

FLUID TESTING SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of U.S. Provisional Application Serial No. 63/665,929, entitled "FLUID TESTING SYSTEM" and filed June 28, 2024, and U.S. Provisional Application Serial No. 63/514,684, entitled "FLUID TESTING SYSTEM" and filed July 20, 2023, the disclosures of which are incorporated herein by reference in its entirety for all purposes.

BACKGROUND

[0002] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present disclosure, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

[0003] Natural resources, such as oil and gas, are used as fuel to power vehicles, heat homes, and generate electricity, in addition to various other uses. Once a desired resource is discovered below a surface of the earth, drilling systems are often employed to carry out drilling operations to access the desired resource. During the drilling operations, drilling fluid is pumped through a drill string into a wellbore to facilitate drilling a well. The drilling fluid then flows through an annular space defined between the drill string and the wellbore to return to equipment located at a surface. It is presently recognized that it is desirable to monitor properties of the drilling fluid.

SUMMARY

[0004] A summary of certain embodiments disclosed herein is set forth below. It should be understood that these aspects are presented merely to provide the

reader with a brief summary of these certain embodiments and that these aspects are not intended to limit the scope of this disclosure. Indeed, this disclosure may encompass a variety of aspects that may not be set forth below.

[0005] In certain embodiments, a fluid testing system includes an enclosure, a fluid container within the enclosure, and a passageway formed in a wall of the fluid container. The fluid testing system also includes a suction pump coupled to the passageway and configured to pump a sample fluid through the passageway to provide a positive level for the sample fluid in an interior chamber of the fluid container.

[0006] In certain embodiments, a fluid testing system includes a fluid container. The fluid testing system also includes a passageway within a side wall of the fluid container, wherein at least a vertical portion of the passageway extends vertically within the side wall of the fluid container. The fluid testing system further includes a suction pump coupled to the passageway and configured to pump a sample fluid through the passageway to provide a positive level for the sample fluid in an interior chamber of the fluid container.

[0007] In certain embodiments, a method of operating a fluid testing system includes controlling, via a controller, a fill pump to pump a sample fluid into an interior chamber of a fluid container. The method also includes controlling, via the controller, a suction pump to withdraw the sample fluid from the interior chamber of the fluid container via a passageway that includes a vertical portion that extends vertically within a wall of the fluid container to provide a positive level for the sample fluid in the interior chamber of the fluid container.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Various features, aspects, and advantages of the present disclosure will become better understood when the following detailed description is read with reference to the accompanying figures in which like characters represent like parts throughout the figures, wherein:

[0009] FIG. 1 is a perspective front view of a fluid testing system, wherein a portion of an enclosure is removed to facilitate visualization of a fluid container, in accordance with an embodiment of the present disclosure;

[0010] FIG. 2 is a perspective side view of a portion of the fluid testing system of FIG. 1, in accordance with an embodiment of the present disclosure;

[0011] FIG. 3 is a perspective bottom view of a portion of the fluid testing system of FIG. 1, in accordance with an embodiment of the present disclosure;

[0012] FIG. 4 is a perspective front view of a portion of the fluid testing system of FIG. 1, in accordance with an embodiment of the present disclosure;

[0013] FIG. 5 is a cross-sectional side view of a portion of the fluid testing system of FIG. 1, in accordance with an embodiment of the present disclosure;

[0014] FIG. 6 is a cross-sectional side view of a portion of the fluid testing system of FIG. 1, wherein arrows indicate a flow path of fluid into and out of the fluid container, in accordance with an embodiment of the present disclosure;

[0015] FIG. 7 is a cross-sectional perspective view of a portion of the fluid testing system of FIG. 1, in accordance with an embodiment of the present disclosure;

[0016] FIG. 8 is a perspective rear view and a corresponding schematic diagram of passageways formed in the fluid container of the fluid testing system of FIG. 1, in accordance with an embodiment of the present disclosure;

[0017] FIG. 9 is a series of side views of portions of the fluid testing system of FIG. 1, in accordance with an embodiment of the present disclosure; and

[0018] FIG. 10 is a flow diagram of a method of operating the fluid testing system of FIG. 1, in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[0019] One or more specific embodiments of the present disclosure will be described below. These described embodiments are only exemplary of the present

disclosure. Additionally, in an effort to provide a concise description of these exemplary embodiments, all features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0020] During drilling operations, drilling fluid is pumped through a drill string into a wellbore to facilitate drilling a well. The drilling fluid then flows through an annular space defined between the drill string and the wellbore to return to equipment located at a surface. Further, during the drilling operations, a fluid testing system may monitor certain properties of the drilling fluid. For example, during the drilling operations, the fluid testing system may be operated to periodically monitor rheological properties of the drilling fluid.

