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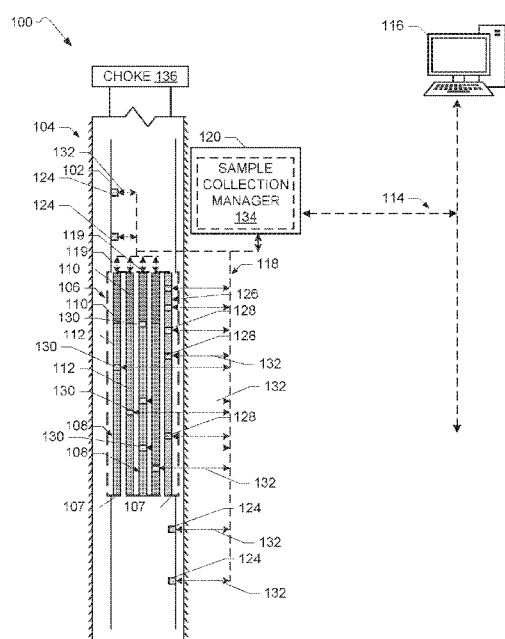


FIG. 1

(57) Abstract: Fluid sampling apparatus and related methods are disclosed herein. An example apparatus includes processor to implement a rules manager to access fluid data generated by a sensor disposed in a wellbore for fluid flowing in the wellbore. The processor is to analyze the fluid data relative to a rule and determine if the fluid data satisfies the rule. The processor of the example apparatus is to implement a communicator to generate an instruction for a sampling device disposed in the wellbore to collect the fluid if the fluid data satisfies the rule and transmit the instruction to the sampling device. The sampling device is to collect the fluid based on the instruction.

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FLUID SAMPLING APPARATUS AND RELATED METHODS

BACKGROUND

[0001] This disclosure relates generally to fluid sampling and, more particularly, to smart fluid sampling apparatus and related methods.

Description of the Related Art

[0002] Testing a well commonly involves collecting samples of formation fluids downhole and retrieving the samples at the surface for analysis. However, downhole fluid conditions may not be known at the surface and, thus, a decision of whether or not to collect fluid samples is often made without feedback of current downhole fluid conditions. Thus, in some examples, the fluid collected may be of poor quality or not representative of wellbore conditions of interest for testing.

[0003] Wireless acoustic telemetry includes transmission of acoustic signals via a network of repeater nodes that wirelessly receive and send messages included in the signals. One or more acoustic repeaters can interface with downhole equipment, such as a sensor, to transmit data between the surface and the equipment in the form of acoustic wave signals that are propagated across the repeater network via a propagation medium, such as a production pipe to which the repeater is coupled. In some examples, collection of the fluid samples can be selectively triggered based on acoustic commands sent from the surface to a downhole fluid sampling platform via an acoustic telemetry system. The fluid sampling platform can include a carrier holding one or more sampling devices. The sampling device(s) including inlet(s) that can be opened to collect the fluid via activation of a respective triggering mechanism (e.g., a rupture disk).

SUMMARY

[0004] Certain aspects of some embodiments disclosed herein are set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of certain forms the invention might take and that these aspects are not intended to limit the scope of the invention. Indeed, the invention may encompass a variety of aspects that may not be set forth below.

[0005] An example apparatus includes processor to implement a rules manager to access fluid data generated by a sensor disposed in a wellbore for fluid flowing in the wellbore. The processor is to analyze the fluid data relative to a rule and determine if the fluid data satisfies the rule. The processor of the example apparatus is to implement a communicator to generate an instruction for a sampling device disposed in the wellbore to collect the fluid if the fluid data satisfies the rule and transmit the instruction to the sampling device. The sampling device is to collect the fluid based on the instruction.

[0006] Another example apparatus includes a sensor disposed in a wellbore. The sensor is to generate fluid data for a fluid flowing in the wellbore. The example apparatus includes a sampling device disposed in a wellbore. The example apparatus includes a controller. In the example apparatus, the sensor and the sampling device are to be communicatively coupled to the controller. The controller is to selectively instruct the sampling device to one of collect the fluid or release the fluid from the sampling device based on the fluid data.

[0007] An example method includes accessing, by executing an instruction with a processor, fluid condition data for a fluid in a wellbore and sampling device status data for a sampling device disposed in the wellbore. The example method includes performing, by executing an instruction with the processor, a comparison of the fluid condition data to a predefined threshold. The example method includes generating, by executing an instruction with the processor, an instruction for the sampling device to collect the fluid or to refrain from collecting the fluid based on the comparison and the sampling device status data.

[0008] Various refinements of the features noted above may exist in relation to various aspects of the present embodiments. Further features may also be incorporated in these various aspects as well. These refinements and additional features may exist individually or in any combination. For instance, various features discussed below in relation to the illustrated embodiments may be incorporated into any of the above-described aspects of the present disclosure alone or in any combination. Again, the brief summary presented

above is intended just to familiarize the reader with certain aspects and contexts of some embodiments without limitation to the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 illustrates a first example system for collection of downhole fluid samples constructed in accordance with the teachings disclosed herein.

[0010] FIG. 2 is a block diagram of an example sample collection manager that may be used to implement the example system of FIG. 1.

[0011] FIG. 3 illustrates a first example sampling device constructed in accordance with the teaching disclosed herein that may be used with the example system of FIG. 1.

[0012] FIG. 4 illustrates a second example sampling device constructed in accordance with the teachings disclosed herein that may be used with the example system of FIG. 1.

[0013] FIG. 5 illustrates a third example sampling device constructed in accordance with the teachings disclosed herein that may be used with the example system of FIG. 1.

[0014] FIG. 6 is a flow diagram of an example method that may be executed to implement the example system of FIG. 1.

[0015] FIG. 7 is a diagram of a processor platform that may be used to carry out the example method of FIG. 6 and/or, more generally, to implement the example system of FIG. 1.

[0016] The figures are not to scale. Wherever possible, the same reference numbers will be used throughout the drawing(s) and accompanying written description to refer to the same or like parts.

DETAILED DESCRIPTION

[0017] It is to be understood that the present disclosure provides many different embodiments, or examples, for implementing different features of various embodiments. Specific examples of components and arrangements are described below for purposes

of explanation and to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting.

[0018] When introducing elements of various embodiments, the articles “a,” “an,” “the,” and “said” are intended to mean that there are one or more of the elements. The terms “comprising,” “including,” and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements. Moreover, any use of “top,” “bottom,” “above,” “below,” other directional terms, and variations of these terms is made for convenience, but does not mandate any particular orientation of the components.

[0019] Collecting formation fluid samples includes deploying sampling devices such as bottles near a fluid-producing formation to reduce pressure loss between the formation reservoir and the sampling location and to increase a likelihood of collecting fluid samples that are representative of downhole fluid conditions. For example, a well operator may wish to collect fluid samples that satisfy particular saturation pressure thresholds. In some examples, the sampling bottles are disposed downhole via a carrier that holds the bottles. Inlet valves of the bottles can be opened by triggering rupture disks that burst as a result of pressurization of an annulus of the well. In other examples, the inlet valves are selectively opened via a timer-based mechanical trigger that is programmed at the surface. However, the decision to open the valves and collect the sample may be based on, for example, prior knowledge of the well operator with respect to expected fluid conditions rather than actual downhole fluid conditions. In some examples, inadequate samples are not detected until the samples are brought to the surface, thereby resulting in operational inefficiencies.

[0020] In some examples, the operator may adjust (e.g., reduce) a size of a fluid flow control choke to decrease flow rate, provide for a signal phase flow, and/or increase bottomhole flow pressure and, thus, increase a likelihood of taking representative fluid samples that satisfy saturation pressure thresholds. However, such efforts may require

a separate sampling flow period at reduced flow rates for testing purposes, thereby disrupting downhole operations and increasing operational time and costs.

[0021] In some examples, wireline formation testing can include analyzing fluid following through a tester (e.g., Modular Formation Dynamics Tester™ produced by Schlumberger®) via one or more modules, such as an optical spectrometer to perform optical analysis. Optical fluid analysis and fluid resistivity measurements performed by the tester generates data about fluid composition and contamination that can be delivered to the surface via the wireline. Such data can be used to determine when to open the sampling devices to collect fluid representative of fluid in the reservoir.

[0022] Wireless telemetry enables communication between equipment disposed in a wellbore and the surface. Examples of wireless telemetry include acoustic telemetry or electromagnetic telemetry. In the context of fluid sample collection, wireless telemetry can be used to provide operational control of the sampling devices. For example, a valve of a bottle can be operated via an electromechanical actuator communicatively coupled to the wireless telemetry system.

[0023] Example apparatus, systems, and methods disclosed herein generate downhole fluid condition data and transmit the data to the surface via a downhole bi-directional telemetry system to enable decisions as to whether or not to collect fluid samples to be made in substantially real-time. In some disclosed examples, one or more sensors are deployed in production tubing and/or the sampling devices to generate fluid condition measurement data, such as fluid density data, fluid resistivity data, fluid viscosity data, etc. The sensor(s) interface with a downhole-to-surface telemetry system (e.g., a wired telemetry system or a wireless telemetry system) that transmits the data between downhole tools and the surface. Fluid condition data generated by the sensors can be analyzed to decide whether or not to collect fluid samples via one or more sampling devices disposed downhole. In some disclosed examples, the decision to collect fluid samples is made at the surface (e.g., by an operator). In other examples, the decision to collect fluid samples is made using a sampling decision feedback loop

implemented via one or more downhole controllers. The feedback loop can include one or more rules (e.g., algorithms) for controlling sample collection. In some examples, the decision by the downhole controller(s) to collect sample fluid is based on data received from the surface in addition to the rules implemented by the downhole controller(s).

[0024] In some disclosed examples, trigger(s) for the sampling device(s) disposed downhole are also interfaced with the telemetry system. Based on one or more instructions received from the surface and/or the downhole controller, the trigger(s) of the sampling devices can be activated to collect the fluid samples. In some examples, trigger(s) are controlled via instructions received via a wireless telemetry system.

[0025] Also disclosed herein are sampling devices (e.g., bottles) that can be selectively controlled to collect fluid or to release the fluid based on the fluid data generated by the sensors disposed in the sampling devices. In disclosed examples, the sampling devices can be used to collect fluid and/or release the fluid based on instructions generated at the surface and/or via the downhole controller(s). In some disclosed examples, the fluid is released or flushed from the sampling devices and the sampling devices re-collect fluid (e.g., new fluid, additional fluid). Thus, in examples disclosed herein, the sample fluids can be verified as adequate samples before the sampling devices are returned to the surface, thereby increasing an efficiency of the sample collection process.

[0026] In some disclosed examples, a decision is made at the surface to adjust a size of a choke and, therefore, the fluid flow rate, based on the data collected by the sensor(s). For example, the surface operator can adjust the choke size and flow rate and monitor the fluid condition data to determine saturation pressure of the fluid. Based on the monitoring of the fluid conditions after the adjustment to the choke, the operator can make a decision about sample collection and transmit the instructions for execution downhole. Thus, examples disclosed herein provide for sample collection decision-making based on analysis of substantially real-time fluid condition data.

[0027] Although examples disclosed herein are discussed in the context of communication the surface and between one or more fluid collection tools disposed in a wellbore, the examples disclosed herein can be implemented in other environments in which a telemetry system is used for communication with one or more tools.

[0028] FIG. 1 illustrates an example fluid sample collection system 100. The example system 100 includes production tubing 102 disposed in a wellbore 104. In the example system of FIG. 1, a sample carrier 106 is disposed in the production tubing 102. In some examples, the sample carrier 106 is in direct contact with formation fluid. The sample carrier 106 includes one or more slots 107 to receive one or more sampling devices 108 (e.g., bottles). The sample carrier 106 can include additional or fewer slots to hold additional or fewer sampling devices 108 than illustrated in the example of FIG. 1. In other examples, the sampling device(s) 108 are not disposed downhole via the sample carrier 106 but, instead, are disposed downhole as standalone device(s). The sampling device(s) 108 can be conveyed downhole such that the sampling device(s) 108 are disposed in fluid production flow. The sampling device(s) 108 can include, for example, a cushion to maintain a pressure of the sample substantially at or above reservoir pressure after the sample has been collected.

[0029] In the example of FIG. 1, each of the sampling devices 108 includes a trigger 110 that, when activated, enables a sampling device 108 to be selectively opened to collect fluid (e.g. formation fluid) in a sample holding portion 112 of the sampling device 108. The trigger 110 actuates or controls, for example, opening and closing of a valve of an inlet of the sampling device 108. In some examples, the trigger 110 includes one or more mechanical components such as a pin actuated by a motor to open the valve of the sampling device 108. In other examples, the trigger includes a rupture disk that is burst via pressure or a chemical explosion. As disclosed here, in the example system of FIG. 1, the trigger 110 for each of the sampling devices 108 can include an electromechanical actuator coupled to downhole telemetry system and controlled via an electrical signal. The example trigger(s) 110 of FIG. 1 provide for repeated openings and closings of the sampling device(s) 108. In some examples, the trigger(s) 110 selectively adjust a degree

to which the valve of the sampling device(s) 108 is opened to control, for example, a flow rate at which the fluid is collected. When the valve is open, fluid flows into the sample holding portion 112 via the inlet of the respective sampling devices 108.

