is disposed in an aperture 222 in the drill collar 202 and extendable beyond the drill collar 202 outer surface, as shown. The probe member 220 is retractable to a position recessed beneath the drill collar 202 outer surface. The probe assembly 210 may include a recessed outer portion 203 of the drill collar 202 outer surface adjacent the probe member 220. The probe assembly 210 includes a draw down or piston accumulator assembly 208, a sensor 206, a valve assembly 212 having a flow line shutoff valve 214 and equalizer valve 216, and a drilling fluid flow bore 204. At one end of the probe collar 200, generally the lower end when the tool 10 is disposed in the borehole 8, is an optional stabilizer 230, and at the other end is an assembly 240 including a hydraulic system 242 and a manifold 244.

[0024] The piston assembly 208 includes a piston chamber 252 containing a piston 254 and a manifold 256 including various fluid and electrical conduits and control devices. The piston assembly 208, the probe 220, the sensor 206 (*e.g.*, a pressure gauge) and the valve assembly 212 communicate with each other and various other components of the probe collar 200, such as the manifold 244 and hydraulic system 242, as well as the tool 10 via conduits 224a, 224b, 224c and 224d. The conduits 224a, 224b, 224c, 224d include various fluid flow lines and electrical conduits for operation of the probe assembly 210 and probe collar 200.

[0025] Downhole formation fluid sampling allows representative fluid and gas samples to be moved to the surface in sample chambers, such as to be available for analysis in PVT laboratories apart from the well site. The PVT laboratory may perform chemical and gas compositional analysis, among other tests. Depending on how critical the downhole fluid information is to the well operation, the fluid sample may be rushed to the laboratory or opened on the well site to make basic measurements. These actions generally require additional, multiple, or redundant samples to be taken. The fluid samples should be substantially free of contamination for accurate analysis in the PVT laboratory. Contamination may include fluid introduced by the drilling process. As the drilling mud invades the formation, it becomes a

contaminant of the pristine formation fluids and is commonly called filtrate. Once a sample bottle is removed to the surface, analysis requires that it be opened so that the contained fluid can be tested. If the sample is tested at an offsite PVT laboratory, the time needed to transport the sample bottle and sample fluids to the PVT laboratory generally exceeds what is considered a reasonable time to wait on the well site (due to the high cost of well and rig time). Further, the ability to generate a high quality lab measurement requires the sample bottle to be heated and agitated for long periods of time to ensure that the fluid sample is at the sample chemical composition as when it was captured downhole.

[0026] Referring now to Figure 6, an embodiment of a formation tester tool string 300 is shown including certain principles disclosed herein. The formation tester tool string 300 comprises a series of subs or modules physically coupled and fluidically interconnected as will be described. An upper connector sub 302 provides a module for support of the formation tester and attachment to a conveyance above the formation tester. Coupled below the connector sub 302 is a sampling module 304 including multiple probes 338 for receiving formation fluids and a primary flowline 305 for transporting the formation fluids through the module. The sampling module also includes a piston 306 for drawings formation fluids into the probes 338. Coupled below the sampling module 304 is a first sensor module 310 including a primary flowline 315 coupled to the flowline 305, and a fluid sensor 312. Coupled below the first sensor module 310 is a second sensor module 320 including a primary flowline 325 coupled to the flowline 315, and a pressure sensor 322. Coupled below the second sensor module 320 is a pump module 330 including a pump 334, such as a dual action pump, and a primary flowline 335 having a check valve 332. The primary flowline 335 is coupled between the flowline 325 and a primary flowline 345 of a third sensor module 340 including another fluid or pressure sensor 342. Coupled below the third sensor module 340 is a sample bottle module 350 including a primary flowline 355 and multiple removeable sample bottles 360.

[0027] When the formation tester 300 is engaged and testing is begun, formation fluid enters the formation tester at probes 338 and passes through fluid sensors 312, 322 into the pump module 330. The flow path from the probes 338 to the inlet of the pump module 330 is at or below formation pressure if communication with the surrounding formation is established. The pump module 330 operates to draw fluid into the pump module, reducing the pressure further and then expelling the fluid into the flowlines 335, 345 at the outlet of the pump module. The fluid travels to the sensor 342 and is expelled through a purge valve in the sample bottle module 350. The formation fluids are generally pumped from the formation until the desired

minimum contamination is reached, at which time the formation fluids can be re-directed to the sample bottles 360 in the sample bottle module 350.

[0028] Referring now to Figure 7, an enlarged representation of the sample bottle module 350 is shown schematically, to illustrate several embodiments in accordance with the inventive principles disclosed herein. The primary flowline 355 extends from an upper portion 355a to a lower portion 355b in the module. The flowline portion 355a may be coupled to the outlet of the pump module 330, and in some embodiments fluid property measurements may be made as the fluid enters or exits in a pump up configuration wherein the fluid enters at 355b and exits at 355a. In other embodiments, the fluid property measurements may be made in a pump down configuration wherein the fluid enters at 355a and exits at 355b. A flowline 357 directs fluids between the primary flowline 355 and the sample bottles portion of the module 350. The flowline 357 includes a purge valve 368 and a check valve 370. If formation fluid samples are required by the sample bottle module 350, the purge valve 368 is opened at a beginning stage of the process to allow fluid to be expelled out of the check valve 370 into the surrounding borehole annulus 15.

[0029] The module 350 includes multiple removeable sample bottles. In some embodiments, three removeable sample bottles 360a, 360b, 360c are mounted in the sample bottle module 350. Each sample bottle includes a manual transport valve 361a, 361b, 361c on the inlet of each respective bottle. The transport valves 361a, 361b, 361c are used to isolate the bottle chambers such that the bottles can be removed from the sample bottle module 350 and transported safely to the PVT laboratory. The transport valves 361a, 361b, 361c are open during the downhole sampling process. A series of feeder flowlines 362a, 362b, 362c couple the sample bottles 360a, 360b, 360c into the flowline 357, and are equipped with ports or drain adapters 364a, 364b, 364c.

[0030] In the beginning stages of the sampling process, the pump module 330 will pass fluid through the flowlines 355, 357 towards the purge valve 368, which is open, and out the check valve 370 to the borehole annulus 15. If fluid samples are ready to be taken, and the operator decides a sample is to be acquired, one or more sample valves 366a, 366b, 366c are opened. Once opened, the sample valves 366a, 366b, 366c allow the flow of formation fluid to enter the sample bottles 360a, 360b, 360c along the flow paths through flowlines 362a, 362b, 362c. For example, if the target bottle is sample bottle 360a, the sample valve 366a is opened and the purge valve 368 is closed allowing substantially all of the fluid pumped from the pump module 330 to enter the sample bottle 360a through the flowline 362a and through the open transport valve 361a. After the sample bottle 360a is filled, the system is overpressured causing the

sample valve 366a to close and capturing the fluid sample in the sample bottle 360a and the flowline 362a. In various embodiments, the sampling operation will result in captured fluids from a single depth in the well or several depths, depending on the sampling job requirements. The formation testing tool is brought to the surface with first and primary sample volumes captured and isolated in sample bottles 360a, 360b, 360c by sample valves 361a, 361b, 361c, with additional second fluid sample volumes also captured in the flowlines 362a, 362b, 362c adjacent and leading into the sample bottles. The sample bottles 360a, 360b, 360c include basic, generic fluid chambers, but additional embodiments are also contemplated as will be described below, including sample chambers that can be referenced to hydrostatic pressure using a floating piston or a nitrogen buffer.

[0031] Referring now to Figure 8, an enlarged schematic representation of single removeable sample bottle 380a and associated flowline 362a is shown. The sample bottle 380a is slightly different from the sample bottle 360a, as will be described. For reference purposes, the sample bottle 380a is shown in the condition it would be after sampling and retrieval from the borehole. During the sampling process, the sample bottle 380a is filled and the formation fluid is captured in a chamber 378a. The fluid sample is isolated in the chamber 378a and the flowline 362a by the sample valve 366a. The sample bottle 380a also includes a nitrogen buffer having a piston 372a, 374a and a nitrogen filled chamber 376a. The nitrogen buffer 376a maintains the pressure of the sample in the chamber 378a and the flowline 362a at the downhole pressure existing during sampling. The charge of nitrogen reacts to the pressure and temperature of the sampling process to maintain that pressure during retrieval to the surface. When the sample module 350 is retrieved from the well to surface, the operator isolates the sample bottle chamber by closing a manual transport valve 381a to ensure the integrity of the formation fluid sample. The formation fluid sample is thereby sealed in the sample chamber 378a. If desired, the sample bottle 380a can then be safely removed from the sample module 350.