[0021] In certain embodiments, the fluid testing system may be located onsite (e.g., on a skid placed at the surface above the wellbore). In certain embodiments, the fluid testing system may be subject to ATEX, UKEX, and/or IECex standards. For example, the fluid testing system may be subject to ATEX, UKEX, and/or IECex standards due to presence of the drilling fluid and/or due to being located in an area with a potential presence of explosive gases. Accordingly, a fluid container and certain non-rated components, such as a viscometer, of the fluid testing system may be positioned within an enclosure that is purged and pressurized. Further, the fluid container is made to be infallible (e.g., continuous, one-piece construction and weldments; devoid of fittings) in portions that contain sample fluid (e.g., sample of the drilling fluid; fluid that may be capable of releasing flammable gases/vapors). In this way, the fluid testing system enables the sample fluid to circulate through the fluid container in a manner certified by ATEX, UKEX, and/or IECex (e.g., in compliance with ATEX, UKEX, and/or IECex standards).

[0022] ATEX refers to “Atmospheres Explosibles” and is a set of European Union regulations related to products used in explosive environments. UKEX refers to “The Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations” and is a set of regulations that apply to products sold in Great Britain. IECex refers to “International Electrotechnical Commission for Explosive Atmospheres” and is a set of regulations accepted in several countries and related to products used in explosive environments. It should be appreciated that the fluid testing system may be subject to any of a variety of regulations set forth by one or more countries, agencies, or so forth, and features of the fluid testing system may enable the fluid testing system to satisfy or meet any of a variety of regulations set forth by one or more countries, agencies, or so forth.

[0023] Additionally, the fluid testing system enables the sample fluid to be periodically introduced into the fluid container, characterized via analysis with the viscometer while in the fluid container, and then removed from the fluid container. Further, the fluid testing system enables the sample fluid to circulate through the fluid container in a manner that provides a fresh test fluid aliquot for each analysis (e.g., for each rheological characterization).

[0024] To obtain accurate measurements with the viscometer, the sample fluid within the fluid container should be at a defined level (e.g., target level; a bob and sleeve are immersed to the defined level). As described herein, the fluid testing system provides a positive level via placement of an opening in the fluid container at the defined level. Further, the fluid testing system facilitates extraction of the sample fluid through the opening in the fluid container via operation of a suction pump (e.g., level pump). The opening may connect to cross-drilled passageways that extend through the fluid container, and the cross-drilled passageways may provide a compact structure (e.g., without external attachments for extraction of the sample fluid), facilitate cleaning, facilitate draining, and so forth. Advantageously, these features enable the defined level to be achieved without use of any sensors to monitor a level of the sample fluid in the fluid container.

[0025] As noted herein, the fluid container may include a level limit switch port that supports a level limit sensor (e.g., capacitance sensor) to detect occurrence of a high level of the sample fluid in the fluid container (e.g., above the defined level), but the level limit sensor is used only as a “high-high” switch that indicates improper operation and to shut-down the suction pump and/or a fill pump to enable maintenance operations. Further, as noted herein, the fluid container may include a reference port, which is positioned above the level limit sensor relative to a vertical axis of the fluid container (e.g., relative to a gravity vector; relative to the sample fluid in the fluid container).

[0026] The fluid testing system described herein may be an automated system that is configured to circulate and test the sample fluid via automated processes (e.g., move between at least some steps without human intervention). Additionally, the fluid testing system may perform other types of tests on the sample fluid, such as weight, density, water-oil content, emulsion electrical stability, fluid conductivity, particle size, and so forth.

[0027] FIG. 1 is a perspective front view of an embodiment of a fluid testing system 10, wherein a portion of an enclosure 12 is removed to facilitate visualization of a fluid container 14. In particular, in FIG. 1, one wall of the enclosure 12 is removed to show placement of the fluid container 14 and related parts within the enclosure 12. However, while in use, the enclosure 12 may be configured to form a fully enclosed and sealed interior cavity 15 that houses the fluid container 14 and the related parts. Further, while in use, the enclosure 12 may be purged and pressurized via a flow of compressed air into the enclosure 12 to block ingress of other gases into the enclosure 12. As discussed in more detail herein, the enclosure 12 that is purged and pressurized (e.g., to provide a first pressure within the enclosure 12 that at least exceeds a second pressure outside of the enclosure 12, wherein the second pressure may be an atmospheric pressure or 1 atmosphere) may enable introduction of sample fluid (e.g., drilling fluid) and/or other fluid (e.g., cleaning fluid) that may be flammable (e.g., capable of releasing flammable gases/vapors) into the fluid container 14 within the enclosure 12. For example, the sample fluid and/or the other fluid within the fluid container 14 may

release gases into a space within the fluid container 14 (e.g., the space above the sample fluid and/or the other fluid).