[0030] The example system 100 of FIG. 1 includes a bi-directional telemetry system 114 that provides for communication between a processor 116 disposed outside the wellbore at the surface and one or more tools disposed in the wellbore 104. The telemetry system 114 can include wireless acoustic telemetry or electromagnetic telemetry. In other examples, the telemetry system 114 is wireline. In some examples, the telemetry system 114 communicates with two or more surface processors.

[0031] In the example of FIG. 1, each of the triggers 110 (e.g., the electromechanical actuators) of the sampling devices 108 is communicatively coupled to a tool bus 118, as represented by arrows 119 in FIG. 1. The tool bus 118 is communicatively to the telemetry system 114 via a downhole tool controller 120 (e.g., a processor). Although the example of FIG. 1 includes one tool controller 120, the example system 100 can include additional tool controllers 120 disposed downhole in the wellbore 104. For example, each tool controller 120 can be communicatively coupled to one or more sampling device(s) 108 via the tool bus 118.

[0032] In the example of FIG. 1, one or more instructions can be delivered from the surface processor 116 to the trigger(s) 110 via the telemetry system 114, the tool controller 120, and the tool bus 118. In other examples, the instruction(s) for the trigger(s) 110 are generated by the tool controller 120 and delivered by the tool controller 120 via the tool bus 118. The instructions can include, for example, an instruction for the trigger(s) 110 to open the valve(s) of the sampling device(s) 108 to allow the sampling device(s) 108 to collect fluid.

[0033] In the example of FIG. 1, a decision (e.g., made at the surface or by the tool controller 120) as to whether to instruct the trigger(s) 110 to enable the sampling device(s) 108 to collect fluid is based on substantially real-time fluid condition data generated downhole and transmitted to the surface processor 116 via the telemetry

system 114. The example system 100 of FIG. 1 includes one or more sensors disposed in the production tubing 102 to measure one or more properties of the fluid and generate the downhole fluid condition data. In some examples, the sensors are disposed in the sample carrier 106 and/or the sampling device(s) 108 (e.g., proximate to the trigger(s) 110, the sample holding portion(s) 112). In the example of FIG. 1, the data generated by the sensors in the production tubing is transmitted to a processor (e.g., the tool controller 120 and/or the surface processor 116) at a rate that exceeds a speed at which the fluid flows. Thus, in some examples, a decision can be made (e.g., at the surface) whether to collect the fluid before the fluid reaches the sampling device(s) 108.

[0034] For example, the system 100 of FIG. 1 includes a plurality of sensors 124 disposed in (e.g., coupled to) the production tubing 102 external to the sample carrier 106. The example system 100 of FIG. 1 can include additional or fewer sensors 124 disposed in the production tubing 102 external to the sample carrier 106. Position(s) of the sensor(s) 124 relative to the production tubing 102 can differ from that shown in FIG. 1.

[0035] The example system 100 of FIG. 1 includes a fluid sensing platform 126 disposed in the sample carrier 106. The fluid sensing platform 126 can be disposed in, for example, one of the sampling device receiving slots 107 of the sample carrier 106. Thus, in some examples, the fluid sensing platform 126 is disposed in a slot 107 of the sample carrier 106 instead of a sampling device 108. The fluid sensing platform 126 includes one or more sensors 128 disposed in (e.g., coupled to) the fluid sensing platform 126. The fluid sensing platform 126 can include additional or fewer sensors 128. Position(s) of the sensor(s) 128 relative to the fluid sensing platform 126 can differ from that shown in FIG. 1. The example of FIG. 1 can include additional fluid sensing platforms 126 disposed in the sample carrier 106. Position(s) of the fluid sensing platform(s) 126 can differ from that shown in FIG. 1.

[0036] In the example system 100 of FIG. 1, one or more of the sampling devices 108 includes one or more sensors 130. The sensor(s) 130 can be disposed in the sample

holding portion(s) 112 of the sampling device(s) 108. The sampling device(s) 108 can include additional sensors 130 beyond those illustrated in FIG. 1. In some examples, all of the sampling devices 108 include at least one sensor 130. In other examples, not all of the sampling devices 108 include sensor(s) 130. A position of a sensor 130 relative to a respective sampling device 108 can differ from that shown in FIG. 1. For example, a sampling device 108 can include a sensor 130 disposed proximate to an inlet of the sampling device 108. In some examples, the sensor(s) 130 are disposed proximate to the trigger(s) 110 of the sampling device(s) 108.

[0037] Although the example of FIG. 1 includes the sensor(s) 124 disposed in the production tubing 102 external to the sample carrier 106, the sensor(s) 128 disposed in the fluid sensing platform 126, and the sensor(s) 130 disposed in the sampling device(s) 108, in some examples, the system 100 includes fewer sensor(s) 124, 128, 130 and/or different combinations of sensor(s) 124, 128, 130. For example, as disclosed herein, in some examples, the sampling device(s) 108 are disposed in the production tubing 102 without the sample carrier 106. In such examples, the system 100 of FIG. 1 may include the sensor(s) 124 disposed in the production tubing 102 and the sensor(s) 130 disposed in the sampling device(s) 108 but not the fluid sensing platform 126. In other examples, the system 100 of FIG. 1 only includes the sensor(s) 128 disposed in the fluid sensing platform 126. The example system 100 can include other sensors and/or combinations of sensors 124, 128, 130 than illustrated in FIG. 1.

[0038] Examples of fluid properties measured by one or more of the sensors 124, 128, 130 include fluid composition, water cut, gas hold-up, fluid density, fluid viscosity, fluid compressibility, fluid resistivity, bubble detection, etc. Any of the respective sensors 124, 128, 130 can measure different fluid properties, the same fluid properties, or combination thereof (e.g., one of the sensors 124 coupled to the production tubing can measure a first fluid property and one of the sensors 128 of the fluid sensing platform 126 can measure a second fluid property different from the first fluid property). In examples where the sensor(s) 130 are disposed proximate to or at a respective inlet of the sampling device(s)

108, the fluid properties measured by the sensor(s) 130 can represent properties of the fluid sample that is collected by the sampling device(s) 108.

[0039] In some example, the sensor(s) 130 of the respective sampling device(s) 108 detect an operational status of the sampling device(s) 108, such as whether there is fluid disposed in the sample holding portion(s) 112 of the sampling device(s) 108. In some examples, a sampling device 108 includes a sensor 130 disposed proximate to a trigger 110 of the sampling device 108. In such examples, the sensor 130 detects a position of the trigger 110 and/or a position of a valve controlled by the trigger 110.

[0040] In the example system 100 of FIG. 1, the sensor(s) 124, 128, 130 are communicatively coupled to the tool controller 120 via the tool bus 118, as represented by arrows 132 in FIG. 1. The sensor(s) 124, 128, 130 are communicatively coupled to the telemetry system 114 and, thus, the surface processor 116 via the tool controller 120. In the example of FIG. 1, the fluid condition data generated by the sensor(s) 124, 128, 130 is transmitted to the tool controller 120 via the tool bus 118.

[0041] The example tool controller 120 includes a sample collection manager 134. The example sample collection manager 134 can perform one or more operations on the data generated by the sensor(s) 124, 128, 130 such as filtering the raw signal data, removing noise from the raw signal data, converting the signal data from analog to digital data, and/or analyzing the data. In some examples, the sample collection manager 134 of the tool controller 120 processes the data in substantially real-time as the data is received from the sensor(s) 124, 128, 130.

[0042] In some examples, the tool controller 120 transmits the fluid condition data to the surface processor 116 via the telemetry system 114 (e.g., in substantially real-time). The surface processor 116 can perform one or operations on the data, such as filtering the data, analyzing the data, outputting the data for display via an interface, etc. Based on the fluid condition data received and processed by the surface processor 116, an operator can decide whether or not the trigger(s) 110 of the sampling device(s) 108 should be activated to collect formation fluid.

[0043] If the operator decides to sample the fluid based on the downhole fluid condition data received by the surface processor 116, the operator can provide one or more instructions via the surface processor 116 directing the activation of the trigger(s) 110 to enable the sampling device(s) 108 to collect sample fluid. In the example system of FIG. 1, such instructions are transmitted from the surface processor 116 to the sample collection manager 134 of the tool controller 120 via the telemetry system 114 (e.g., wirelessly or via a wired connection). The sample collection manager 134 transmits the instructions to the trigger(s) 110 via the tool bus 118 (e.g., wirelessly or via a wired connection). Thus, the trigger(s) 110 can be triggered via instructions transmitted from the surface based on an analysis of substantially real-time fluid condition data.

[0044] In some examples, the operator may decide to adjust a size of a wellhead choke 136 based on the sensor data received at the surface to adjust the fluid flow rate, provide for a single phase flow in the reservoir, etc. In some such examples, the operator can monitor changes in the fluid condition data generated by the sensor(s) 124, 128, 130 and received at the surface processor 116 in response to the adjustment to the choke 136. Based on the data monitoring, the operator can determine saturation pressure, select a sampling condition for the fluid, adjust the flow rate, further adjust the choke 136, etc. In some examples, the saturation pressure measurements are used to calibrate fluid models for well test interpretation and reservoir simulation analysis.

[0045] In some examples, the surface processor 116 analyzes fluid conditions at the surface (e.g., based on surface fluid information from surface well testing) and presents the surface fluid condition data in addition to the downhole fluid condition data generated by the sensor(s) 124, 128, 130. In such examples, the operator can decide whether or not to collect fluid samples based on conditions of the fluid at the surface and/or downhole.

[0046] In some examples, the decision as to whether to collect sample fluid is made by the tool controller 120 based on the data generated by the sensor(s) 124, 128, 130 and one or more rules (e.g., algorithms) implemented by the sample collection manager

134 of the tool controller 120. Thus, in some examples, the decision as to whether to collect sample fluid can be made downhole via a feedback loop between the sensor(s) 124, 128, 130, the tool controller 120, and the trigger(s) 110 of the sampling device(s) 108 that are controlled by the tool controller 120. In some such examples, the operator may provide one or more instructions via the surface processor 116 that are used by the sample collection manager 134 of the tool controller 120 in the downhole decision-making. The user instructions can include, for example, modifications to one or more rules (e.g., parameters of the algorithms).

[0047] In the example system of FIG. 1, the sample collection manager 134 generates instruction(s) regarding the activation of the trigger(s) 110. The instructions are transmitted (e.g., wirelessly or via a wired connection) to the trigger(s) 110 via the tool bus 118. Based on the instruction(s) received from the sample collection manager 134, the trigger(s) 110 cause the sampling device(s) 108 to open and collect fluid or to close. The decision by the sample collection manager 134 to collect sample fluid can be made in substantially real-time based on the data received from the sensor(s) 124, 128, 130. In some examples, the decision by the sample collection manager 134 to collect sample fluid is based on previously collected fluid condition data (e.g., stored by the tool controller 120) and/or a combination of substantially real-time fluid condition data and previously collected fluid condition data.

[0048] The example tool controller 120 of FIG. 1 can control one or more of the sampling devices 108. In some examples, the system 100 includes at least two tool controllers 120. Each tool controller 120 is communicatively coupled to one or more different sampling devices 108 via the tool bus 118. Each of the tool controllers 120 is communicatively coupled to one or more of the sensor(s) 124, 128, 130 via the tool bus 118. Each of the tool controllers 120 can decide whether or not to activate the trigger(s) 110 of the respective sampling device(s) 108 with which the tool controllers 120 are associated based on the fluid condition data received from the sensor(s) 124, 128, 130 and one or more rules implemented by the respective tool controller(s) 120. In some examples, the at least two tool controllers 120 are communicatively coupled via the tool

bus 118 and communicate with one another regarding the selective opening or closing of the sampling devices 108.

[0049] FIG. 2 is a block diagram of the example sample collection manager 134 that may be implemented by the example tool controller 120 of FIG. 1. The example sample collection manager 134 implements one or more instructions received from the surface to control of one or more sampling devices (e.g., the sampling devices 108 of FIG. 1) disposed downhole in a wellbore (e.g., the wellbore 104 of FIG. 1). In some examples, the sample collection manager 134 automatically determines whether sample fluid should be collected based on the sensor data and one or more rules implemented by the sample collection manager 134. Although the example sample collection manager 134 of FIG. 2 is discussed in connection with the example downhole tool controller 120, one or more of the components of the example sample collection manager 134 could be implemented by one or more processors, including, for example, the surface processor 116 of FIG. 1.

[0050] The example sample collection manager 134 includes a database 200 to store signal data generated by one or more of the sensors 124, 128, 130 and transmitted to the sample collection manager 134 via the tool bus 118. The database 200 can be associated with, for example, a memory of the tool controller 120. The data can include fluid condition data 202 generated by the one or more sensor(s) 124, 128, 130. The fluid condition data 202 can include measurements with respect to fluid properties such as density, viscosity, resistivity, etc. In some examples, the database 200 of the sample collection manager 134 stores sampling device status data 204 regarding an operational state of the sampling devices 108 and generated by the one or more sensor(s) 124, 128, 130. The sampling device status data 204 can indicate a position of inlet valve(s) the sampling device(s) 108, such as whether the valves are open (and, thus, the sampling device(s) are able to collect fluid) or closed. The sampling device status data 204 can also indicate whether the sampling device(s) are holding fluid in the sample holding portion(s) 112. The sampling device status data 204 can be based on, for example, a position of the trigger(s) 110 as detected by one or more of the sensors 124, 128, 130

associated with the sampling devices 108 and/or the sample carrier 106 (e.g., the sensor(s) 130 of the sampling device(s) 108).