[0032] Upon closing the transport valve 381a to seal the primary formation fluid sample in the sample chamber 378a, an additional or secondary volume of formation fluid remains trapped or captured in the flowline 362a at the pressure at which the transport valve 381a is closed. The secondary volume of formation fluid is captured upstream of the transports valve 381a and the sample bottle 380a, or between the transport valve 381a and the sample valve 366a. Such a captured fluid sample volume has testing value. The adapter 364a (and adapters 364b, 364c of Figure 7) coupled into the flowline 362a can be used to access the captured formation fluid volume sealed in the flowline 362a. A secondary or smaller sample bottle

390a, also referred to as a mini-sample bottle, can now be coupled or attached to the drain adapter 364a to provide a fluidic coupling with the flowline 362a. This fluidic coupling can be used to extract fluid and gas from the flowline 362a for storage in the mini-sample bottle 390a. As shown in Figure 8, the fluidic coupling between the mini-sample bottle 390a and the flowline 362a is separate and apart from the fluidic coupling between the primary sample bottle 380a and the flowline 362a. In some embodiments, the mini-sample bottle 390a includes a vacuum filled chamber allowing fluid and gas to enter the chamber. In some embodiments, the mini-sample bottle 390a is a zero volume cylinder with a vacuum backed piston to allow fluid and gas to enter into the cylinder.

[0033] The drain adapter 364a may include manual or mechanical valves that will maintain pressure in the flowline 362a while also allowing the mini-sample bottle 390a to be connected thereto for retrieval of gas and liquids from the flowline 362a. Once the sample is retrieved or the bottle appropriately filled, the mini-sample bottle 390a can be removed from the flowline 362a, independently of the primary sample bottle 380a, such that the formation fluids therein can be tested and analyzed. Further, the flowline 362a is pressure-reduced to atmospheric such that the first or primary sample bottle 380a can safely be removed at any time thereafter and provided for PVT analysis.

[0034] In another embodiment, and still referring to Figure 8, the sample bottle assembly is retrieved to the surface of the borehole. A first or primary formation fluid sample volume is captured in the sample chamber 378a. Now, a pressure can be applied by an external pump to a port 385a to pressurize the piston 374a, which will then pressurize the nitrogen in the chamber 376a. The pressurized nitrogen acts against the piston 372a to increase the pressure of the formation fluids in the sample chamber 378a and the flowline 362a. Then, the sample chamber 378a is isolated by closing the manual transport valve 381a, thereby sealing the first or primary formation fluid sample volume. The pressurized formation fluid in the flowline 362a is a second formation fluid sample volume that is captured upstream of the transport valve 381a and the sample bottle 380a and downstream of the sample valve 366a. The captured second formation fluid sample can be separately accessed or vented by connecting the mini-sample bottle 390a via the adapter 364a at a location separate from the fluidic coupling of the primary sample bottle 380a, as previously described. The mini-sample bottle 390a can then be removed from the flowline 362a independently of the primary sample bottle 380a for testing and analysis.

[0035] Referring now to Figure 9, a schematic representation of another embodiment of a sample bottle assembly is shown. A first or primary sample bottle 460 is shown configured as

it is retrieved from the borehole, including a filled, standard sample chamber 478 having a single piston 472 and an isolating transport valve 461. The sample bottle 460 also includes a port 485. When the sample module 350 is retrieved from the borehole to the surface, the pressure of the formation fluid in the sample chamber 478 depends on the thermal coefficient of expansion of the fluid as well as the compressibility and pressure that was applied to the fluid before the sample valve 366a was closed. The pressure of the fluid in the chamber 478 is generally much lower than the pressure at the time of sampling from the formation. Consequently, an external pump may be coupled to the port 485 and used to apply pressure to the piston 472, which will then pressurize the formation fluids in the sample chamber 478 and the flowline 362a. The sample chamber 478 is then isolated by closing the manual transport valve 461 to seal the sample chamber 478 and ensure the integrity of the first or primary fluid sample volume in preparation for removal of the sample bottle 460 from the sample module 350. Prior to removal of the sample bottle 460, the second formation fluid volume captured in the flowline 362a between the valves 366a and 461 and upstream of the sample bottle 460, currently at the pressure applied by the pressure pump connected to the port 485, can be accessed or vented using the mini-sample bottle 390a and the adapter 364a, as previously described. The mini-sample bottle 390a is then removable for testing and analysis.

[0036] Still referring to Figure 9, certain components may be added to the sample bottle assembly to assess or monitor the integrity of the fluid transfer or venting to the mini-sample bottle 390a. For example, a sensor 491 is coupled to the mini-sample bottle 390a. In other embodiments, an additional or alternative sensor 493 is coupled to the drain adapter 364a. The sensors 491, 493, alternatively or in combination, are used to analyze the purity of the fluid transfer to the mini-sample bottle 390a such as by detecting any pressure loss or other exposure to ambient conditions during the transfer.

[0037] As will now be described, the several embodiments described above can be used in various processes to enable sampled formation fluids identical to those captured in the primary sample bottle during the downhole sampling process to be extracted and analyzed without having to interfere with the primary sample integrity. Further, the embodiments enable live or real-time formation fluid analysis at the well site without having to disturb the primary sample integrity in the main sample bottles. Alternatively, the embodiments allow easy and safe transport to a laboratory of a second volume of the sample formation fluids, using a sample container separate from the primary sample bottle. These and other processes and methods are now detailed more fully below.

[0038] Referring now to Figure 10, a method 500 for accessing and analyzing a formation fluid sample is detailed more fully. Initially, the method 500 includes drawing a formation fluid into a sample module and through a flowline, at 502, and flowing the formation fluid toward a sample bottle module, at 504. Next, the method 500 includes capturing a first formation fluid volume in a first sample bottle, at 506, and capturing a second formation fluid volume in the flowline, at 508. The method 500 then includes coupling a second sample bottle into the flowline to access the second formation fluid volume, at 510. The method 500 may further include re-directing at least a portion of the second formation fluid volume into the second sample bottle, at 512. In some embodiments, the re-directed portion of the second formation fluid volume is maintained in a single phase. The method 500 may further include removing the second sample bottle from the flowline independently of the first sample bottle, at 514. The method 500 may further include testing the second formation fluid volume in the second sample bottle independently of the first formation fluid sample in the first sample bottle, at 516. In some embodiments, testing the second formation fluid volume may include at least one of performing chemical composition analysis, performing gas composition analysis, acquiring a gas/oil ratio (GOR), or acquiring a live oil signature. The method 500 may further include removing the second sample bottle from the flowline and transporting the second sample bottle from a well site, at 518. In some embodiments, the method 500 may include collecting evolved gas from the second formation fluid volume in the second sample bottle. The method 500 may further include accessing the second sample bottle prior to accessing the first sample bottle, at 520.

[0039] In other embodiments, a method 600 for accessing and analyzing a formation fluid sample includes drawing a formation fluid into a sample module and through a flowline at 602, flowing the formation fluid toward a sample bottle module at 604, capturing a first formation fluid volume in a first sample bottle at 606, and capturing a second formation fluid volume in the flowline at 608. The method 600 further includes retrieving the sample module and the sample bottle module to the surface of a well at 610, applying pressure from an external source to the first sample bottle to increase the formation fluid pressure in the first sample bottle and the flowline at 612, closing a valve in the first sample bottle at 614, capturing the second formation fluid volume in the flowline at the increased pressure at 616, and coupling a second sample bottle into the flowline to access the second formation fluid volume at 618. The method 600 may further include maintaining the increased formation fluid pressure in the flowline using a drain adapter, then coupling the second sample bottle to the drain adapter to access and retrieve the increased formation fluid pressure from the flowline at 620.

[0040] In various embodiments described herein, a formation fluid sampling process includes capturing fluids in a sampling tool flowline and then accessing those fluids, independently of the primary sample fluid, while maintaining the fluids in a single phase. The fluids can then be transported and analyzed. In some embodiments, the fluids are contained and transported in a secondary sample bottle relative to the primary sample bottle. In some embodiments, the secondary sample bottle is smaller than the primary sample bottle, and thus may be referred to as a miniature or mini-sample bottle. The secondary formation fluid sample can then be tested or analyzed, independently of the primary formation fluid sample, to obtain characteristics of the formation fluid such as chemical or gas composition, gas/oil ratio (GOR), live oil signatures, and others. In some embodiments, the secondary formation fluid sample in the mini-sample bottle can be analyzed for argon, H₂S, CO₂, paraffins, and other substances.

[0041] In certain embodiments, the secondary or mini-bottle provides efficient and flexible access to formation fluids for testing and analysis separate from the formation fluids captured by the primary sample bottles. Now with reference to Figure 12, a method 700 includes capturing a second formation fluid volume in a flowline coupled to a primary sample bottle with a primary formation fluid volume at 702, and accessing and receiving the second formation fluid volume with a second formation fluid bottle coupled into the flowline at 704. In some embodiments, the method includes analyzing the second formation fluid volume at the wellsite or rigsite, at 706. In other embodiments, the method includes analyzing the second formation fluid volume at 708, and determining a quality of the primary formation fluid volume based on the second formation fluid volume analysis at 710. Thus, using the various embodiments described herein, preliminary analysis can be done on the secondary formation fluid samples such that quality control of the primary samples can be achieved.