[0028] However, the first pressure within the enclosure 12 may reach the space within the fluid container 14 (e.g., via one or more openings that fluidly couple the interior cavity 15 surrounding the fluid container 14 to the space within the fluid container 14). Thus, the first pressure within the enclosure 12 may be applied to the gases in the space within the fluid container 14. Further, a reference port 26 (e.g., atmospheric reference port) may extend between and fluidly couple the space within the fluid container 14 to an outside of the enclosure 12) to enable removal of any gases in the space within the fluid container 14. Accordingly, the first pressure within the enclosure 12 may block the gases from passing through the one or more openings from the space within the fluid container 14 into the interior cavity 15 surrounding the fluid container 14, which may block (e.g., prevent) arcing, sparking, and fire conditions within the enclosure 12 and enable use of various types of equipment within the enclosure 12 (e.g., fluid testing equipment, electrically powered equipment).

[0029] As shown in FIG. 1, the fluid container 14 is coupled to a rheology sensor 16 (e.g., viscometer) and a temperature control system 18. The fluid container 14 is also supported on a frame 20 that is coupled (e.g., via one or more fasteners, such as threaded fasteners) to the enclosure 12. As described in more detail herein, an inlet line 22 may provide sample fluid (e.g., drilling fluid) to the fluid container 14, and an outlet line 24 may enable extraction of the sample fluid from the fluid container 14. Additionally, a level limit switch port 28 may support a level limit sensor (e.g., capacitance sensor) to detect occurrence of a high level of the sample fluid (e.g., above a defined level or target level). To facilitate discussion, the fluid testing system 10 and its components (e.g., the fluid container 14) may be described with reference to a vertical axis or direction 30, a lateral or radial axis or direction 32, and/or a circumferential axis or direction 34.

[0030] FIG. 2 is a perspective side view of an embodiment of a portion of the fluid testing system 10, and FIG. 3 is a perspective bottom view of an embodiment

of a portion of the fluid testing system 10. As shown, the fluid container 14 is coupled to the rheology sensor 16 and the temperature control system 18. The fluid container 14 is also supported on the frame 20. The frame 20 defines a recess 36 to facilitate placement of the inlet line 22 and the outlet line 24 through the frame 20 and the enclosure 12 (FIG. 1). Additionally, the fluid container 14 includes or is coupled to the reference port 26 and the level limit switch port 28, as well as ports 38, 40 (e.g., closed or sealed via a plug) that are coupled to a passageway (e.g., cross-drilled passageway) that extends through the fluid container 14 to the outlet line 24.

[0031] FIG. 4 is a perspective front view of an embodiment of a portion of the fluid testing system 10, and FIG. 5 is a cross-sectional side view of an embodiment of a portion of the fluid testing system of FIG. 1. As shown, the inlet line 22 and the outlet line 24 extend from the fluid container 14, through the frame 20, and through the enclosure 12. The inlet line 22 may include an inlet tube 50 that is integrally formed with the fluid container 14 and/or welded to the fluid container 14. The inlet tube 50 may be integrally formed with and/or welded to a support block 52 that defines an inlet passageway 54. The support block 52 and the inlet passageway 54 extend through the frame 20, extend through a seal carrier 56 positioned in the recess 36 and that supports an inlet annular seal ring 58 (e.g., o-ring), and connect (e.g., via threads) to an inlet connector 60 that extends through the enclosure 12 to connect to a fluid source external to the enclosure 12.

[0032] Similarly, the outlet line 24 may include an outlet tube 70 that is integrally formed with the fluid container 14 and/or welded to the fluid container 14. The outlet tube 70 may be integrally formed with and/or welded to the support block 52 that defines an outlet passageway 74. The support block 52 and the outlet passageway 74 extend through the frame 20, extend through the seal carrier 56 positioned in the recess 36 and that supports an outlet annular seal ring 68 (e.g., o-ring), and connect (e.g., via threads) to an outlet connector 80 that extends through the enclosure 12 to connect to a fluid drain external to the enclosure 12. As shown, a fastener 82 (e.g., threaded fastener, such as a bolt) may couple (e.g., via threads) the support block 52 and the seal carrier 56 to one another and to the

frame 20. Additionally, a reference line (e.g., atmospheric reference line) that extends from the reference port 26 of FIG. 1 may extend through the enclosure 12 of FIG. 1. For example, the reference line 84 may extend through the enclosure 12 of FIG. 1 to couple to a reference connector 86 (e.g., atmospheric reference connector) positioned external to the enclosure 12 to connect to a reference vent (e.g., atmospheric reference vent) external to the enclosure 12. In this way, the reference port 26 of FIG. 1, the reference line 84, the reference connector 86, and the reference vent provide a pathway for removal of the gases in the space within the fluid container 14 (e.g., via pressure differential between the first pressure in the enclosure 12, which reaches the space within the fluid container 14, and the second pressure at the reference vent/external to the enclosure 12). It should be appreciated that one or more gaskets 88 may be positioned between components of the fluid testing system 10.