[0051] The example sample collection manager 134 includes a data analyzer 206. The example data analyzer 206 performs one or more data processing techniques such as converting the signal data 202, 204 from analog to digital data, filtering the data, removing noise from the signal data, compressing the data, etc. The processed data can be stored in the database 200.

[0052] The example sample collection manager 134 includes a communicator 208. The communicator 208 generates one or more instructions to enable transmission of the sensor data 202, 204 (e.g., the processed data) between the tool controller 120 and the downhole-to-surface bi-directional telemetry system 114 of FIG. 1. For example, the communicator 208 can generate an instruction for the tool controller 120 to transmit the sensor data 204, 202 to the surface processor 116 via the telemetry system 114.

[0053] The example communicator 208 can also receive instructions from the surface processor 116 via the telemetry system 114. For example, based on the analysis of the sensor data 202, 204 via the surface processor 116, an operator may decide that the fluid should be collected by the sampling device(s) 108. In such examples, the operator provides one or more user inputs 210 with respect to the opening of the sampling device(s) 108 via the surface processor 116. The user inputs 210 (e.g., instructions or commands) are transmitted downhole via the telemetry system 114 and received by the communicator 208 of the sample collection manager 134. In some examples, the user input(s) 210 are stored in the database 200. Other examples of user input(s) 210 can include instructions related to adjustments to the choke 136 and/or data regarding fluid measurements taken at the surface. In some examples, the user input(s) 210 include one or more parameters (e.g., thresholds, criteria, variables) to be used by the sample collection manager 134 in determining whether or not to collect fluid.

[0054] In some examples, based on the user input(s) 210, the communicator 208 generates one or more device control instructions 212. The device control instructions

212 can include instructions directing the trigger(s) 110 to open the sampling device(s) 108. In examples where the trigger(s) 110 provide for repeated opening and closing of the sampling device(s) 108, the instruction(s) 212 can direct the trigger(s) 110 to fully open, partially open, or close the valve(s) of the sampling device(s) 108. Thus, the instruction(s) 212 can enable fluid sampling to be started, stopped, and re-started via control of the trigger(s) 110.

[0055] As disclosed herein, in some examples, the instruction(s) 212 generated by the sample collection manager 134 are based on the user input(s) or instruction(s) 210 received from the surface based on the analysis of the sensor data 202, 204 at the surface. In other examples, the sample collection manager 134 automatically generates the instruction(s) 212 to control the sampling device(s) 108 based on the sensor data 202, 204 and one or more rules.

[0056] The example sample collection manager 134 of FIG. 2 includes a rules manager 214. The example rules manager 214 of FIG. 2 analyzes the fluid condition data 202 and/or the sampling device status data 204 generated by the sensors 124, 128, 130. The example rules manager 214 applies one or more rules 216 (e.g., algorithms) to determine whether the trigger(s) 110 should be activated to collect fluid or to stop fluid collection. Based on the rule(s) 216 and the sensor data 202, 204, the sample collection manager 134 instructs the communicator 208 to generate the instruction(s) 212 and to transmit the instruction(s) 212 to the trigger(s) 110 via the tool bus 118.

[0057] The rule(s) 216 can be based on one or more user inputs (e.g., the user input(s) 210) received by the sample collection manager 134. In some examples, the rule(s) 216 are previously programmed in the sample collection manager 134 before the tool controller 120 is disposed downhole. In other examples, the rule(s) 216 and/or modifications to the rule(s) 216 are received at the sample collection manager 134 from the surface processor 116 via the telemetry system 114. In some examples, the rule(s) 216 and/or modification(s) to the rule(s) 216 are received in substantially real-time based on the sensor data 202, 204. For example, the sensor data 202, 204 can be sent to the

surface processor 116 in addition to being analyzed downhole by the rules manager 214. In such examples, an operator may wish to modify one or more of the rule(s) 216 to be applied by the rules manager 214 based on the sensor data 202, 204.

[0058] The rule(s) 216 can include one or more predefined threshold values for the fluid condition data 202 to determine whether the fluid is adequate for sampling (e.g., based on whether or not the fluid condition data 202 meets the threshold values). In some examples, the rules(s) 216 include criteria for analyzing the sampling device status data 204 with respect to, for example, the number of times the trigger(s) 110 have been activated, whether there is fluid already stored in the sample holding portion 112 of the sampling device(s) 108, etc.

[0059] For example, the fluid condition data 202 can include fluid density measurements for the fluid. Based on the fluid density measurements and the rule(s) 216, the example rules manager 214 can distinguish between liquid oil, water, and gas. The rules manager 214 can communicate with the communicator 208 to generate instruction(s) 212 directing the trigger(s) 110 to open the sampling device(s) 108 to collect fluid samples when the rules manager 214 detects liquid oil.

[0060] As another example, the fluid condition data 202 can include one or more capacitive measurements. Based on the rule(s) 216 and the capacitive measurements, the example rules manager 214 can determine or estimate the permittivity of the fluid. The rules manager 214 can use the permittivity measurements to determine water cut values (e.g., a ratio of water to a total volume of liquid).

[0061] As another example, the fluid condition data 202 can include fluid resistivity measurements. Based on the fluid resistivity measurements and the rule(s) 216, the example rules manager 214 can distinguish between hydrocarbons and water. The rules manager 214 can communicate with the communicator 208 to generate instruction(s) 212 directing the trigger(s) 110 to open and/or close the sampling device(s) 108 based on the identification of hydrocarbons versus water.

[0062] As another example, the fluid condition data 202 can include optical measurements. For example, optical measurements can be generated via absorption spectroscopy and can be analyzed with respect to an absorption spectrum of the fluid at different wavelengths. Based on the analysis, the rules manager 214 can determine or estimate fluid composition (e.g., hydrocarbon compositions such as C1, C2, C5, C6+). The rules manager 214 can distinguish between oil, water, and gas based on the rule(s) 216 and the fluid composition estimates. In some examples, the rules manager 214 identifies a presence of carbon dioxide in the fluid based on the optical measurements and the rule(s) 216. In some examples, the fluid condition data 202 includes optical measurements based on refractometry. In such examples, the rules manager 214 can identify a presence of gas bubbles in the fluid based on the optical measurements.

[0063] In some examples, the fluid condition data 202 is generated by sensor(s) 124, 128 located upstream of the sampling device(s) 108 and/or the sample carrier 106. In such examples, the sensor(s) 124, 128, measure conditions of the fluid before the fluid reaches the sampling devices 108. In some such examples, the fluid condition data 202 is transmitted to the sample collection manager 134 before the fluid from which the data is generated reaches the sampling device(s) 108. Thus, the rules manager 214 can evaluate the fluid condition data 202 collected upstream to determine whether or not the fluid should be sampled before the fluid reaches the sampling device(s) 108.

[0064] In some examples, the rules manager 214 analyzes the sensor data 202, 204 based on the rules 216 and one or more user input(s) 210 received from the surface. For example, fluid measurements taken at the surface (e.g., from fluid previously collected from the wellbore 104) can be transmitted downhole via the surface processor 116 and the telemetry system 114. As another example, the user input(s) 210 can include a command to override the rule(s) 216 with respect to sampling the fluid or refraining from sampling the fluid. As another example, modifications to the rule(s) 216 and/or additional rule(s) 216 can be received from the surface processor 116 in substantially real-time as the rules manager 214 analyzes the sensor data 202, 204, before the analysis, and/or after the analysis.

[0065] As disclosed herein, if the rules manager 214 determines that the fluid should be collected, the rules manager 214 sends the instruction(s) 212 to the trigger(s) 110 of the sampling device(s) 108 to open the sampling device(s) 108 to collect fluid. In some examples, a sensor 130 disposed in a sampling device 108 generates fluid condition data 202 for the fluid collected by the sampling device 108 in response to a decision by the rules manager 214. The example sample collection manager 134 includes a feedback analyzer 218 to analyze the fluid data generated by the sensor(s) 130 disposed in the sampling device(s) 108 to determine whether the rules manager 214 appropriately decided that the fluid should be sampled.

[0066] For example, the feedback analyzer 218 can compare the fluid condition data 202 generated by the sensor 130 disposed inside the sampling device 108 with the fluid condition data 202 generated by the sensor(s) 124, 128 disposed outside the sampling device 108. Based on the comparison and/or the rule(s) 216, the feedback analyzer 218 determines whether the fluid collected by the sampling device 108 is representative of the fluid following in the production tubing 102 (e.g., by comparing fluid properties such as saturation pressure to one or more predefined thresholds). Thus, the feedback analyzer 218 verifies that the fluid in the sampling device 108 is representative of the fluid in the production tubing 102 or, more generally, possesses one or more particular (e.g., predefined) sample properties. The sample properties analyzed by the feedback analyzer 218 can be based on, for example, the rule(s) 216 and/or the user input(s) 210 and can include, for example, saturation pressure, density, composition, etc. In some examples, the feedback analyzer 218 may determine that the fluid in the sampling device 108 is not an adequate sample or does not possess the one or more particular sample properties.

[0067] In the example of FIG. 2, the feedback analyzer 218 communicates with the rules manager 214 such that the rules manager 214 learns from the sample verification performed by the feedback analyzer 218 for future sample collection decision-making (e.g., via one or more machine learning algorithms). For example, if the feedback analyzer 218 determines that the fluid does not possess the one or more particular

sample properties, the rules manager 214 adjusts the application of the rule(s) 216 when analyzing future fluid condition data 202 based on the feedback from the feedback analyzer 218 to reduce or decrease a likelihood of erroneous decision-making. If the feedback analyzer 218 determines that the fluid in the sampling device 108 is an adequate sample (e.g., the sample possess the one or more sample properties of interest), the rules manager 214 uses the feedback to make future sample collection decisions. Thus, the example sample collection manager 134 provides for a feedback loop between the rules manager 214, the sensor(s) 124, 128, 130, and the feedback analyzer 218.

[0068] In some examples, if the feedback analyzer 218 determines that the fluid in the sampling device(s) 108 is not an adequate sample, the feedback analyzer 218 communicates with the communicator 208 to generate one or more instruction(s) 212 for the trigger(s) 110 to close the sampling device(s) 108 to stop collecting fluid. In some examples, the communicator 208 generates one or more instruction(s) 212 for the fluid to be released from the sampling device(s) 108. In some examples, the communicator 208 generates one or more instruction(s) 212 for the sampling device(s) 108 to release or flush the fluid (e.g., a first portion of the fluid flowing in the wellbore) from the sampling device(s) 108 and to collect additional fluid (e.g., a second portion of the fluid flowing in the wellbore).

[0069] In some examples, the feedback analyzer 218 determines that the fluid is not an adequate sample based on one or more user inputs 210. For example, a determination may be made at the surface that the sample is not adequate based on an analysis of the fluid condition data 202 generated by a sensor 130 disposed in a sampling device 108 and transmitted to the surface processor 116 via the telemetry system 114. Thus, the surface operator can analyze the properties of the fluid collected by the sampling device based on the decision by the rules manager 214 and, thereby, monitor the activity of the rules manager 214. In some examples, the operator can provide an instruction for the fluid to be released (e.g., flushed) from the sampling device 108, as disclosed herein. The rules manager 214 can learn from user input(s) 210 with respect

to identifying fluid properties that result in adequate samples. Therefore, in some examples, the feedback loop includes feedback received from the surface.

[0070] Thus, the example sample collection manager 134 provides for automatic, rules-based decision-making with respect to whether or not to collect sample fluid based on sensor data representative of substantially real-time fluid conditions in the wellbore 104. The example sample collection manager 134 makes sample collection decisions based on self-learning from feedback generated downhole and/or user input(s) received from the surface.

[0071] In some examples, the sample collection manager 134 is programmed to automatically determine whether the fluid should be collected when the tool controller 120 is disposed downhole. In other examples, the sample collection manager 134 provides for back-up fluid collection decision-making if, for example, communication is lost with the surface processor 116. The sample collection manager 134 can automatically provide for back-up decision-making if predefined criteria stored in the database 200 are satisfied. For example, if the fluid condition data 202 indicates that a saturation pressure threshold is satisfied and if an instruction to take a sample is not received by the sample collection manager 134 from the surface processor 116 after a predefined length of time, then the sample collection manager 134 can automatically generate instruction(s) 212 to collect the sample (e.g., via the rules manager 214 and/or the communicator 208). Thus, the sample collection manager 134 can provide for self-monitoring relative to the downhole fluid conditions and interactions with the surface.