[0042] Still referring to Figure 12, further embodiments of the method include analyzing a plurality of second formation fluid volumes each corresponding with a different primary sample bottle at 712, removing or replacing one or more of the primary sample bottles based on the second formation fluid volumes analyses at 714, and returning one or more primary sample bottles to the wellbore based on the second formation fluid volumes analyses at 716. Thus, the preliminary analysis and quality control aspects of testing the captured secondary formation fluid samples can be expanded. For example, the additional secondary samples gathered in the secondary mini-bottles can be pre-tested to determine whether expensive primary bottle testing is necessary for any given primary sample bottle. If a sample module includes primary sample bottles 1-5, and pre-tests of the corresponding secondary mini-bottles indicate that primary sample bottle 3 contains the best fluid sample for full testing, then primary sample bottle 3 can

be chosen for full testing while primary sample bottles 1, 2, 4, and 5 can be eliminated for testing thereby reducing costs. Furthermore, after analyzing the secondary samples, one or more primary bottles of interest for testing can be chosen for removal and/or replacement with empty primary bottles prior to returning the system back into the wellbore. In some embodiments, one or more of the primary bottles may simply be left coupled into the sample module before the system is returned to the wellbore. In still further embodiments, all of the primary sample bottles are removed and/or replaced after the secondary samples are removed and/or analyzed. In some embodiments, the pre-testing of the secondary mini-bottles allows analysis to be obtained more quickly, such that efficient decisions can be made about whether drilling should continue or whether a section of the reservoir should be produced.

[0043] The disclosure herein includes embodiments of an apparatus for accessing a formation fluid sample including a downhole sample bottle module including a formation fluid flowline coupled to a primary sample bottle, an adapter coupled into the formation fluid flowline, and a second sample bottle to couple to the adapter and communicate with the formation fluid flowline. In some embodiments, the coupling between the primary sample bottle and the flowline is separate and apart from the coupling at the adapter between the second sample bottle and the flowline. In some embodiments, the adapter seals the formation fluid flowline, and a transport valve seals the primary sample bottle such that the second sample bottle is connectable to and removable from the flowline independently of the primary sample bottle. In some embodiments, a fluid flow is established between the second sample bottle and the flowline while a primary formation fluid sample is contained in the primary sample bottle. The apparatus may include a transport valve to seal the primary sample bottle from the formation fluid flowline, and wherein the adapter is coupled into the formation fluid flowline upstream of the transport valve. The apparatus may include a sample valve upstream of the adapter to capture a second volume of formation fluid separated from the primary sample bottle by the transport valve.

[0044] In some embodiments, the apparatus may include a first fluid transfer sensor coupled to the second sample bottle, a second fluid transfer sensor coupled to the adapter, or a combination thereof. The apparatus may include a sample module including a formation probe to receive formation fluids and direct the formation fluids to the flowline.

[0045] In some embodiments, a method for accessing a formation fluid sample includes drawing a formation fluid into a sample module and through a flowline, flowing the formation fluid toward a sample bottle module and into a first sample bottle to capture a first formation fluid volume, capturing a second formation fluid volume in the flowline, and coupling a second

sample bottle into the flowline to access the second formation fluid volume. The method may include re-directing at least a portion of the second formation fluid volume into the second sample bottle. The method may include maintaining the re-directed portion of the second formation fluid volume in a single phase. The method may include removing the second sample bottle from the flowline independently of the first sample bottle. The method may include testing the second formation fluid in the second sample bottle independently of the first formation fluid sample in the first sample bottle. The method may include removing the second sample bottle from the flowline and transporting the second sample bottle from a well site. The method may include collecting evolved gas from the second formation fluid in the second sample bottle. The method may include accessing the second sample bottle prior to accessing the first sample bottle. The method may include, prior to coupling the second sample bottle into the flowline, retrieving the sample module and sample bottle module to the surface of a well, applying pressure from an external source to the first sample bottle to increase the formation fluid pressure in the first sample bottle and the flowline, closing a valve in the first sample bottle, and capturing the second formation fluid volume in the flowline at the increased pressure. The method may include maintaining the increased formation fluid pressure in the flowline using a drain adapter, then coupling the second sample bottle to the drain adapter to access and retrieve the increased formation fluid pressure from the flowline.

[0046] In some embodiments, a method for accessing a formation fluid sample includes capturing a second formation fluid volume in a flowline coupled to a primary sample bottle with a primary formation fluid volume, accessing the second formation fluid volume with a second sample bottle coupled into the flowline, and receiving the second formation fluid with the second sample bottle. In some embodiments, the capturing the second formation fluid volume in the flowline further includes drawing a formation fluid into a sampling tool and through the flowline, flowing the formation fluid into the primary sample bottle, and closing a primary sample bottle valve to capture the primary formation fluid volume and isolate the second formation fluid volume in the flowline. The method may include closing a sample valve upstream of the primary sample bottle valve to capture the second formation fluid volume in the flowline upstream of the primary sample bottle. The method may include analyzing the second formation fluid at a well site. The method may include analyzing the second formation fluid, and determining a quality of the primary formation fluid based on the second formation fluid analysis. The method may include analyzing a plurality of second formation fluid volumes each corresponding with a different primary sample bottle, and removing or replacing one or more of the primary sample bottles based on the second formation fluid analyses. The

method may include analyzing a plurality of second formation fluid volumes each corresponding with a different primary sample bottle, and returning one or more of the primary sample bottles to the wellbore based on the second formation fluid analyses.

[0047] The embodiments set forth herein are merely illustrative and do not limit the scope of the disclosure or the details therein. It will be appreciated that many other modifications and improvements to the disclosure herein may be made without departing from the scope of the disclosure or the inventive concepts herein disclosed. For example, the secondary or mini-sample bottles described herein for accessing and receiving the captured secondary formation fluid volume may be other types of fluid containers and vehicles for receiving and/or transporting the formation fluids from the captured volume section of the formation fluid flowline leading into the primary sample bottle. Because many varying and different embodiments may be made within the scope of the inventive concept herein taught, including equivalent structures or materials hereafter thought of, and because many modifications may be made in the embodiments herein detailed in accordance with the descriptive requirements of the law, it is to be understood that the details herein are to be interpreted as illustrative and not in a limiting sense.

CLAIMS

What is claimed is:

1. An apparatus for accessing a formation fluid sample comprising:
 - a downhole sample bottle module including a formation fluid flowline coupled to a primary sample bottle;
 - an adapter coupled into the formation fluid flowline; and
 - a second sample bottle to couple to the adapter and communicate with the formation fluid flowline.
2. The apparatus of claim 1 wherein the coupling between the primary sample bottle and the flowline is separate and apart from the coupling at the adapter between the second sample bottle and the flowline.
3. The apparatus of claim 1 wherein the adapter seals the formation fluid flowline, and a transport valve seals the primary sample bottle such that the second sample bottle is connectable to and removable from the flowline independently of the primary sample bottle.
4. The apparatus of claim 1 wherein a fluid flow is established between the second sample bottle and the flowline while a primary formation fluid sample is contained in the primary sample bottle.
5. The apparatus of claim 1 further comprising a transport valve to seal the primary sample bottle from the formation fluid flowline, and wherein the adapter is coupled into the formation fluid flowline upstream of the transport valve.
6. The apparatus of claim 5 further comprising a sample valve upstream of the adapter to capture a second volume of formation fluid separated from the primary sample bottle by the transport valve.
7. The apparatus of claim 1 further including a first fluid transfer sensor coupled to the second sample bottle, a second fluid transfer sensor coupled to the adapter, or a combination thereof.
8. The apparatus of claim 1 further including a sample module including a formation probe to receive formation fluids and direct the formation fluids to the flowline.
9. A method for accessing a formation fluid sample comprising:
 - drawing a formation fluid into a sample module and through a flowline;
 - flowing the formation fluid toward a sample bottle module and into a first sample bottle to capture a first formation fluid volume;
 - capturing a second formation fluid volume in the flowline; and

coupling a second sample bottle into the flowline to access the second formation fluid volume.

10. The method of claim 9 further comprising re-directing at least a portion of the second formation fluid volume into the second sample bottle.
11. The method of claim 10 further comprising maintaining the re-directed portion of the second formation fluid volume in a single phase.
12. The method of claim 9 further comprising removing the second sample bottle from the flowline independently of the first sample bottle.
13. The method of claim 10 further comprising testing the second formation fluid in the second sample bottle independently of the first formation fluid sample in the first sample bottle.
14. The method of claim 9 further comprising removing the second sample bottle from the flowline and transporting the second sample bottle from a well site.
15. The method of claim 10 further comprising collecting evolved gas from the second formation fluid in the second sample bottle.
16. The method of claim 9 further comprising accessing the second sample bottle prior to accessing the first sample bottle.
17. The method of claim 9 further comprising, prior to coupling the second sample bottle into the flowline:
 - retrieving the sample module and sample bottle module to the surface of a well;
 - applying pressure from an external source to the first sample bottle to increase the formation fluid pressure in the first sample bottle and the flowline;
 - closing a valve in the first sample bottle; and
 - capturing the second formation fluid volume in the flowline at the increased pressure.
18. The method of claim 17 further comprising maintaining the increased formation fluid pressure in the flowline using a drain adapter, then coupling the second sample bottle to the drain adapter to access and retrieve the increased formation fluid pressure from the flowline.
19. A method for accessing a formation fluid sample comprising:
 - capturing a second formation fluid volume in a flowline coupled to a primary sample bottle with a primary formation fluid volume;
 - accessing the second formation fluid volume with a second sample bottle coupled into the flowline; and

receiving the second formation fluid with the second sample bottle.