[0072] While an example manner of implementing the example sample collection manager 134 is illustrated in FIGS. 1 and 2, one or more of the elements, processes and/or devices illustrated in FIGS. 1 and 2 may be combined, divided, re-arranged, omitted, eliminated and/or implemented in any other way. Further, the example database 200, the example data analyzer 206, the example communicator 208, the example rules manager 214, the example feedback analyzer 218 and/or, more generally, the example sample collection manager 134 of FIGS. 1 and 2 may be implemented by hardware,

software, firmware and/or any combination of hardware, software and/or firmware. Thus, for example, any of the example database 200, the example data analyzer 206, the example communicator 208, the example rules manager 214, the example feedback analyzer 218 and/or, more generally, the example sample collection manager 134 of FIGS. 1 and 2 could be implemented by one or more analog or digital circuit(s), logic circuits, programmable processor(s), application specific integrated circuit(s) (ASIC(s)), programmable logic device(s) (PLD(s)) and/or field programmable logic device(s) (FPLD(s)). When reading any of the apparatus or system claims of this patent to cover a purely software and/or firmware implementation, at least one of the example database 200, the example data analyzer 206, the example communicator 208, the example rules manager 214, the example feedback analyzer 218 and/or, more generally, the example sample collection manager 134 of FIGS. 1 and 2 is/are hereby expressly defined to include a non-transitory computer readable storage device or storage disk such as a memory, a digital versatile disk (DVD), a compact disk (CD), a Blu-ray disk, etc. storing the software and/or firmware. Further still, the example sample collection manager 134 of FIGS. 1 and 2 may include one or more elements, processes and/or devices in addition to, or instead of, those illustrated in FIGS. 1 and 2, and/or may include more than one of any or all of the illustrated elements, processes and devices.

[0073] FIG. 3 illustrates a first example sampling device 300 (e.g., the sampling device 108 of FIGS. 1 and 2) that enables fluids that are determined not be to adequate samples to be released from the sampling device 300. The example sampling device 300 of FIG. 3 can be used with the example system 100 of FIGS. 1 and 2. The example sampling device 300 is communicatively coupled to one or more tool controllers 301. The tool controller(s) 301 can include the tool controller 120 of FIGS. 1 and 2 that is communicatively coupled to the sampling device 300 via the telemetry system 114 of FIGS. 1 and 2. In some examples, the tool controller(s) 301 include a dedicated tool controller for the sampling device 300 (and/or other sampling devices).

[0074] As disclosed herein, if the feedback analyzer 218 of the example sample collection manager 134 of FIGS. 1 and 2 determines that the fluid collected by the sampling device(s) 108 does not possess one or more particular sample properties and, thus, is not an adequate sample, the communicator 208 may generate instruction(s) 212 for the fluid to be released from the sampling device(s). In some examples, the decision to release the fluid is based on an instruction received from the surface and transmitted downhole (e.g., via the surface processor 116 and the telemetry system 114 of FIGS. 1 and 2). The first example sampling device 300 can also release the fluid based on one or more instructions received from the tool controller(s) 301.

[0075] The example sampling device 300 of FIG. 3 includes a sample chamber 302 (e.g., the sample holding portion 112 of FIG. 1) and a dump chamber 304 defined by a housing 305 of the sampling device 300. The example sampling device 300 includes an inlet 306 disposed proximate to the sample chamber 302 such that fluid entering the inlet 306 flows into the sample chamber 302. The inlet 306 includes an inlet valve 308 to control the flow of fluid through the inlet 306. In the example of FIG. 3, opening and closing of the inlet valve 308 is controlled by a trigger 309 (e.g., the trigger 110 of FIGS. 1 and 2). The trigger 309 is communicatively coupled to the tool controller(s) 301. The trigger 309 can include, for example, an electromechanical actuator.

[0076] The example sampling device 300 includes a piston 310 (e.g., a floating piston) disposed in the sample chamber 302. The piston 310 defines two volumes in the sample chamber 302, namely, a sample volume portion 312 and a hydraulic fluid volume portion 314. The example sampling device 300 includes an orifice 316 that couples the hydraulic fluid volume portion 314 to the dump chamber 304. An orifice valve 318 is disposed in the orifice 316.

[0077] Before the sampling device 300 of FIG. 3 is disposed downhole, the sample chamber 302 is primed with a hydraulic fluid 320 (e.g., hydraulic oil). Also, the piston 310 is disposed proximate to (e.g., pushed toward) the inlet 306.

[0078] The example sampling device 300 of FIG. 3 includes a sensor 321 disposed in the sample volume portion 312. The example sampling device 300 of FIG. 3 can include additional sensor(s) and/or sensor(s) disposed in the sampling device 300 at different locations than illustrated in FIG. 3. The example sensor 321 measures one or more fluid properties of fluid collected by the sampling device 300 of FIG. 3. As illustrated in FIG. 3, the sensor 321 is communicatively coupled to the tool controller(s) 301.

[0079] In some examples, the sampling device 300 of FIG. 3 is disposed downhole via carrier such as the example sample carrier 106 of FIG. 1. In other examples the sampling device 300 of FIG. 3 is disposed downhole as a standalone device. For example, the sampling device 300 can be a wireless-enabled device. The example sampling device 300 of FIG. 3 can be disposed downhole from the surface until the sampling device 300 is located at a point of interest for sampling fluid. The wireless-enabled sampling device 300 can interface with a downhole telemetry system (e.g., the telemetry system 114 of FIGS. 1 and 2) to access the downhole telemetry network. Thus, the sampling device 300 of FIG. 3 becomes a node of the downhole telemetry network. The sampling device 300 can be controlled by instructions generated at, for example, the surface and wirelessly transmitted to the sampling device 300 (e.g., to a local controller 301 of the sampling device 300) via the downhole network. For example, when a decision is made to collect fluid in the sampling device 300 (e.g., based on instruction(s) 212 generated at the surface and/or by the sample collection manager 134 of FIGS. 1 and 2), the tool controller(s) 301 instruct the trigger 309 to open the inlet valve 308 via wireless communication between the tool controller(s) 301 and the sampling device 300.

[0080] When a decision is made to collect fluid in the sampling device 300, the inlet valve 308 is opened and the orifice valve 318 of the orifice 316 is opened (e.g., based on instruction(s) from the tool controller(s) 301). Sample fluid 322 (e.g., formation fluid) flows into the sample volume portion 312 of the sample chamber 302 via the inlet 306. The entry of the sample fluid 322 into the sample volume portion 312 of the sample chamber 302 causes the piston 310 to push the hydraulic fluid 320 from the hydraulic fluid volume portion 314 into the dump chamber 304 via the orifice 316. As the hydraulic fluid 320

moves from the hydraulic fluid volume portion 314 into the dump chamber 304, the hydraulic fluid 320 moves from an area of high pressure to an area low pressure.

[0081] In the example of FIG. 3, the sensor 321 generates data about the sample fluid 322 in the sample chamber 302 and transmits the data to the tool controller(s) 301. The data generated by the sensor 321 can be analyzed by, for example, the sample collection manager 134 of FIGS. 1 and 2 and/or transmitted to the surface via a downhole telemetry system.

[0082] In some examples, based on the data generated by the sensor 307, a decision is made to release the sample fluid 322 from the sampling device 300 (e.g., based on an instruction received from the surface and/or by the sample collection manager 134 of FIGS. 1 and 2). In such examples, the orifice valve 318 is closed (e.g., based on an instruction 212 from the sample collection manager 134 of FIGS. 1 and 2). A hydraulic pump 324 is coupled to the example sampling device 300 of FIG. 3. In particular, the pump 324 is coupled to the dump chamber 304 via a first channel 326 and to the hydraulic fluid volume portion 314 of the sample chamber 302 via second channel 328. The example pump 324 of FIG. 3 can be controlled by the tool controller(s) 301.

[0083] To release the sample fluid 322 from the sample volume portion 312, the pump 324 moves the hydraulic fluid from the dump chamber 304 to the hydraulic fluid volume portion 314 of the sample chamber 302 via the channels 326, 328. The example pump 324 of FIG. 3 pressurizes the hydraulic fluid to a pressure greater than a pressure of the fluid in the sample volume portion 312 of the sample chamber 302. As the hydraulic fluid flows into the hydraulic fluid volume portion 314 via the pump 324, the piston 310 pushes the sample fluid 322 out of the sample volume portion 312. The tool controller(s) 301 instruct the trigger 309 to open the inlet valve 308 (e.g., re-open the inlet valve 308 if the inlet valve 308 was previously closed). The sample fluid 322 flows out of the sampling device 300 via the inlet 306. Thus, the example sampling device 300 of FIG. 3 can be flushed of fluid collected in the sample chamber 302 based on sensor data collected by the sensor 321 disposed in the sampling device 300 and instructions received from the

tool controller(s) 301 via the surface and/or via a downhole sample collection manager such as the sample collection manager 134 of FIGS. 1 and 2.

[0084] FIG. 4 illustrates a second example sampling device 400 (e.g., the sampling device 108 of FIGS. 1 and 2) that enables fluids that are determined not be to adequate samples to be released from the sampling device 400. The example sampling device 400 of FIG. 4 can be used with the example system 100 of FIGS. 1 and 2. The example sampling device 400 is communicatively coupled to one or more tool controllers 401 (e.g., the tool controller 120 of FIGS. 1 and 2, a dedicated tool controller for the sampling device 400, etc.). The example sampling device 400 of FIG. 4 can be disposed downhole as part of a sample carrier (e.g., the sample carrier 106 of FIG. 1) or as a standalone, wireless-enabled device that can interface with a downhole telemetry system (e.g., the telemetry system 114 of FIGS. 1 and 2).

[0085] The example sampling device 400 of FIG. 4 includes a housing 402 defining a sample chamber 404 (e.g., the sample holding portion 112 of FIG. 1). The example sampling device 400 includes an inlet 406 disposed proximate to the sample chamber 404 such that fluid entering the inlet 406 flows into the sample chamber 404. The inlet 406 includes an inlet valve 408 to control the flow of fluid through the inlet 406.

[0086] In the example of FIG. 4, opening and closing of the inlet valve 408 is controlled by a trigger 410 (e.g., the trigger 110 of FIGS. 1 and 2). The trigger 410 is communicatively coupled to the tool controller(s) 401. The trigger 410 can include, for example, an electromechanical actuator.

[0087] The example sampling device 400 of FIG. 4 includes a sensor 411 disposed in the sample chamber 404 (e.g., proximate to the inlet 406). The example sampling device 400 of FIG. 4 can include additional sensor(s) and/or sensor(s) disposed in the sampling device 400 at different locations than illustrated in FIG. 4. The example sensor 411 measures one or more fluid properties of fluid collected by the sampling device 400 of FIG. 4. As illustrated in FIG. 4, the sensor 411 is communicatively coupled to the tool controller(s) 401.

[0088] The example sampling device 400 of FIG. 4 includes a piston 412 disposed in the sample chamber 404. In the example of FIG. 4, movement of the piston 412 is controlled by a linear actuator 414. The linear actuator 414 can include, for example, a liner electrical motor. As another example, the linear actuator 414 can include a ball screw coupled to a rotary electrical motor.

[0089] In the example of FIG. 4, when a decision is made to collect sample fluid 416 in the sampling device 400, the tool controller(s) 401 instruct the trigger 410 to open the inlet valve 408. Also, the linear actuator 414 moves the piston 412 (e.g., away from the inlet 406) to increase a volume of the sample chamber 404 (e.g., based on instruction(s) from the tool controller(s) 401). The sample fluid 416 is collected in the sample chamber 404.

[0090] In the example of FIG. 4, the sensor 411 generates data about the sample fluid 416 and transmits the data to the tool controller(s) 401. The data generated by the sensor 411 can be analyzed by, for example, the sample collection manager 134 of FIGS. 1 and 2 and/or transmitted to the surface via a downhole telemetry system.

[0091] In some examples, based on the data generated by the sensor 411, a decision is made to release the sample fluid 416 from the sampling device 400 (e.g., based on an instruction received from the surface and/or by the sample collection manager 134 of FIGS. 1 and 2). In such examples, the tool controller(s) 401 instruct the trigger 410 to open the inlet valve 408 (or to keep the inlet valve 408 open if the inlet valve 408 has not been closed). The linear actuator 414 reverses the movement of the piston 412 (e.g., based on instruction(s) from the tool controller(s) 401). The linear actuator 414 moves the piston 412 toward the inlet 406 to cause the sample fluid 416 to exit the sampling device 400 via the inlet 406. Thus, the sample fluid 416 is released from the example sampling device 400 of FIG. 4.

[0092] FIG. 5 illustrates a third example sampling device 500 (e.g., the sampling device 108 of FIGS. 1 and 2) that enables fluids that are determined not be to adequate samples to be released from the sampling device 500. The example sampling device

500 of FIG. 5 can be used with the example system 100 of FIGS. 1 and 2. The example sampling device 500 is communicatively coupled to one or more tool controllers 501 (e.g., the tool controller 120 of FIGS. 1 and 2, a dedicated tool controller for the sampling device 500, etc.). The example sampling device 500 of FIG. 5 can be disposed downhole as part of a sample carrier (e.g., the sample carrier 106 of FIG. 1) or as a standalone, wireless-enabled device that can interface with a downhole telemetry system (e.g., the telemetry system 114 of FIGS. 1 and 2).

[0093] The example sampling device 500 of FIG. 5 includes a housing 502 defining a sample chamber 504 (e.g., the sample holding portion 112 of FIG. 1). The example sampling device 500 includes an inlet 506 disposed at a first end 508 of the sampling device 500. Fluid entering the inlet 506 flows into the sample chamber 504. The inlet 506 includes an inlet valve 510 to control the flow of fluid through the inlet 506.

[0094] In the example of FIG. 5, opening and closing of the inlet valve 510 is controlled by an inlet valve trigger 512 (e.g., the trigger 110 of FIGS. 1 and 2). The trigger 512 is communicatively coupled to the tool controller(s) 501. The inlet valve trigger 512 can include, for example, an electromechanical actuator.