20. The method of claim 19 wherein the capturing the second formation fluid volume in the flowline further comprises:

drawing a formation fluid into a sampling tool and through the flowline;

flowing the formation fluid into the primary sample bottle; and

closing a primary sample bottle valve to capture the primary formation fluid volume and isolate the second formation fluid volume in the flowline.

21. The method of claim 20 further comprising closing a sample valve upstream of the primary sample bottle valve to capture the second formation fluid volume in the flowline upstream of the primary sample bottle.

22. The method of claim 19 further comprising analyzing the second formation fluid at a well site.

23. The method of claim 19 further comprising analyzing the second formation fluid, and determining a quality of the primary formation fluid based on the second formation fluid analysis.

24. The method of claim 19 further comprising:

analyzing a plurality of second formation fluid volumes each corresponding with a different primary sample bottle; and

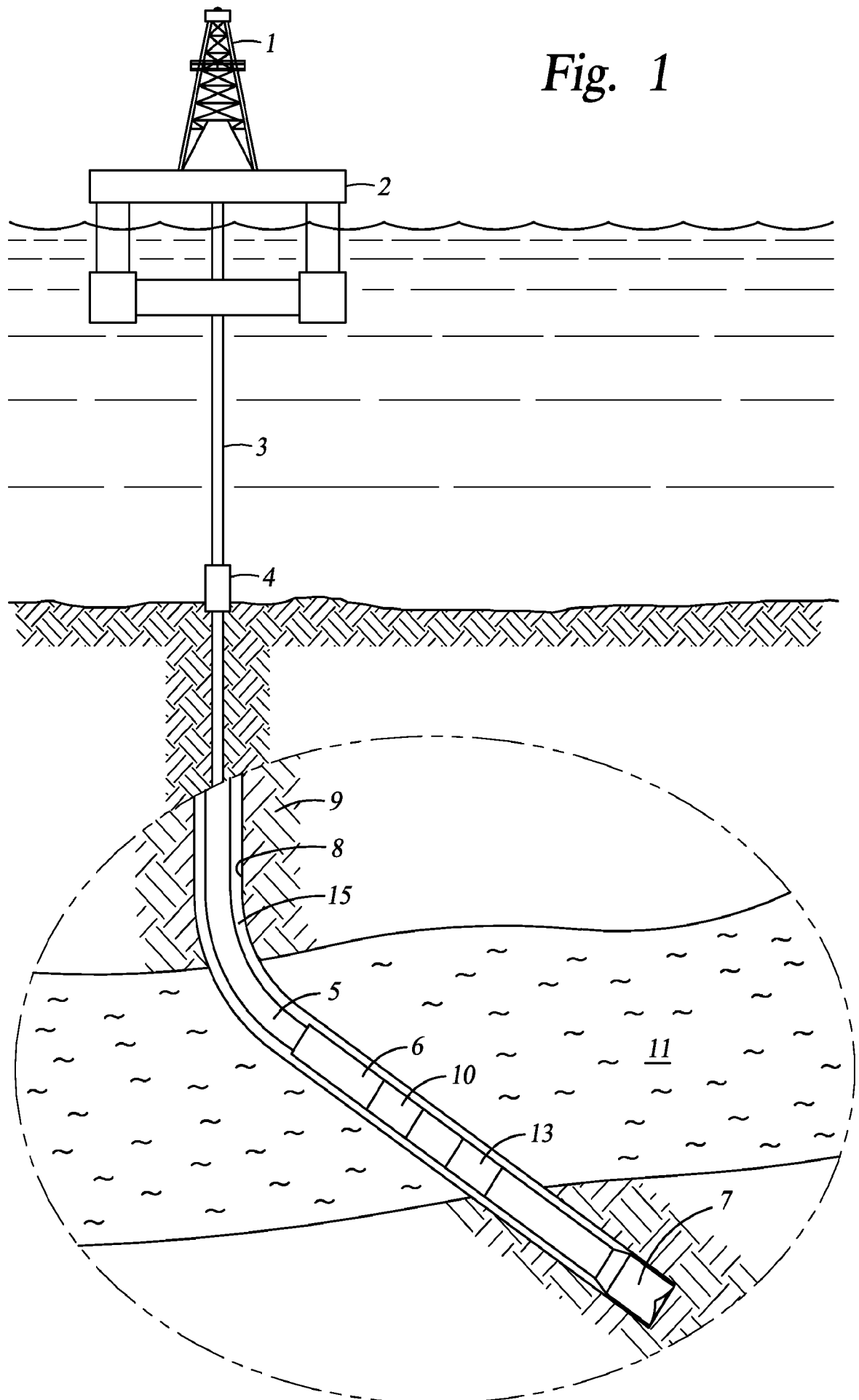
removing or replacing one or more of the primary sample bottles based on the second formation fluid analyses.

25. The method of claim 19 further comprising:

analyzing a plurality of second formation fluid volumes each corresponding with a different primary sample bottle; and

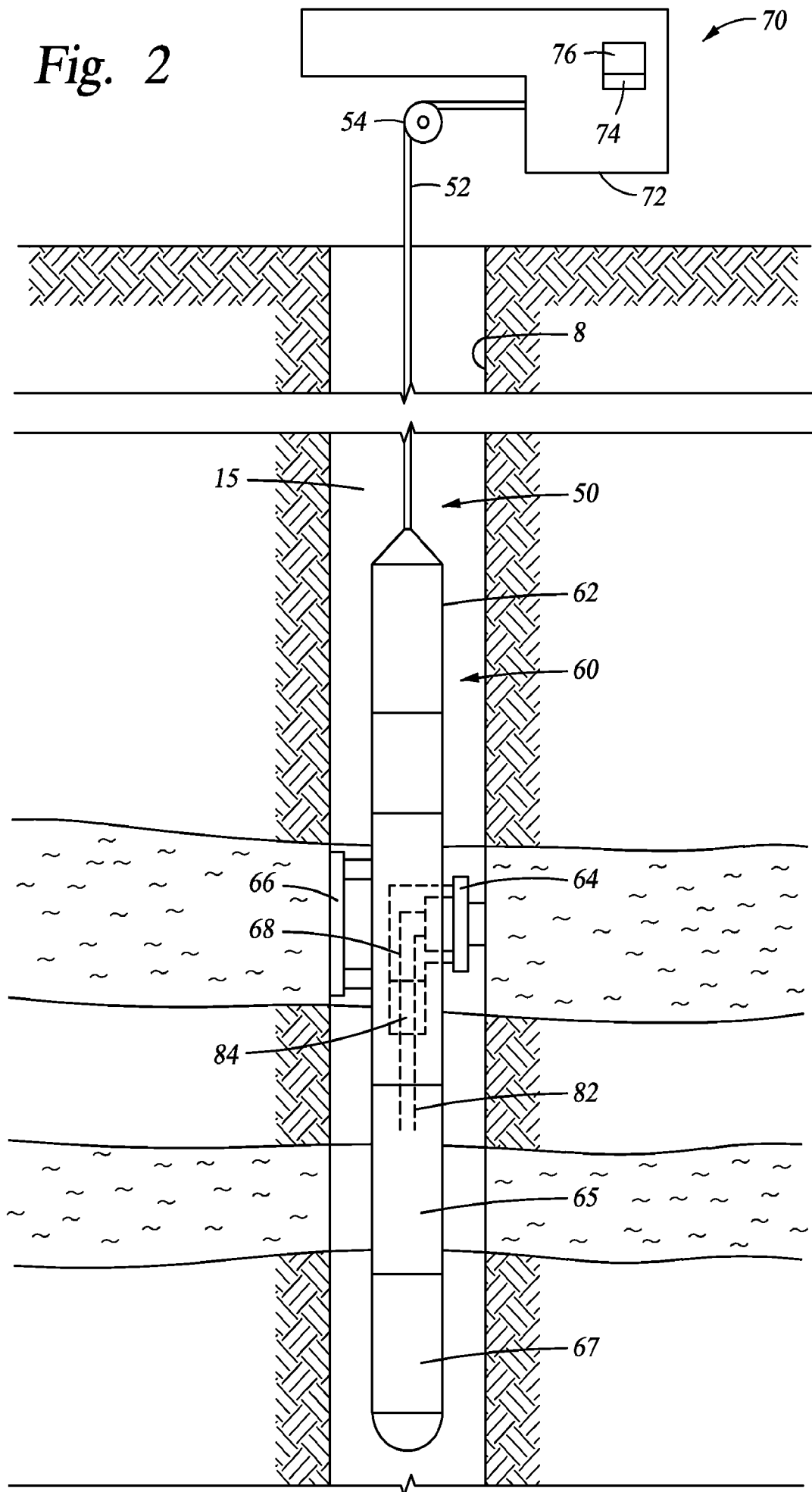
returning one or more of the primary sample bottles to the wellbore based on the second formation fluid analyses.

Fig. 1



2/11

Fig. 2



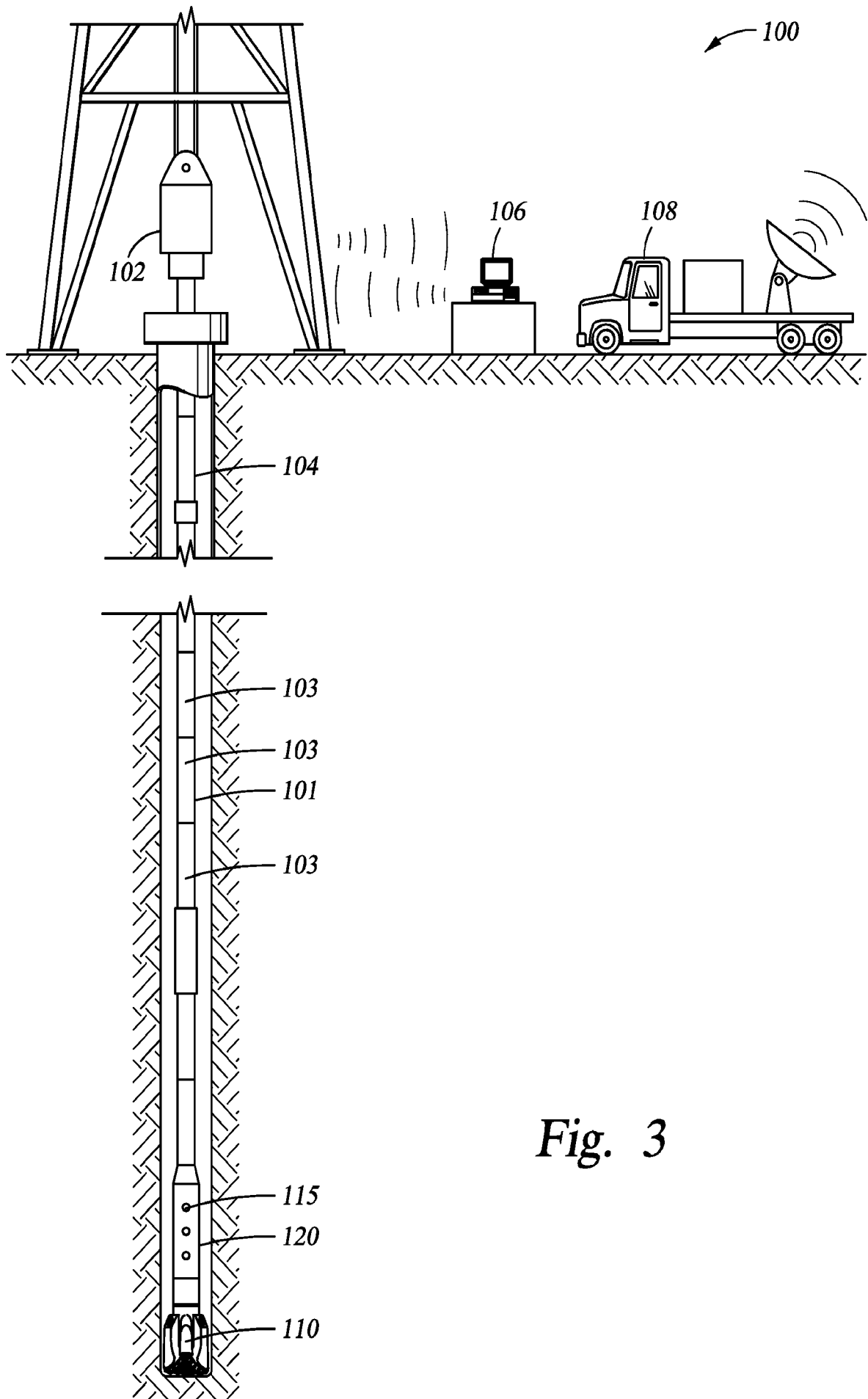
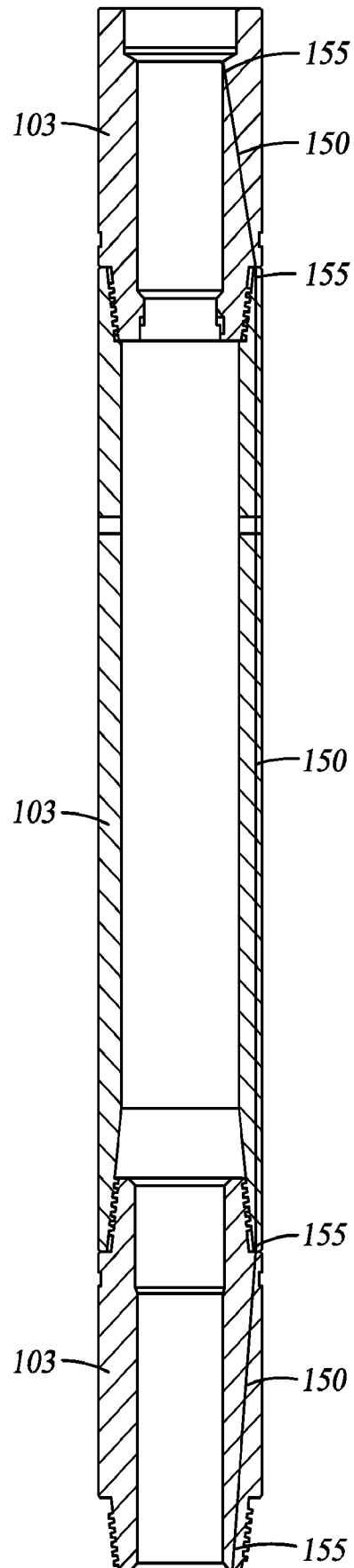
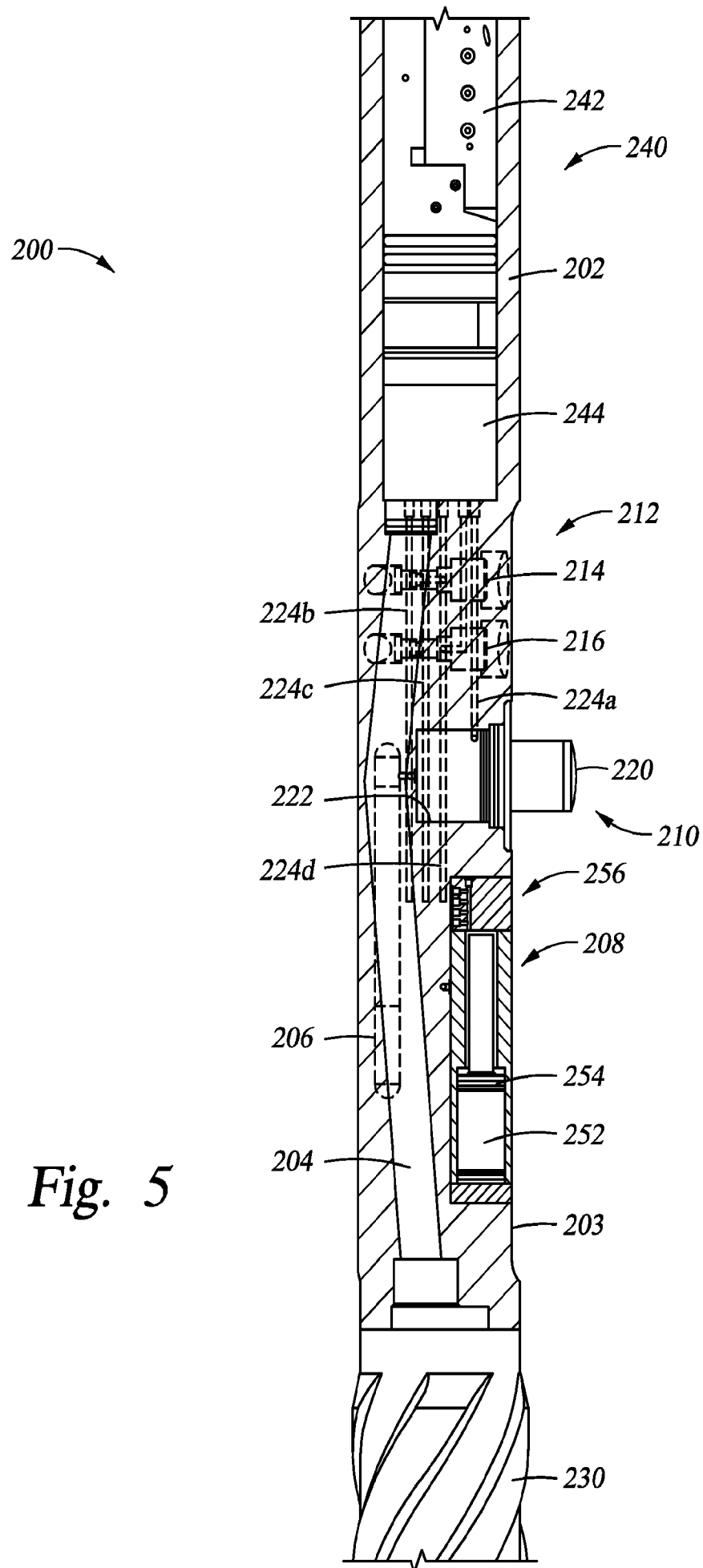