[0095] The example sampling device 500 of FIG. 5 includes an outlet 514 disposed at a second end 516 of the sampling device 500 opposite the first end 508. The outlet 514 includes an outlet valve 518 to control a flow of fluid out of the sample chamber 504. In the example of FIG. 5, the outlet valve 518 is controlled by an outlet valve trigger 520 (e.g., an electromechanical actuator). The outlet valve trigger 520 can be communicatively coupled to the tool controller(s) 501.

[0096] The example sampling device 500 of FIG. 5 includes a sensor 522 disposed in the sample chamber 504. The example sampling device 500 of FIG. 5 can include additional sensor(s) and/or sensor(s) disposed in the sampling device 500 at different locations than illustrated in FIG. 5. The example sensor 522 measures one or more fluid properties of fluid collected by the sampling device 500 of FIG. 5. As illustrated in FIG. 5, the sensor 522 is communicatively coupled to the tool controller(s) 501.

[0097] In the example of FIG. 5, when a decision is made to collect sample fluid 524 sampling device 500, the tool controller(s) 501 instruct the trigger 512 to open the inlet valve 506. In such examples, the outlet valve 518 is closed so as not to allow the sample fluid 524 to exit the sampling device 500. The sample fluid 524 is collected in the sample chamber 504.

[0098] In the example of FIG. 5, the sensor 522 generates data about the sample fluid 524 and transmits the data to the tool controller(s) 501. The data generated by the sensor 522 can be analyzed by, for example, the sample collection manager 134 of FIGS. 1 and 2 and/or transmitted to the surface via a downhole telemetry system.

[0099] In some examples, based on the data generated by the sensor 522, a decision is made to release the sample fluid 524 from the sampling device 500 (e.g., based on an instruction received from the surface and/or by the sample collection manager 134 of FIGS. 1 and 2). In such examples, the tool controller(s) 501 instruct the trigger 512 to open the inlet valve 510 (or to keep the inlet valve 510 open if the inlet valve 510 has not been closed). Also, the tool controller(s) 501 instruct the outlet valve trigger 520 to open the outlet valve 518. Thus, both the inlet valve 510 and the outlet valve 518 are opened. As a result, new fluid flowing into the sample chamber 504 via the inlet 506 flushes out the sample fluid 524 previously collected in the sample chamber 504 via the outlet 514. When the previously collected sample fluid 524 has been released from the sample chamber 504, the inlet valve 510 and the outlet valve 518 can be closed (e.g., via the respective triggers 512, 520) to trap the newly collected fluid in the sample chamber 504.

[0100] Thus, the example sampling devices 300, 400, 500 of FIGS. 3–5 provide for collection and disposal of fluid based on instructions generated at the surface and/or by a downhole tool controller. The example sampling devices 300, 400, 500 of FIGS. 3–5 enable collection of fluid and provide for real-time measurements of the fluid properties via sensor(s) disposed in the sampling devices. The sensor data generated for the fluid disposed in the example sampling devices 300, 400, 500 can be analyzed to determine whether the fluid is an adequate sample or should be discarded. Thus, re-usable nature

of the example sampling devices 300, 400, 500 in conjunction with the ability to generate substantially real-time data about the fluid in the sample chambers via the sensors reduces instances in which inadequate samples are brought to the surface. As disclosed herein, in some examples, the sample collection manager 134 of FIGS. 1 and 2 learns from the release the fluids from the sampling devices 300, 400, 500 when making future decisions to collect the fluid (e.g., via the feedback analyzer 218 of FIG. 2).

[0101] FIG. 6 illustrates a flowchart representative of an example method 600 that can be implemented to selectively collect downhole sample fluid based on an analysis of fluid property data generated in substantially real-time. The method 600 of FIG. 6 can be implemented by the example system 100 of FIGS. 1–5, including, for example, the example sample collection manager 134 of the downhole tool controller(s) 120, 301, 401, 501 and/or the surface processor 116. The sample fluid can be collected in, for example, any of the sampling devices 108, 300, 400, 500 of FIGS. 1–5.

[0102] The example method 600 begins with communicatively coupling one or more sampling devices to a downhole telemetry system (block 602). For example, the sampling devices 108, 300, 400, 500 of FIGS. 1–5 can be deployed downhole in the wellbore 104 in a carrier (e.g., the carrier 106 of FIG. 1). The sampling device(s) 108, 300, 400, 500 include trigger(s) 110, 309, 410, 512, such as electromechanical actuators. In some examples, the sampling device(s) 108, 300, 400, 500 include local controller(s) (e.g., the tool controllers 301, 401, 501 of FIGS. 3–5). The trigger(s) and/or the local controllers of the sampling device(s) can be communicatively coupled to the tool controller 120 and, thus, the example telemetry system 114 of FIG. 1 via the tool bus 118. The communicative coupling between the sampling device(s) 108, 300, 400, 500 and the telemetry system 114 can be established via one or more wireless connections, wireline connections, or a combination of wireless and wireline connections. In some examples, the sampling device(s) 108, 300, 400, 500 are disposed downhole as stand-alone, wireless-enabled devices that are communicatively coupled to the telemetry system 114 when the sampling device(s) 108, 300, 400, 500 are disposed at a particular

sampling location in the wellbore 104 and a wireless interface connection is established between the sampling device(s) and the downhole telemetry system.

[0103] The example method 600 includes communicatively coupling one or more sensors to a downhole telemetry system (block 604). For example, the sensor(s) 124 of FIG. 1 can be coupled to the production tubing 102 disposed in the wellbore 104. In some examples, the sensor(s) 128 are disposed downhole as via a fluid sensing platform 126 disposed in, for example, the sample carrier 106 of FIG. 1. In some examples, the sensor(s) 130 are disposed in sampling device(s) 108, 300, 400, 500 (e.g., proximate to the trigger(s), in the sample holding portion(s) 112). The sensor(s) 124, 128, 130 can be communicatively coupled to the tool controller(s) 120, 301, 401, 501 and, thus, the telemetry system 114 via the tool bus 118. The communicative coupling between the sensor(s) 124, 128, 130 and the telemetry system 114 can be established via one or more wireless connections, wireline connections, or a combination of wireless and wireline connections.

[0104] The method of FIG. 6 includes accessing sensor data generated for formation fluid conditions and/or sampling device status (block 606). In the example of FIG. 6, the sensor data can be accessed by, for example, one or more downhole tool controller(s) and/or one or more surface processor(s). For example, the sensor(s) 124, 128, 130 can generate fluid condition data 202 based on measurements of one or more properties of formation fluid flowing in the wellbore 104, such as fluid composition, fluid density, fluid viscosity, fluid compressibility, etc. In some examples, the sensor(s) 124 coupled to the production tubing 102 generate the fluid condition data before the fluid reaches the sampling device(s) 108, 300, 400, 500. In some examples, sensor(s) 124, 128, 130 generate sampling device status data 204 about the operational status of the sampling device(s) 108, 300, 400, 500. The sampling device status data 204 can include a state of the trigger(s) 110, 309, 410, 512 of the sampling device(s), whether there is fluid in the sample holding portion(s) 112 of the sampling device(s), etc. The example downhole tool controller(s) 120, 301, 401, 501 and/or the example surface processor 116 can access the sensor data 202, 204 generated by the sensor(s) 124, 128 via the tool bus

118 and the telemetry system 114 of FIGS. 1 and 2. In some examples, the data analyzer 206 of the example sample collection manager 134 of the downhole tool controller 120 of FIGS. 1 and 2 processes the sensor data 202, 204 by, for example, filtering the sensor data.

[0105] The example method of FIG. 6 includes analyzing the sensor data based on one or more rule(s) (block 608). In the example of FIG. 6, the rule(s) can include predefined rules such as a fluid property thresholds, algorithms, etc. stored in and/or implemented by the downhole tool controller(s) and/or the surface processor(s). For example, the database 200 of the sample collection manager 134 of FIGS. 1 and 2 stores rule(s) 216, which can be predefined rule(s) received from the surface. The rules manager 214 analyzes the sensor data 202, 204 based on the rule(s) 216 (e.g., the algorithms, fluid measurement threshold values, etc.). In other examples, the sensor data 202, 204 is transmitted to the surface processor 116 and the surface processor 116 performs the analysis of the sensor data based on rule(s) stored in the surface processor 116. In some examples, the downhole tool controller(s) 120, 301, 401, 501 and the surface processor 116 analyze the sensor data 202, 204. In some examples, the rule(s) 216 include user input(s) 210 received from the surface.

[0106] The example method of FIG. 6 includes a decision of whether to collect sample fluid in the sampling device(s) (block 610). In the example of FIG. 6, the decision of whether or not to collect the fluid is based on the analysis of the sensor data by the downhole tool controller(s) and/or the surface processor(s). For example, if the data analyzer 206 of the example sample collection manager 134 of FIGS. 1 and 2 determines that one or more properties of the fluid satisfy respective thresholds defined by the rule(s) 216, the data analyzer 206 determines that the fluid should be collected. The data analyzer 206 instructs the communicator 208 to generate the instruction(s) 212 to activate the trigger(s) 110, 309, 410, 512 of the sampling device(s) 108, 300, 400, 500 to open the sampling device(s) (or to keep the sampling device(s) open if the sampling device status data 204 indicates that the sampling device(s) are already open). In some examples, the surface processor 116 determines that the fluid should be collected and

communicates with the downhole communicator 208 via the telemetry system 114 to generate the instruction(s) 212.

[0107] If a decision is made to collect the sample fluid, the example method 600 includes activating the trigger(s) of the sampling device(s) to enable the fluid to flow into the sampling device(s) (block 612). For example, the communicator 208 of the example sample collection manager 134 transmits instruction(s) 212 to the trigger(s) 110, 309, 410, 512 to adjust a valve of 308, 408, 510 of the sampling device(s) 108, 300, 400, 500 to allow fluid to flow through the inlet(s) 306, 406, 506 of the sampling device(s) and into the sample chamber(s) 112, 302, 404, 504. The communicator 208 transmits the instruction(s) to the trigger(s) via the tool bus 118.

[0108] The example method 600 includes accessing sensor data generated by the sensor(s) for the fluid collected in the sampling device(s) (block 614). In the example of FIG. 6, the sensor data for the fluid can be generated by sensors disposed in the sampling device(s) and can be accessed the downhole tool controller(s) and/or the surface processor(s). For example, the sensor(s) 130, 321, 411, 522 of the sampling device(s) 108, 300, 400, 500 can generate fluid condition data 202 with respect to one or more fluid properties for the fluid collected in the sample chamber(s) 112, 302, 404, 504. The fluid properties can include, for example, fluid composition, saturation pressure, etc. The downhole tool controller(s) 120, 301, 401, 501 and/or the example surface processor 116 can access the sensor data 204 generated by the sensor(s) 130, 321, 411, 522 of the sampling device(s) 108, 300, 400, 500 via the tool bus 118 and the telemetry system 114.

[0109] The example method 600 includes analyzing the sensor data generated by the sensors for the fluid collected in the sampling device(s) based on one or more rules (block 616). In the example of FIG. 6, the rule(s) can include predefined rules such as a fluid property thresholds, algorithms, etc. stored in and/or implemented by the downhole tool controller(s) and/or the surface processor(s). For example, the feedback analyzer 218 of the example sample collection manager 134 of FIGS. 1 and 2 analyzes the fluid condition data for the fluid collected in the sampling device(s) 108, 300, 400, 500 based

on the rule(s) 216 with respect to whether the fluid includes one or more predefined sample qualities, such as composition, volume, pressure, etc. In some examples, the surface processor 116 analyzes the sample fluid.

[0110] The example method 600 includes a decision of whether to retain the sample fluid that has been collected in the sampling device(s) (block 618). In the example of FIG. 6, the decision of whether to retain the sample fluid is based on the analysis of the sensor data for the fluid collected in the sampling device(s). For example, the feedback analyzer 218 of the example sample collection manager 134 determines whether the rules manager 214 appropriately decided that the fluid should be sampled. In some examples, the feedback analyzer 218 determines the fluid in the sampling device(s) 108, 300, 400, 500 exhibits one or more particular (e.g., predefined) sample properties and thus, the sample fluid is an adequate sample. In other examples, the feedback analyzer 218 determines that the fluid collected by the sampling device(s) does not possess the one or more particular properties. In such examples, the feedback analyzer 218 determines that the fluid in the sampling device(s) is not an adequate sample and, thus, should not be retained. In FIG. 6, the determination of whether to retain the sample can be made by the downhole tool controller(s) and/or the surface processor(s).

[0111] If a decision is made that the sample fluid should not be retained, the example method 600 of FIG. 6 includes activating sampling device release mechanism(s) of the sampling device(s) (block 620). In the example of FIG. 6, the sampling device release mechanism(s) are activated via one or more instructions generated by the downhole controller(s) and/or the surface processor(s). The sampling device release mechanism(s) can include, for example, a hydraulic pump to cause a piston of the sampling device to push the sampling fluid out of the sampling device, such as the hydraulic pump 324 of the example sampling device 300 of FIG. 3. In some examples, the sampling device release mechanism(s) include a linear actuator to cause a piston to push the fluid out of the sampling device, such as the linear actuator 414 of the example sampling device 400 of FIG. 4. In some examples, the sampling device release mechanism(s) include an outlet valve that can be selectively opened via an outlet valve

trigger, such as the outlet valve 518 and the outlet valve trigger 520 of the example sampling device 500 of FIG. 5. Based on the determination from, for example, the feedback analyzer 218 of the sample collection manager 134 of FIGS. 1 and 2., the communicator 208 can generate instruction(s) activate the example hydraulic pump 324 of FIG. 3, the example linear actuator 414 of FIG. 4, and/or the example outlet valve trigger 520 of the respective sampling device(s) 108, 300, 400, 500 to cause the fluid collected in the sampling devices(s) to be released.