Fig. 3

Fig. 4





6/11

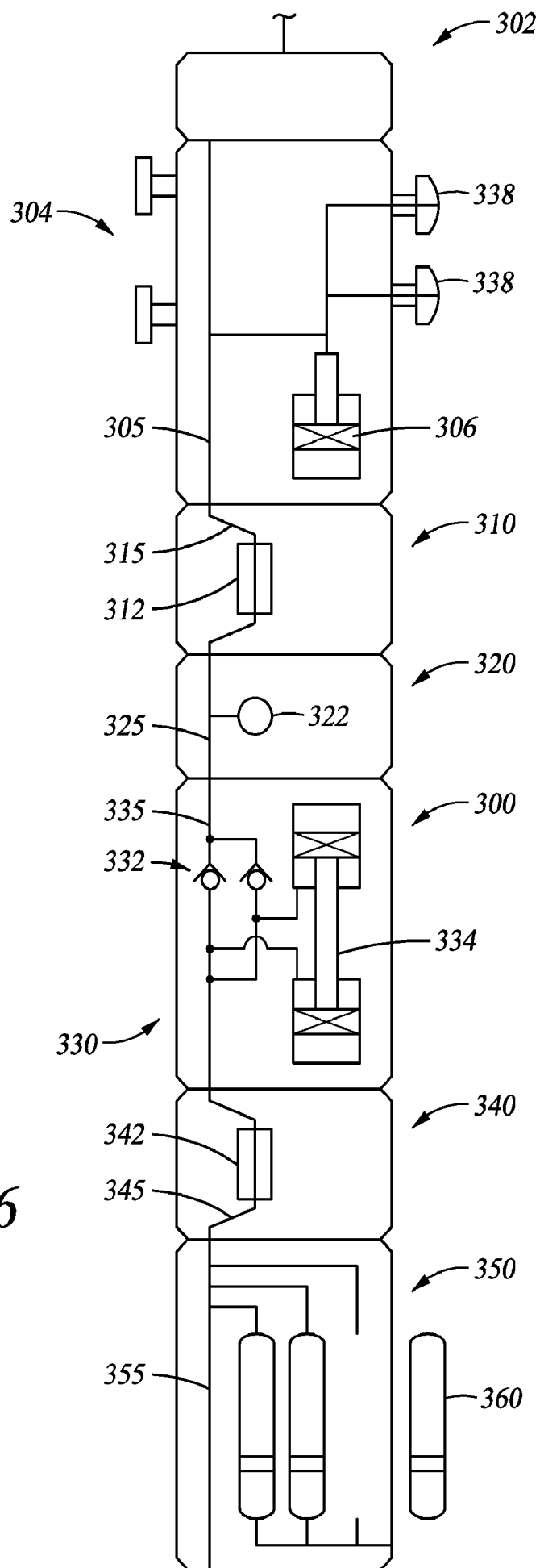
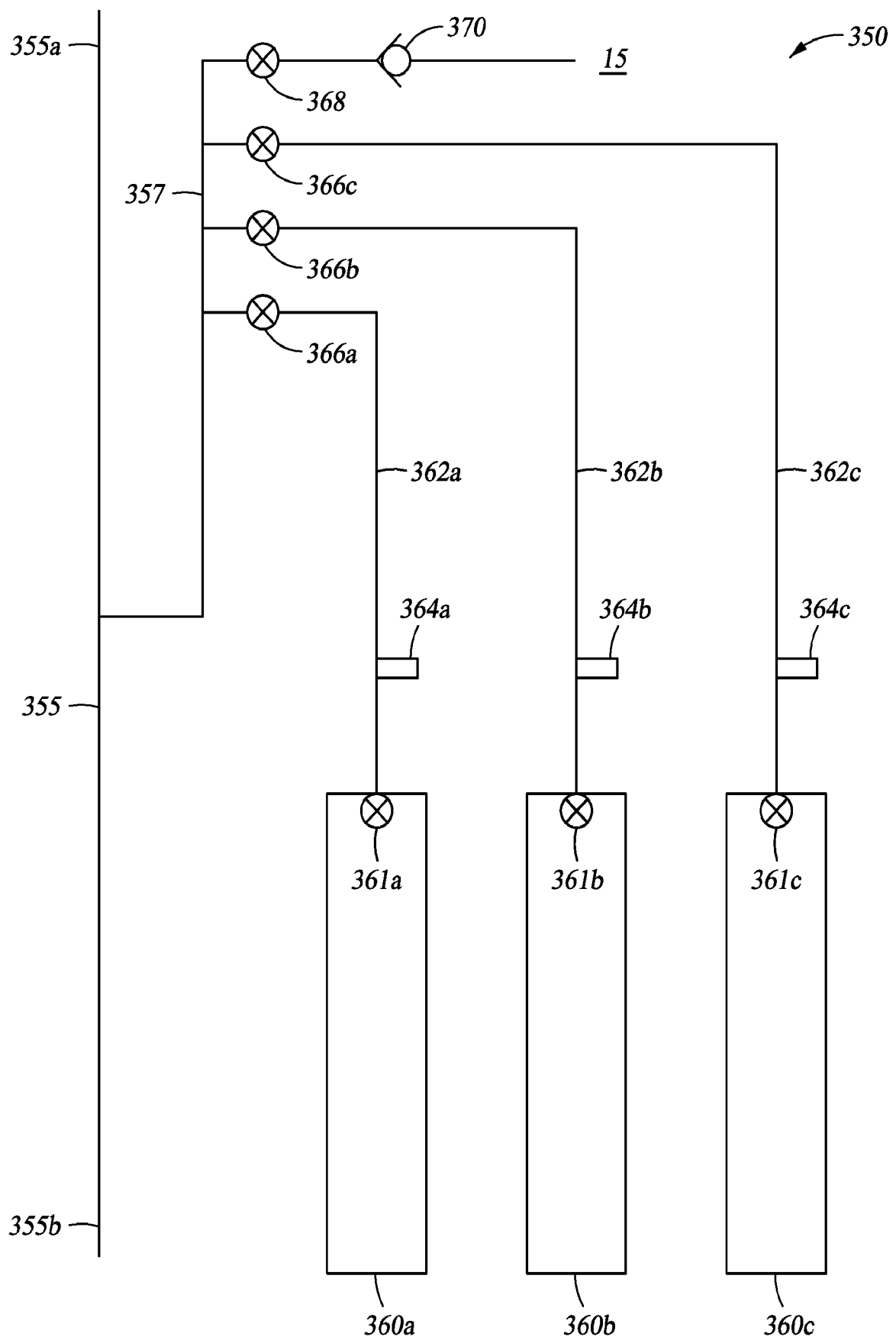


Fig. 6

**Fig. 7**

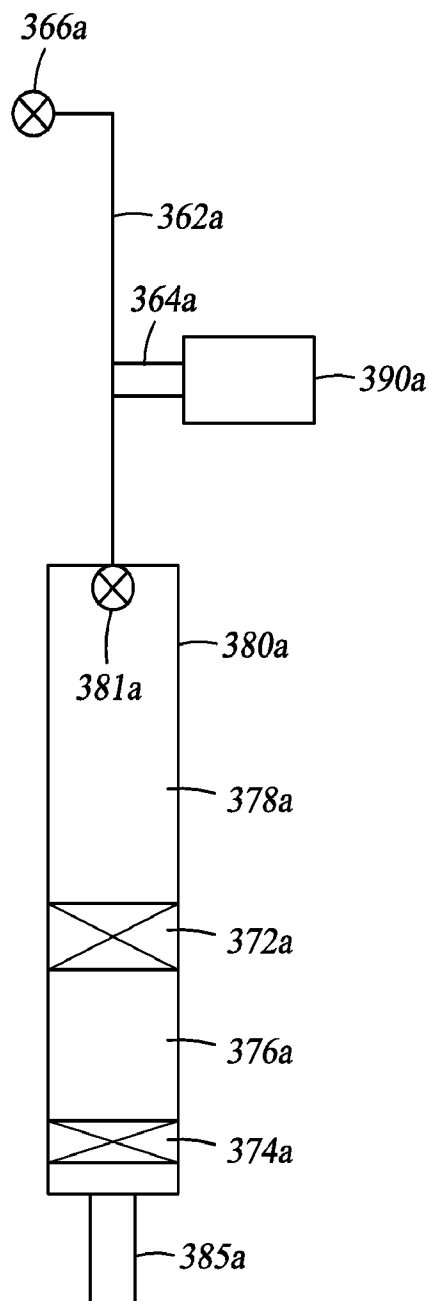


Fig. 8

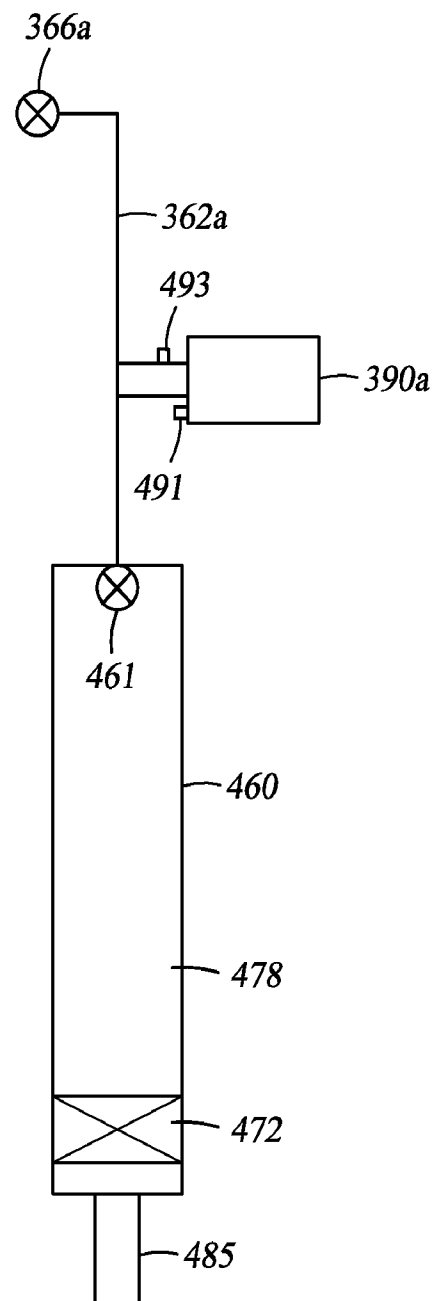
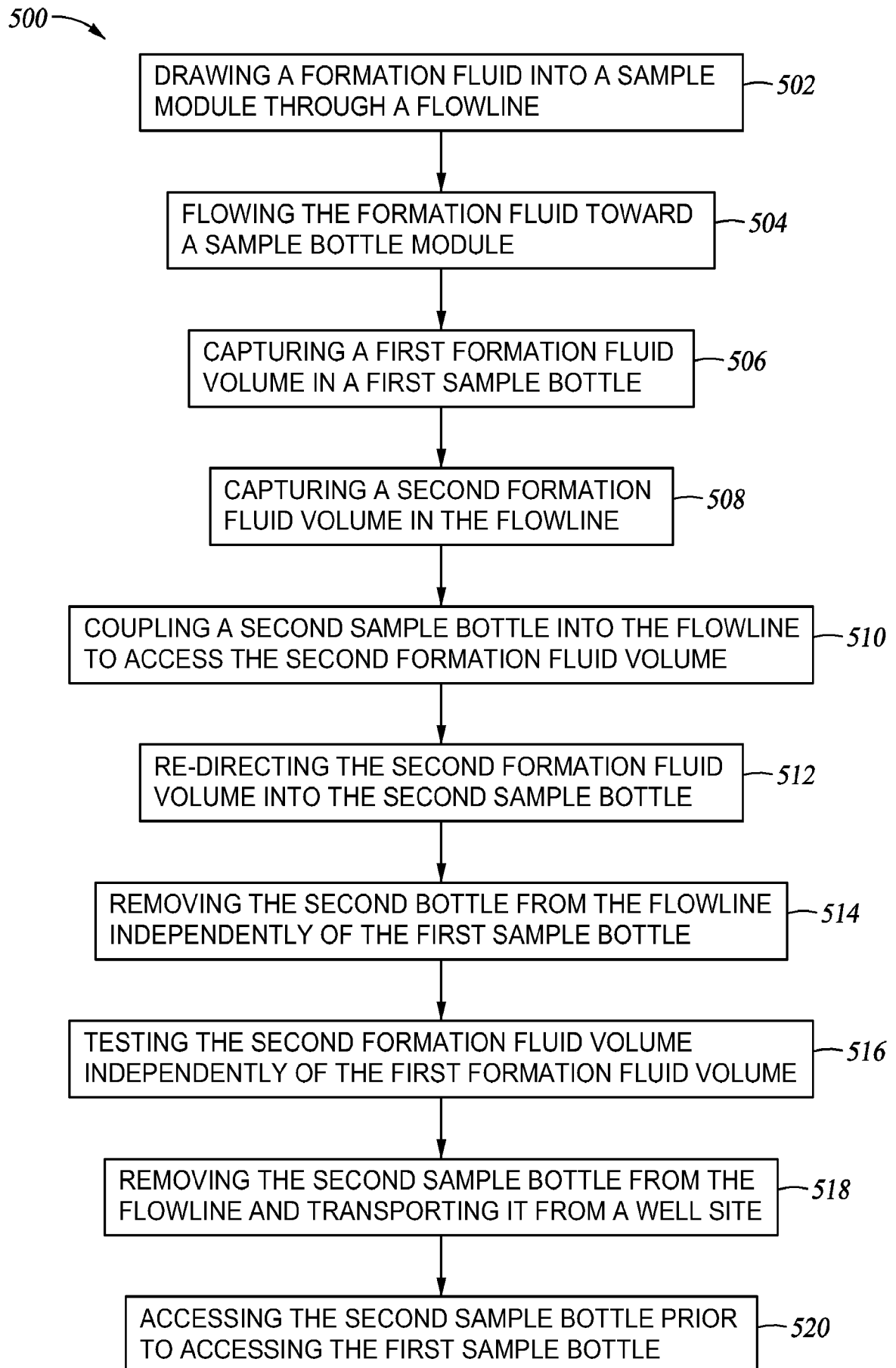
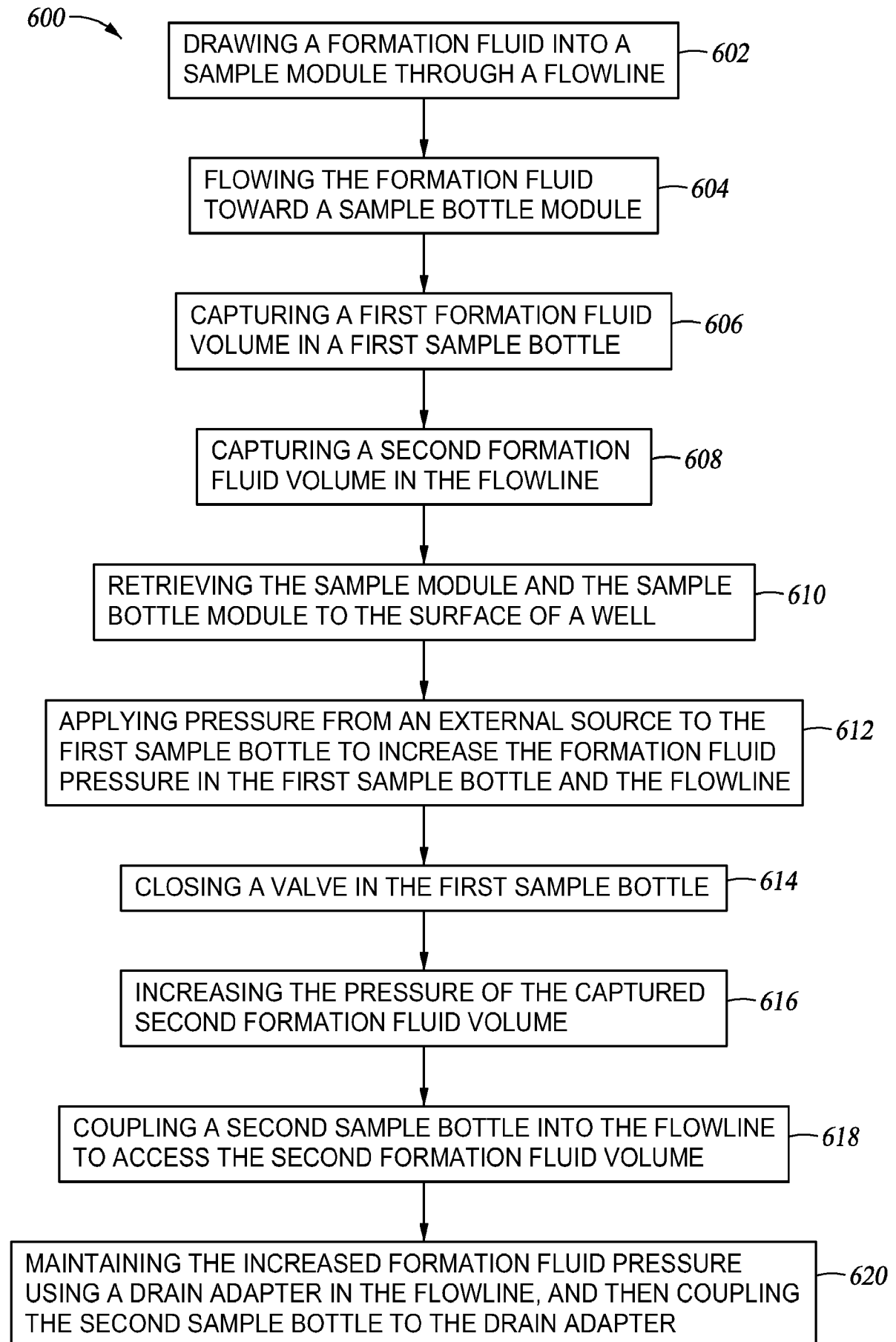
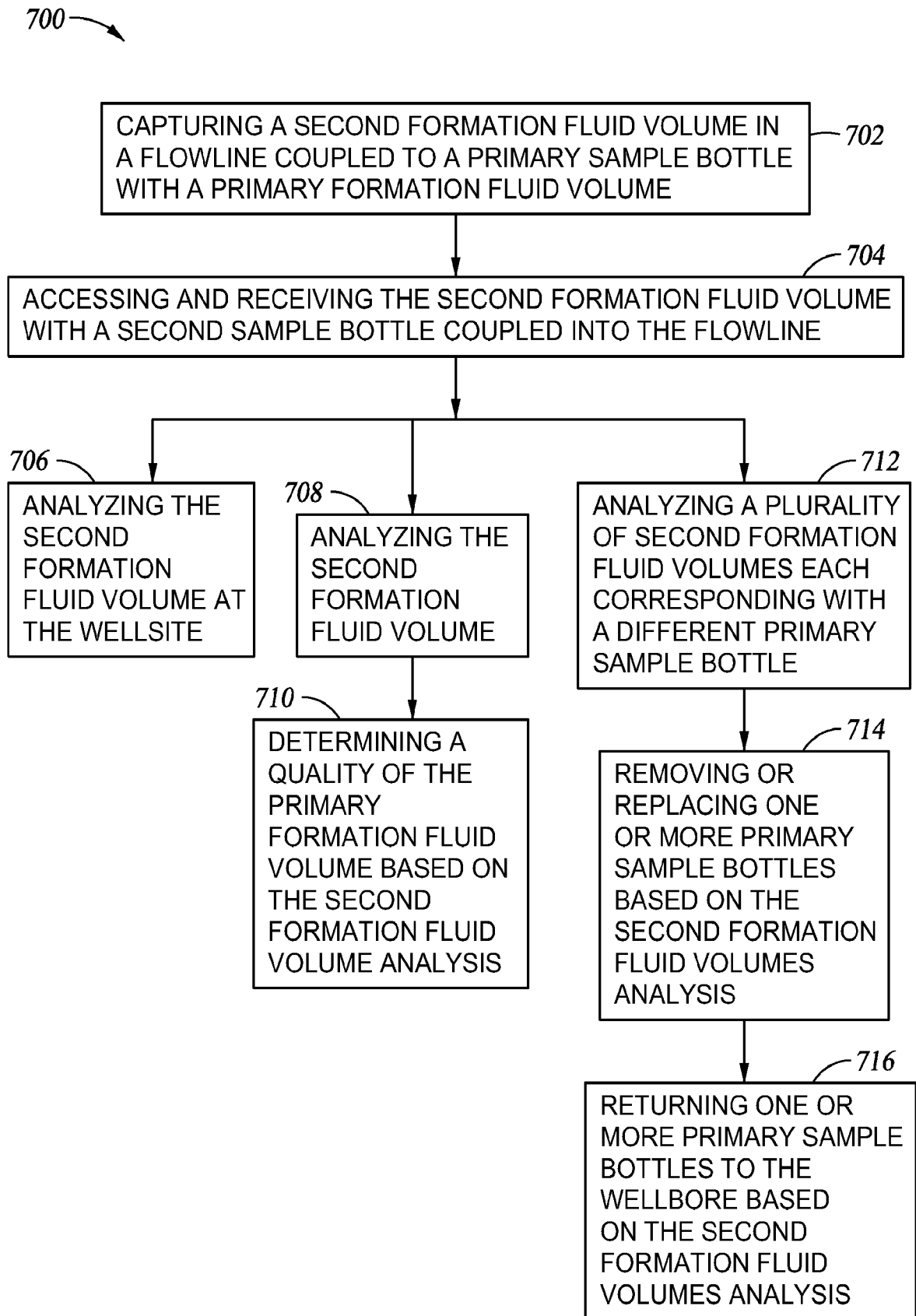