[0112] The example method 600 of FIG. 6 includes the decision to collect fluid by the downhole tool controller(s) and/or the surface processor(s) (block 622). For example, if the feedback analyzer 218 of the example sample collection manager 134 of FIGS. 1 and 2 determines that the sample fluid is an adequate sample (e.g., the fluid possesses one or more predefined properties), the feedback analyzer 218 communicates with the rules manager 214 to confirm that the sample was an adequate sample and verify that the instruction to collect the fluid was appropriate. The rules manager 214 uses the verification from the feedback analyzer 218 to make future decisions about whether or not to collect fluid. In other examples, if the feedback analyzer 218 determines that the sample fluid should be released, the feedback analyzer 218 communicates with the rules manager 214 to inform the rules manager 214 that the sample was not an adequate sample. The rules manager 214 learns from the feedback from the feedback analyzer 218 and adjusts the application of the rule(s) 216 when determining whether to collect additional fluid to reduce instances in which inadequate sample fluids are collected. For example, the fluid collected in the sampling device(s) can represent a first portion of the fluid in the wellbore and the rules manager 214 can determine whether to collect a second portion of the fluid based on the feedback from the feedback analyzer 218.

[0113] The example method 600 of FIG. 6 includes continuing to access sensor data generated by the sensor(s) with respect to fluid conditions and/or sampling device status (block 606). The sensor data is analyzed based on the learned feedback (block 608). Also, in examples where the downhole controller(s) and/or surface processor(s) determine that the fluid should not be collected (block 610), the example method 600

includes continuing to access sensor data generated by the sensor(s) to identify when the fluid should be collected. The example method 600 ends when there is no further sensor data for analysis (block 624).

[0114] Thus, the example method 600 of FIG. 6 provides for learned decision-making with respect to whether to collect sample formation fluid and/or to retain the sample fluid that is collected based on a rules-based analysis of sensor data generated by sensors disposed in production tubing and/or in sampling devices. Although the example method 600 of FIG. 6 is discussed above as being implemented by one or more downhole controller(s) and/or surface processor(s), the example method 600 could be at least partially implemented based on instructions input by a user (e.g., a surface operator) and transmitted downhole. In some examples, the user analyzes the sensor data and determines whether the fluid should be collected. In some examples, the determination of whether the sample fluid should be collected and/or retained is based on a combination of decisions by the downhole controller(s), the surface processor(s), and/or the user. Also, in some examples, one or more other decisions can be made (e.g., by the user, the controller(s)) based on the sensor data, such as a decision to adjust a wellbore choke (e.g., the choke 136 of FIG. 1).

[0115] The flowchart of FIG. 6 is representative of an example method that may be used to implement the example system 100 of FIGS. 1 and 2. In this example, the method may be implemented using machine readable instructions comprise a program for execution by one or more processors such as the processor 712 shown in the example processor platform 700 discussed below in connection with FIG. 7. The program may be embodied in software stored on a tangible computer readable storage medium such as a CD-ROM, a floppy disk, a hard drive, a digital versatile disk (DVD), a Blu-ray disk, or a memory associated with the processor 712, but the entire program and/or parts thereof could alternatively be executed by a device other than the processor 712 and/or embodied in firmware or dedicated hardware. Further, although the example program is described with reference to the flowchart illustrated in FIG. 6, many other methods of implementing the example system 100 and/or components thereof may alternatively be

used. For example, the order of execution of the blocks may be changed, and/or some of the blocks described may be changed, eliminated, or combined.

[0116] As mentioned above, the example processes of FIG. 6 may be implemented using coded instructions (e.g., computer and/or machine readable instructions) stored on a tangible computer readable storage medium such as a hard disk drive, a flash memory, a read-only memory (ROM), a compact disk (CD), a digital versatile disk (DVD), a cache, a random-access memory (RAM) and/or any other storage device or storage disk in which information is stored for any duration (e.g., for extended time periods, permanently, for brief instances, for temporarily buffering, and/or for caching of the information). As used herein, the term non-transitory computer readable storage medium is expressly defined to include any type of computer readable storage device and/or storage disk and to exclude propagating signals and to exclude transmission media. As used herein, "non-transitory computer readable storage medium" and "non-transitory machine readable storage medium" are used interchangeably. As used herein, when the phrase "at least" is used as the transition term in a preamble of a claim, it is open-ended in the same manner as the term "comprising" is open ended.

[0117] FIG. 7 is a block diagram of an example processor platform 700 capable of executing instructions to implement the method of FIG. 6 to implement the sample collection manager 134 of FIGS 1 and 2. The processor platform 700 can be, for example, a server, a personal computer, a mobile device (e.g., a cell phone, a smart phone, a tablet such as an iPad™), a personal digital assistant (PDA), an Internet appliance, or any other type of computing device.

[0118] The processor platform 700 of the illustrated example includes a processor 712. The processor 712 of the illustrated example is hardware. For example, the processor 712 can be implemented by one or more integrated circuits, logic circuits, microprocessors or controllers from any desired family or manufacturer. In this example, the processor 712 implements the sample collection manager 134 and its components (e.g., the example data analyzer 206, the example communicator 208, the example rules

manager 214, the example feedback analyzer 218). The processor 712 can include, for example, the downhole tool controller(s) 120, 301, 401, 501 and/or the surface processor(s) 116 of FIGS. 1–5.

[0119] The processor 712 of the illustrated example includes a local memory 713 (e.g., a cache). The processor 712 of the illustrated example is in communication with a main memory including a volatile memory 714 and a non-volatile memory 716 via a bus 718. The volatile memory 714 may be implemented by Synchronous Dynamic Random Access Memory (SDRAM), Dynamic Random Access Memory (DRAM), RAMBUS Dynamic Random Access Memory (RDRAM) and/or any other type of random access memory device. The non-volatile memory 716 may be implemented by flash memory and/or any other desired type of memory device. Access to the main memory 714, 716 is controlled by a memory controller. The database 200 of the sample collection manager 134 may be implemented by the main memory 714, 716.

[0120] The processor platform 700 of the illustrated example also includes an interface circuit 720. The interface circuit 720 may be implemented by any type of interface standard, such as an Ethernet interface, a universal serial bus (USB), and/or a PCI express interface.

[0121] In the illustrated example, one or more input devices 722 are connected to the interface circuit 720. The input device(s) 722 permit(s) a user to enter data and commands into the processor 712. The input device(s) can be implemented by, for example, an audio sensor, a microphone, a camera (still or video), a keyboard, a button, a mouse, a touchscreen, a track-pad, a trackball, isopoint and/or a voice recognition system.

[0122] One or more output devices 724 are also connected to the interface circuit 720 of the illustrated example. The output devices 724 can be implemented, for example, by display devices (e.g., a light emitting diode (LED), an organic light emitting diode (OLED), a liquid crystal display, a cathode ray tube display (CRT), a touchscreen, a tactile output

device, a printer and/or speakers). The interface circuit 720 of the illustrated example, thus, typically includes a graphics driver card, a graphics driver chip or a graphics driver processor.

[0123] The interface circuit 720 of the illustrated example also includes a communication device such as a transmitter, a receiver, a transceiver, a modem and/or network interface card to facilitate exchange of data with external machines (e.g., computing devices of any kind) via a network 726 (e.g., an Ethernet connection, a digital subscriber line (DSL), a telephone line, coaxial cable, a cellular telephone system, etc.).

[0124] The processor platform 700 of the illustrated example also includes one or more mass storage devices 728 for storing software and/or data. Examples of such mass storage devices 728 include floppy disk drives, hard drive disks, compact disk drives, Blu-ray disk drives, RAID systems, and digital versatile disk (DVD) drives.

[0125] Coded instructions 732 of FIG. 7 may be stored in the mass storage device 728, in the volatile memory 714, in the non-volatile memory 716, and/or on a removable tangible computer readable storage medium such as a CD or DVD.

[0126] From the foregoing, it will be appreciated that the above-disclosed apparatus, systems and methods provide for the selective collection of formation fluid based on fluid condition data generated downhole and analyzed in substantially real-time. In examples disclosed herein, sensors disposed in production tubing and/or in sampling devices generate data about downhole fluid conditions. The sensor data can be transmitted to a downhole controller and/or a surface processor for analysis with respect to whether the sample fluid should be collected and/or retained, if already collected. Using a rules-based analysis of the sensor data, some examples disclosed herein automatically generate instructions to enable the sampling devices to collect the fluid and/or to release previously collected fluid. In examples disclosed herein, a feedback loop between the sensors, the sampling devices, and one or more controllers provides for efficient fluid sample collection in a downhole environment.

[0127] An example apparatus includes a processor to implement a rules manager to access fluid data generated by a sensor disposed in a wellbore for fluid flowing in the wellbore, analyze the fluid data relative to a rule, and determine if the fluid data satisfies the rule. The processor of the example apparatus is to implement a communicator to generate an instruction for a sampling device disposed in the wellbore to collect the fluid if the fluid data satisfies the rule and transmit the instruction to the sampling device. The sampling device is to collect the fluid based on the instruction.

[0128] In some examples, the sensor is a first sensor disposed in production tubing and the apparatus further includes a feedback analyzer to analyze second fluid data generated by a second sensor disposed in the sampling device for fluid collected in the sampling device and verify the instruction to collect the sample fluid based on the rule or a second rule. In some such examples, the communicator is to generate an instruction for the sampling device to release the fluid if the instruction is not verified. In some other examples, the fluid is a first portion of fluid in the wellbore and the rules manager is to determine if a second portion of the fluid satisfies the rule based on the verification.

[0129] In some such examples, the processor is a first processor disposed in the wellbore and the communicator is to transmit the fluid data to a second processor disposed outside the wellbore. In some such examples, the communicator is to receive, from the second processor, a user input to adjust a flow rate of the fluid. In such examples, the communicator is to further generate the instruction based on the user input.

[0130] An example apparatus includes a sensor disposed in a wellbore, the sensor to generate fluid data for a fluid flowing in the wellbore. The example apparatus includes a sampling device disposed in the wellbore. The example apparatus includes a controller. The sensor and the sampling device are to be communicatively coupled to the controller. The controller is to selectively instruct the sampling device to one of collect the fluid or release the fluid from the sampling device based on the fluid data.

[0131] In some examples, the sampling device is wirelessly coupled to the controller.

[0132] In some examples, the sensor is disposed in the sampling device.

[0133] In some examples, the controller is to instruct the sampling device to release the fluid and wherein the sampling device includes a hydraulic pump, the hydraulic pump to cause the sampling device to release the fluid via an inlet of the sampling device.

[0134] In some examples, the apparatus further includes a carrier. Each of the sampling device and the sensor are to be disposed in the carrier.

[0135] In some examples, the controller is to activate a trigger of the sampling device to cause the sampling device to collect the fluid.

[0136] In some examples, the sensor is to generate the fluid data prior to the fluid flowing into the sampling device.

[0137] An example method includes accessing, by executing an instruction with a processor, fluid condition data for a fluid in a wellbore and sampling device status data for a sampling device disposed in the wellbore. The example method includes performing, by executing an instruction with the processor, a comparison of the fluid condition data to a predefined threshold. The example method includes generating, by executing an instruction with the processor, an instruction for the sampling device to collect the fluid or to refrain from collecting the fluid based on the comparison and the sampling device status data.

[0138] In some examples, generating the instruction includes selectively controlling a trigger of the sampling device to one of open an inlet of the sampling device or to close the inlet of the sampling device.

[0139] In some examples, the fluid condition data is first fluid condition data and wherein the sampling device is to collect the fluid based on the instruction and the method further includes accessing second fluid condition data for the fluid disposed in the sampling device, performing a comparison of the second fluid condition data to the threshold, and generating an instruction for the sampling device to release the fluid based on the comparison.

[0140] In some examples, the fluid condition data includes a saturation pressure and the predefined threshold is a saturation pressure threshold.

[0141] In some examples, the sampling device status data includes a status of a valve disposed in an inlet of the sampling device.

[0142] In some examples, the method further includes detecting a user input including an adjustment to a condition in the wellbore and identifying a change in the fluid condition data after execution of the adjustment in the wellbore. In some examples, the adjustment includes an adjustment to a flow rate of the fluid.

[0143] In the specification and appended claims: the terms “connect,” “connection,” “connected,” “in connection with,” and “connecting” are used to mean “in direct connection with” or “in connection with via one or more elements” or connected via one or more communication means. Further, the terms “couple,” “coupling,” “coupled,” “coupled together,” and “coupled with” are used to mean “directly coupled together” or “coupled together via one or more elements” or communicatively coupled.

[0144] The foregoing outlines features of several embodiments so that those skilled in the art may better understand aspects of the present disclosure. Those skilled in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes or achieving the same advantages of the embodiments introduced herein. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure, and that they may make various changes, substitutions and alterations herein without departing from the spirit and scope of the present disclosure.

[0145] Although the preceding description has been described herein with reference to particular means, materials and embodiments, it is not intended to be limited to the particulars disclosed herein; rather, it extends to all functionally equivalent structures, methods, and uses, such as are within the scope of the appended claims.

Claims:

1. An apparatus comprising a processor to implement:
a rules manager to:
access fluid data generated by a sensor disposed in a wellbore for fluid flowing in the wellbore; and
analyze the fluid data relative to a rule; and
determine if the fluid data satisfies the rule; and
a communicator to:
generate an instruction for a sampling device disposed in the wellbore to collect the fluid if the fluid data satisfies the rule; and
transmit the instruction to the sampling device, the sampling device to collect the fluid based on the instruction.
2. The apparatus of claim 1, wherein the sensor is a first sensor disposed in production tubing and further including a feedback analyzer to:
analyze second fluid data generated by a second sensor disposed in the sampling device for fluid collected in the sampling device; and
verify the instruction to collect the sample fluid based on the rule or a second rule.
3. The apparatus of claim 2, wherein communicator is to generate an instruction for the sampling device to release the fluid if the instruction is not verified.
4. The apparatus of claim 2, wherein the fluid is a first portion of fluid in the wellbore and the rules manager is to determine if a second portion of the fluid satisfies the rule based on the verification.

5. The apparatus of claim 1, wherein the processor is a first processor disposed in the wellbore and the communicator is to transmit the fluid data to a second processor disposed outside the wellbore.
6. The apparatus of claim 6, wherein the communicator is to receive, from the second processor, a user input to adjust a flow rate of the fluid, the communicator to further generate the instruction based on the user input.
7. An apparatus comprising:
 - a sensor disposed in a wellbore, the sensor to generate fluid data for a fluid flowing in the wellbore;
 - a sampling device disposed in the wellbore; and
 - a controller, the sensor and the sampling device to be communicatively coupled to the controller, the controller to selectively instruct the sampling device to one of collect the fluid or release the fluid from the sampling device based on the fluid data.
8. The apparatus of claim 7, wherein the sampling device is wirelessly coupled to the controller.
9. The apparatus of claim 7, wherein the sensor is disposed in the sampling device.
10. The apparatus of claim 7, wherein the controller is to instruct the sampling device to release the fluid and wherein the sampling device includes a hydraulic pump, the hydraulic pump to cause the sampling device to release the fluid via an inlet of the sampling device.
11. The apparatus of claim 7, further including a carrier, each of the sampling device and the sensor disposed in the carrier.

12. The apparatus of claim 7, wherein the controller is to activate a trigger of the sampling device to cause the sampling device to collect the fluid.
13. The apparatus of claim 7, wherein the sensor is to generate the fluid data prior to the fluid flowing into the sampling device.
14. A method comprising:
accessing, by executing an instruction with a processor, fluid condition data for a fluid in a wellbore and sampling device status data for a sampling device disposed in the wellbore;
performing, by executing an instruction with the processor, a comparison of the fluid condition data to a predefined threshold; and
generating, by executing an instruction with the processor, an instruction for the sampling device to collect the fluid or to refrain from collecting the fluid based on the comparison and the sampling device status data.
15. The method of claim 14, wherein generating the instruction includes selectively controlling a trigger of the sampling device to one of open an inlet of the sampling device or to close the inlet of the sampling device.
16. The method of claim 14, wherein the fluid condition data is first fluid condition data and wherein the sampling device is to collect the fluid based on the instruction and further including:
accessing second fluid condition data for the fluid disposed in the sampling device;
performing a comparison of the second fluid condition data to the threshold; and
generating an instruction for the sampling device to release the fluid based on the comparison.

17. The method of claim 14, wherein the fluid condition data includes a saturation pressure and the predefined threshold is a saturation pressure threshold.
18. The method of claim 14, wherein the sampling device status data includes a status of a valve disposed in an inlet of the sampling device.
19. The method of claim 14, further including:
detecting a user input including an adjustment to a condition in the wellbore; and
identifying a change in the fluid condition data after execution of the adjustment
in the wellbore.
20. The method of claim 19, wherein the adjustment includes an adjustment to a flow rate of the fluid.

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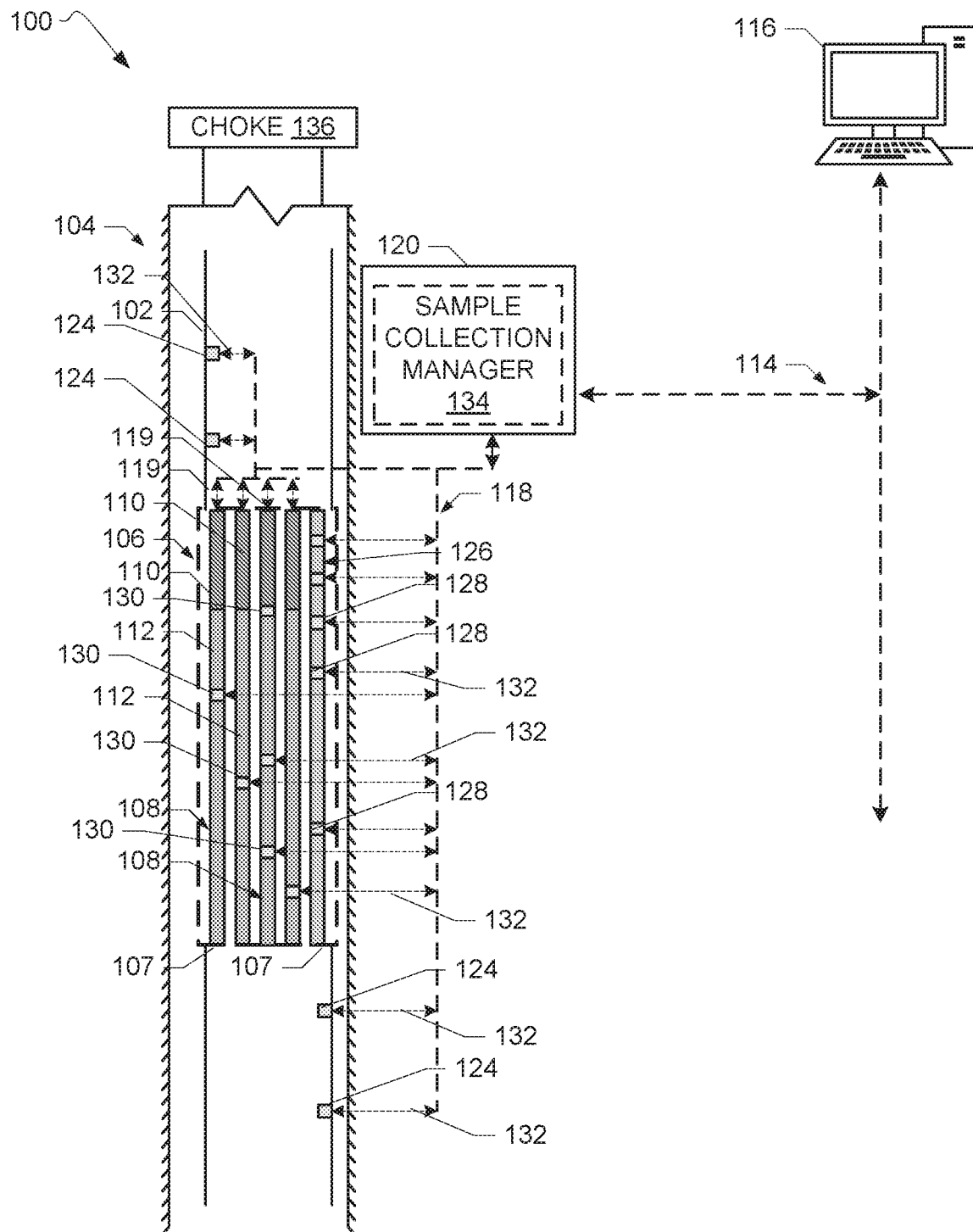


FIG. 1

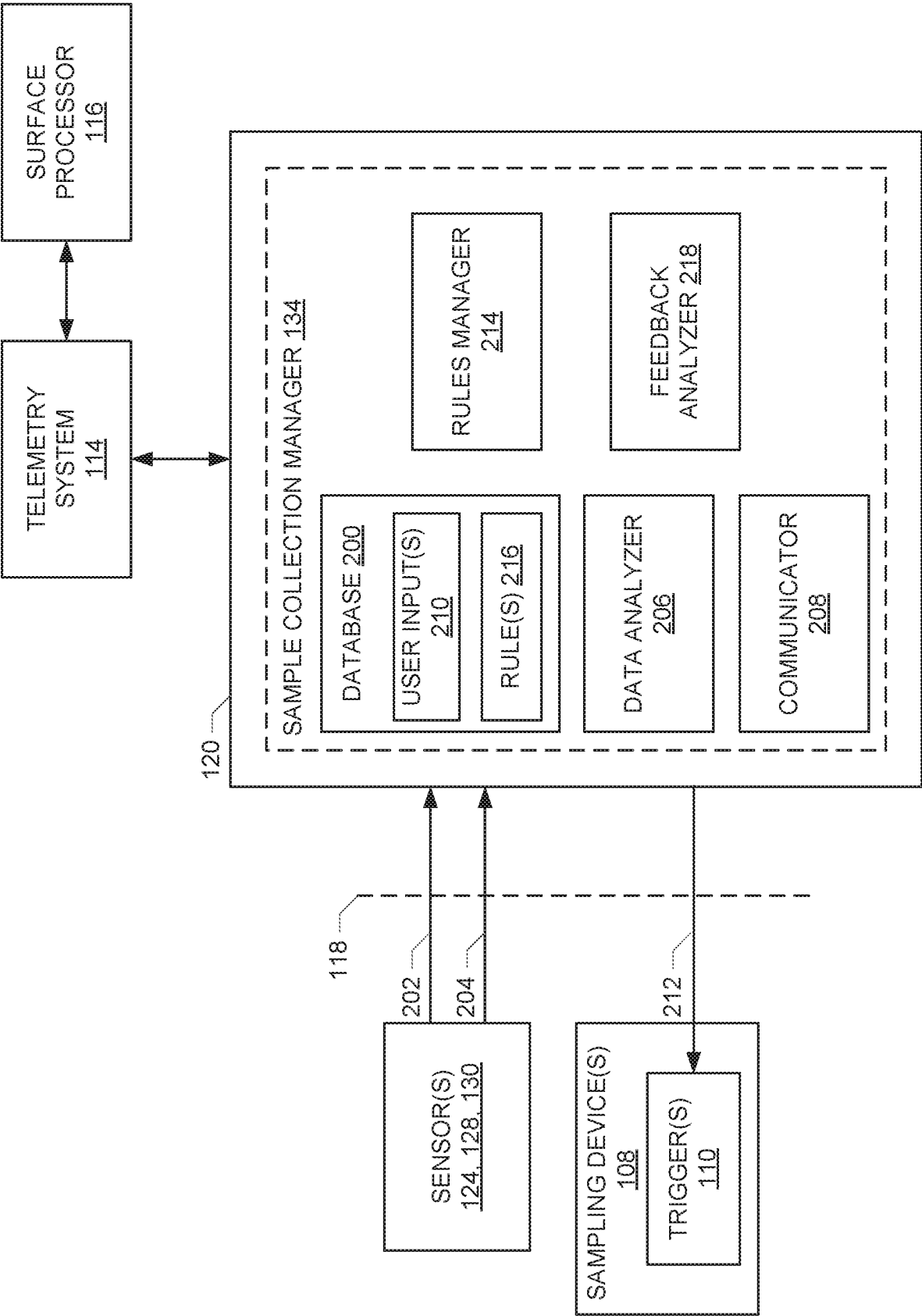
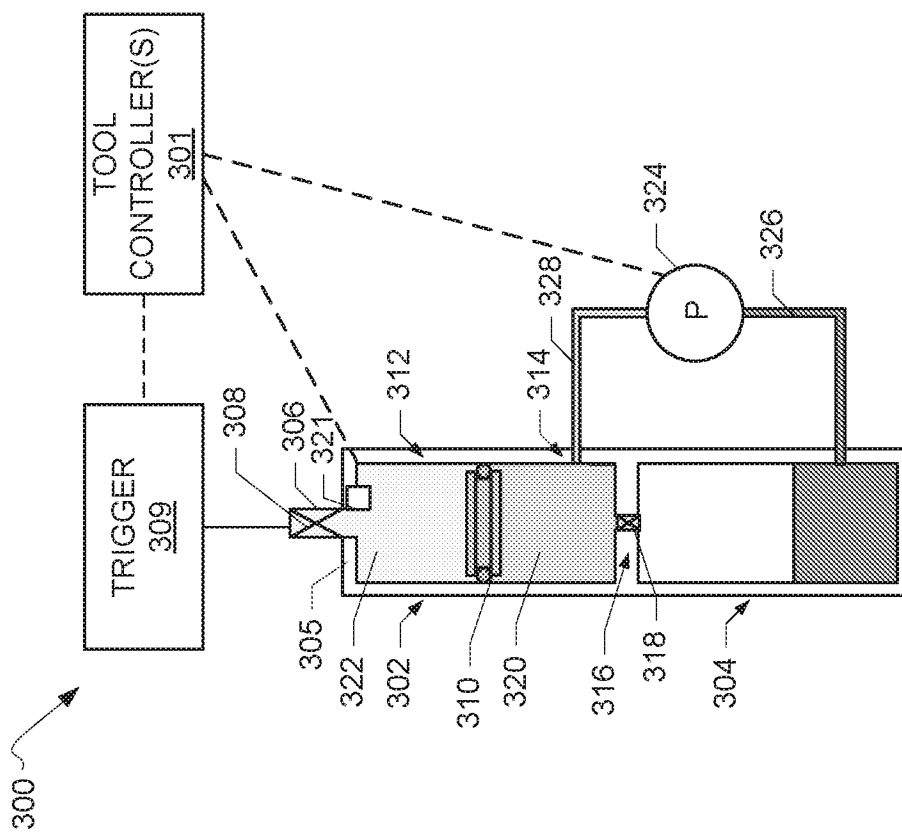