Fig. 9

*Fig. 10*

10/11

*Fig. 11*

*Fig. 12*

A. CLASSIFICATION OF SUBJECT MATTER***E21B 49/10(2006.01)i, E21B 47/00(2006.01)i***

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 49/10; E21B 49/00; E21B 49/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: formation test, sample, bottle, adapter

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6688390 B2 (BOLZE, VICTOR M. et al.) 10 February 2004 See column 9, lines 42-53; column 10, lines 27-61; column 14, lines 32-35; and figures 3, 10	1,2,4,8
A	US 7140436 B2 (GRANT, DOUGLAS W. et al.) 28 November 2006 See column 8, lines 37-52; and figure 3	1-25
A	US 2007-0137896 A1 (VILLAREAL, STEVEN G. et al.) 21 June 2007 See paragraphs 0057, 0059; and figure 3	1-25
A	US 2005-0082059 A1 (NOGUEIRA, MATHEUS et al.) 21 April 2005 See paragraphs 0036, 0037, 0048; and figures 2,8	1-25



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

31 JANUARY 2012 (31.01.2012)

Date of mailing of the international search report

09 FEBRUARY 2012 (09.02.2012)

Name and mailing address of the ISA/KR

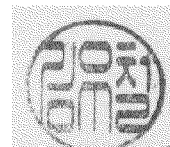
Korean Intellectual Property Office
Government Complex-Daejeon, 189 Cheongsa-ro,
Seo-gu, Daejeon 302-701, Republic of Korea

Facsimile No. 82-42-472-7140

Authorized officer

Kim Woo Chul

Telephone No. 82-42-481-8183



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2011/042631

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6688390 B2	10.02.2004	AU 2000-19543 A1	28.09.2000
		AU 2000-19543 B2	12.07.2001
		CA 2299835 A1	25.09.2000
		CA 2299835 C	13.07.2004
		CN 1191422 C0	02.03.2005
		CN 1269455 A0	11.10.2000
		GB 0005154 D0	26.04.2000
		GB 2348222 A	27.09.2000
		GB 2348222 B	24.10.2001
		N020001544A	26.09.2000
		N020001544D0	24.03.2000
		N0320827B1	30.01.2006
		US 2002-0060067 A1	23.05.2002
		US 2004-0129070 A1	08.07.2004
		US 7243536 B2	17.07.2007
US 7140436 B2	28.11.2006	US 2004-0216874 A1	04.11.2004
		US 2006-0054323 A1	16.03.2006
		US 7198105 B2	03.04.2007
US 2007-0137896 A1	21.06.2007	CA 2568342 A1	19.06.2007
		CA 2568342 C	12.01.2010
		CN 1987045 A	27.06.2007
		CN 1987045 C0	27.06.2007
		DE 102006059936 A1	28.06.2007
		FR 2895013 A1	22.06.2007
		GB 0623129 D0	27.12.2006
		GB 2433274 A	20.06.2007
		GB 2433274 B	17.12.2008
		GB 2469940 A	03.11.2010
		MX PA06013946A	09.10.2008
		RU 2006145002 A	27.06.2008
		RU 2416720 C2	20.04.2011
		US 2008-0087470 A1	17.04.2008
		US 2009-0126996 A1	21.05.2009
		US 2010-0170717 A1	08.07.2010
		US 2010-0170718 A1	08.07.2010
		US 2010-0326727 A1	30.12.2010
		US 7367394 B2	06.05.2008
		US 7845405 B2	07.12.2010
		US 8056625 B2	15.11.2011
		WO 2009-067440 A1	28.05.2009
US 2005-0082059 A1	21.04.2005	AU 2004-218736 A1	05.05.2005
		AU 2004-218736 B2	27.09.2007
		AU 2004-218736 B8	13.03.2008
		AU 2004-218736 B8	27.09.2007
		BR P10404453A	28.06.2005
		CA 2484688 A1	15.04.2005

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2011/042631Patent document
cited in search reportPublication
datePatent family
member(s)Publication
date

CA 2484688 C	15.01.2008
CN 100575663 C	30.12.2009
CN 1611745 A	04.05.2005
CN 1611745 C0	04.05.2005
FR 2861127 A1	22.04.2005
GB 0422574 D0	10.11.2004
GB 2407109 A	20.04.2005
GB 2407109 B	05.07.2006
MX PA04010048A	01.07.2005
N020044366A	18.04.2005
RU 2004129915 A	20.03.2006
RU 2373393 C2	20.11.2009
US 7195063 B2	27.03.2007