FIG. 2



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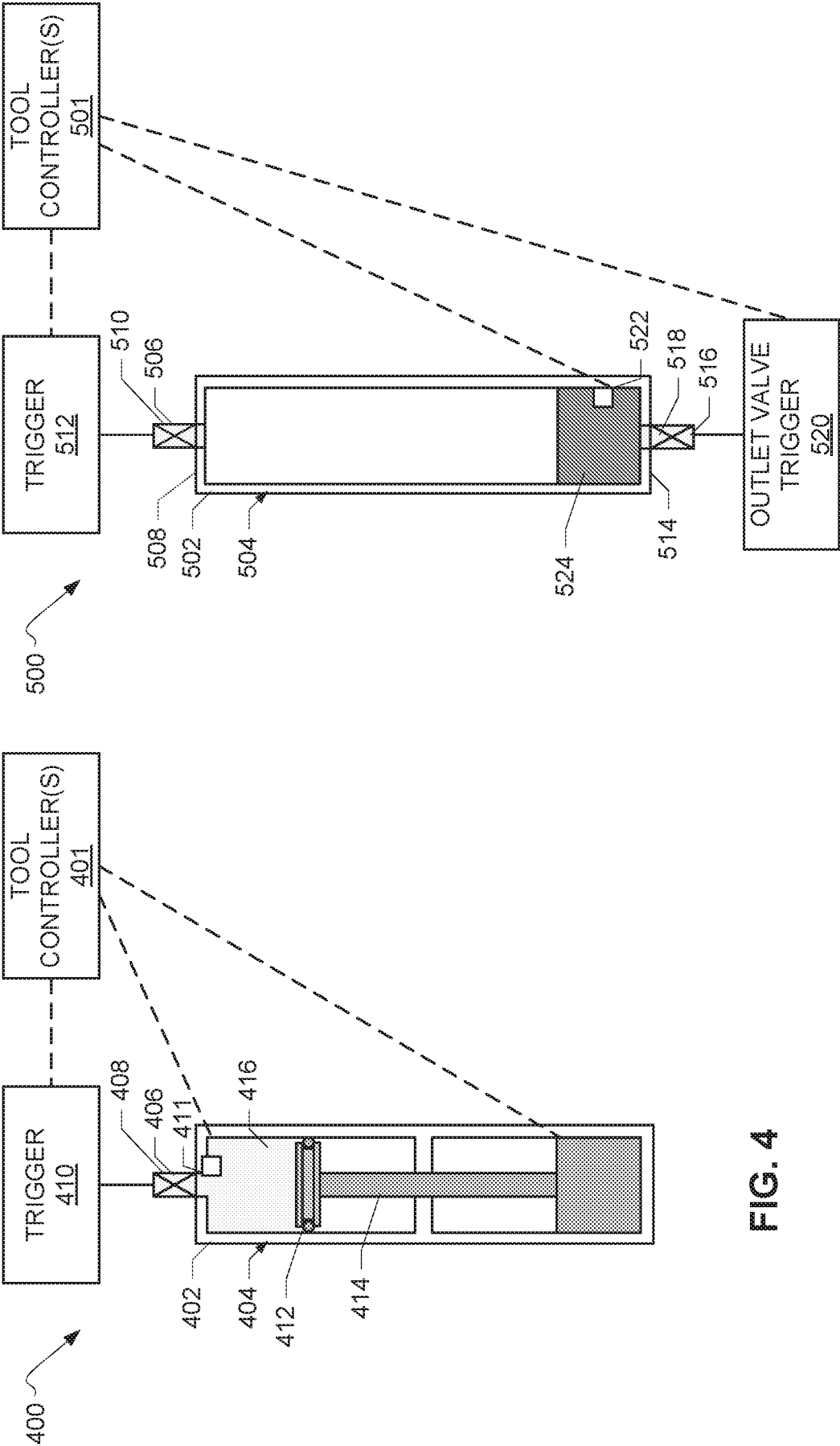


FIG. 5

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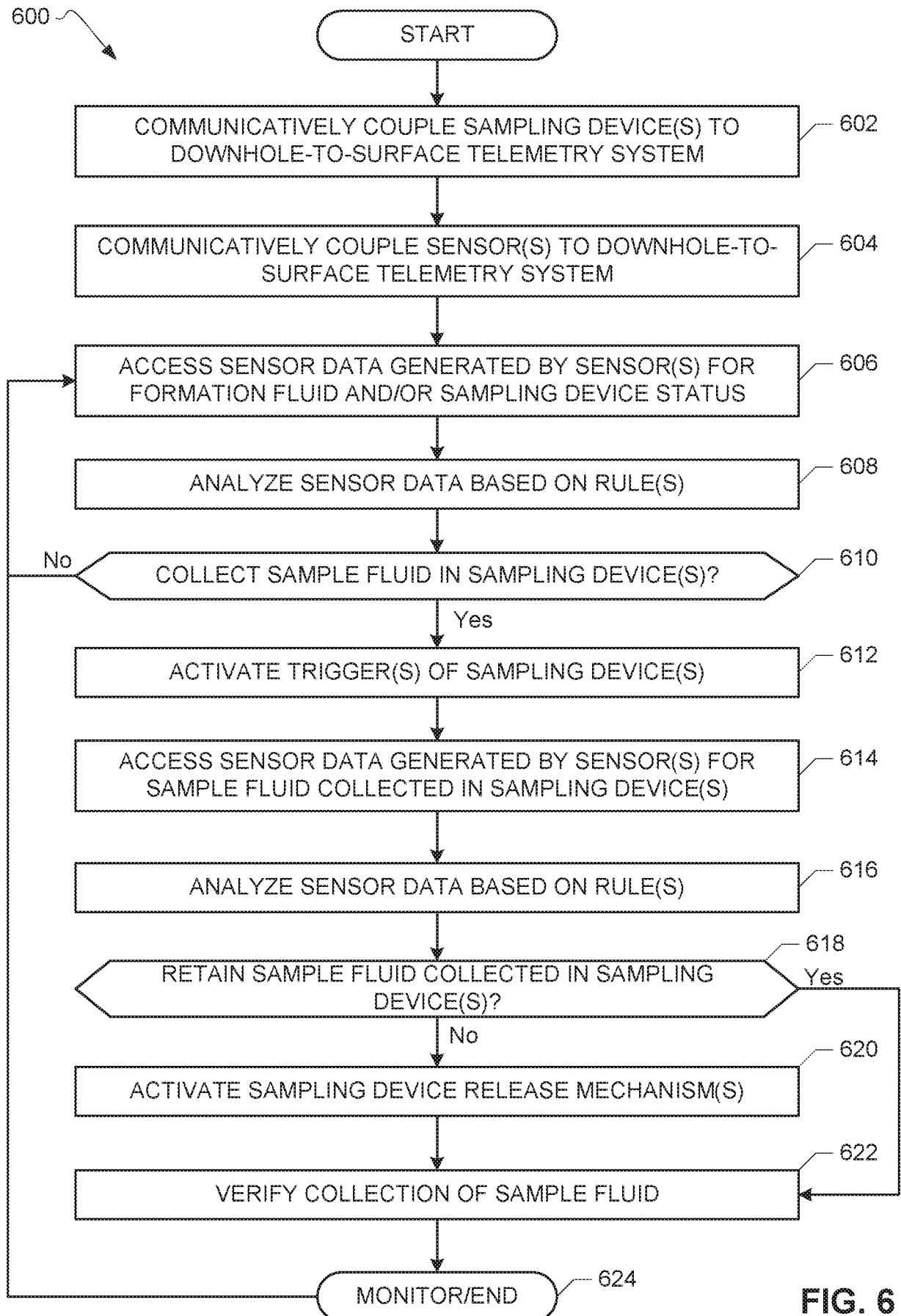


FIG. 6

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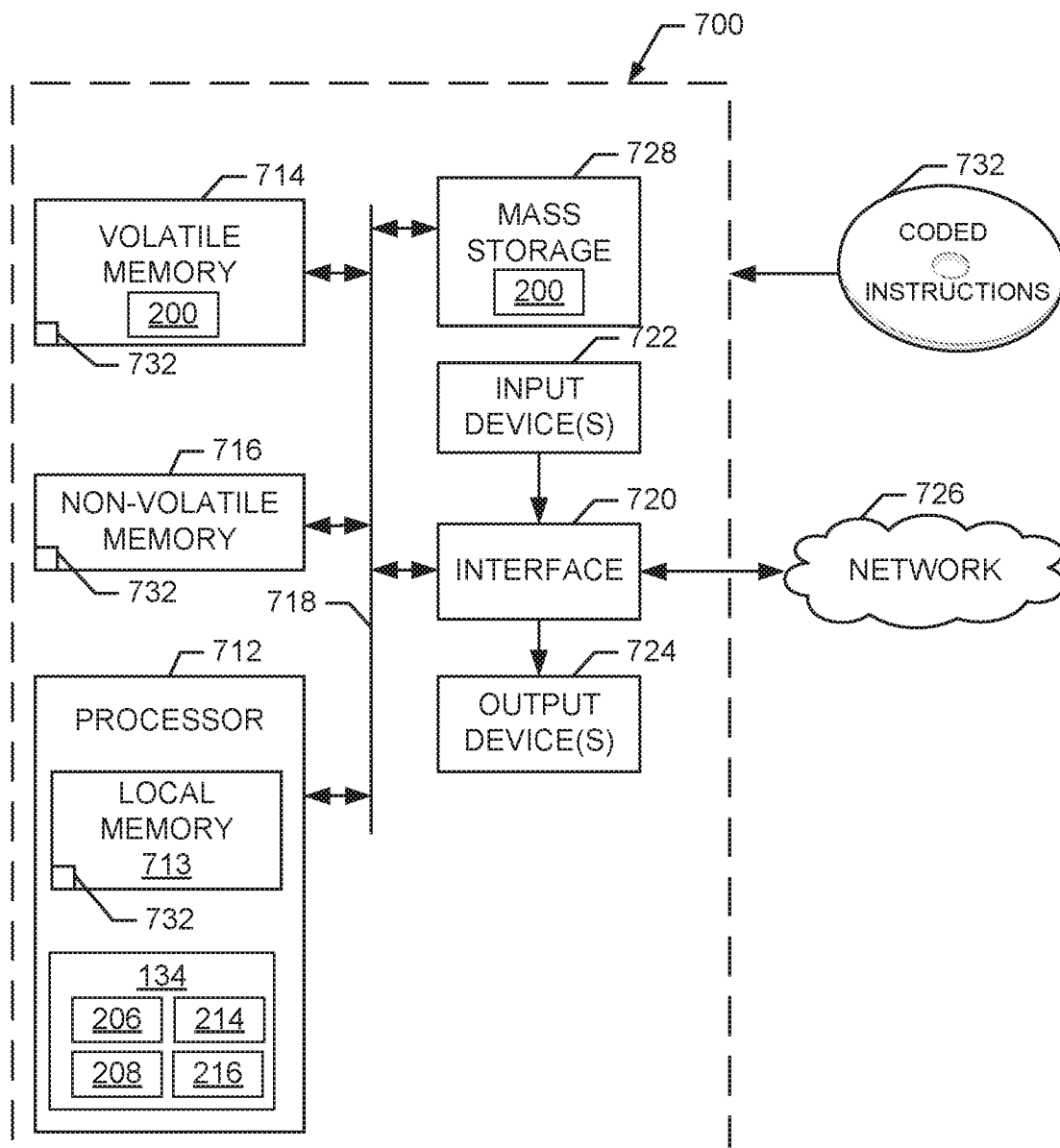


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2018/044133

A. CLASSIFICATION OF SUBJECT MATTER <i>E21B 49/10 (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 49/00-49/10 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) DWPI, EAPATIS, ESP@CENET, PAJ, PCT, PatSearch, RUPTO, USPTO		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010/0257926 A1 (SCHLUMBERGER TECHNOLOGY CORPORATION), 14.10.2010	1-20
A	US 2006/0243047 A1 (TORU TERABAYASHI, et al.), 02.11.2006	1-20
A	US 2015/0012218 A1 (SELMAN AND ASSOCIATES, LTD.), 08.01.2015	1-20
A	WO 2018/056952 A1 (HALLIBURTON ENERGY SERVICES, INC.), 29.03.2018	1-20
A	US 2017/0058659 A1 (AMR EL-BAKRY, et al.), 02.03.2017	1-20
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
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Date of the actual completion of the international search 26 March 2019 (26.03.2019)		Date of mailing of the international search report 04 April 2019 (04.04.2019)
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