[0033] FIG. 6 is a cross-sectional side view of an embodiment of a portion of the fluid testing system 10, wherein arrows 100, 102 indicate a flow path of the sample fluid into and out of the fluid container 14. In particular, the arrows 100 indicate the flow of the sample fluid into the fluid container 14, and the arrows 102 indicate the flow of the sample fluid out of the fluid container 14. As shown, the sample fluid enters into the fluid container 14 via the inlet line 22, and the sample fluid exits from the fluid container 14 via the outlet line 24.

[0034] In operation and to carry out analysis of the sample fluid, a controller 110 that includes a processor(s) 112 and a memory device(s) 114 may control a fill pump 116 and a suction pump 118 in a coordinated manner. The fill pump 116 may be fluidly coupled to a fluid source 122 and the inlet line 22, and the suction pump 118 may be fluidly coupled to a fluid drain 124 and the outlet line 24. It should be appreciated that the fluid drain 124 may be a recycling system to recycle and to reuse the sample fluid (e.g., in the drilling operations).

[0035] To carry out a sequence of tests with the fluid testing system 10, the controller 110 may instruct the rheology sensor 16 of FIG. 1 to test the sample fluid within the fluid container 14. Then, the controller 110 may instruct the suction pump

118 to operate at a suction pump rate to prepare to extract the sample fluid from the fluid container 14. After some period of time, the controller 110 may instruct the fill pump to operate at a fill pump rate to begin pumping the sample fluid into the fluid container 14. In certain embodiments, the suction pump rate is greater than the fill pump rate (e.g., the suction pump rate is 2, 3, 4, 5, 6, 7, 8, or more times the fill pump rate).

[0036] To obtain accurate measurements with the rheology sensor 16 of FIG. 1, the sample fluid within the fluid container 14 should be at a defined level 134 (e.g., target level). Operation of the fill pump 116 and the suction pump 118 as described herein, along with placement of an opening 130 to a cross-drilled passageway 132, provide a positive level for the sample fluid within the fluid container 14 (e.g., cause the sample fluid to be at the defined level 134 due to placement and position of the opening 130 and operation of the suction pump 118; without sensors to monitor a level of the sample fluid and/or without analyzing signals from sensors to determine that the sample fluid is at the defined level 134 and thereafter controlling the pumps 116, 118 based on the signals to achieve the defined level 134). In particular, the opening 130 is formed in an inner surface 136 of the fluid container 14 at the defined level 134. Thus, by operating the fill pump 116 at the fill pump rate to provide the sample fluid to the fluid container 14 and operating the suction pump 118 at the suction pump rate to extract the sample fluid through the opening 130 to the cross-drilled passageway 132, the sample fluid will reach and remain at the defined level 134.

[0037] Then, after some period of time that is sufficient to provide a new aliquot of the sample fluid at the defined level 134, the controller 110 may instruct the fill pump 116 to stop pumping the sample fluid into the fluid container 14 (and may continue to operate the suction pump 118). Then, the controller 110 may instruct the rheology sensor 16 of FIG. 1 to complete rheology testing on the new aliquot of the sample fluid. In this way, multiple separate aliquots of the sample fluid may be separately tested in an efficient, automated process. It should be appreciated that the controller 110 may also receive signals (e.g., from a temperature sensor) indicative of a temperature of the sample fluid and control the temperature control

system 18 of FIG. 1 to perform the rheology testing at different temperatures (e.g., as prescribed by testing protocols).

[0038] As shown, the cross-drilled passageway 132 includes a first portion 140 that extends along a first axis 142 from the opening 130 to the port 38 and a second portion 144 that extends along a second axis 146 from the outlet line 24 to the port 40. The first portion 140 intersects the second portion 144 to form the cross-drilled passageway 132. In certain embodiments, the first axis 142 is transverse to the second axis 146. In certain embodiments, the first axis 142 extends upwardly and outwardly, such that the opening 130 is offset from the port 38 relative to the vertical axis 30 (e.g., the opening 130 is below the port 38; the opening 130 is closer to a bottom surface of the fluid container 14 than the port 38). In certain embodiments, the second axis 146 extends along or is parallel to the vertical axis 30, which may facilitate draining and/or flow of the sample fluid to the outlet line 24 (e.g., gravity). Thus, the first portion 140 may also be referred to a radial portion due to extending along the radial axis 32 (e.g., at least partially or with a component along the radial axis 32), and the second portion 144 may also be referred to as a vertical portion due to extending along the vertical axis 30.

[0039] As noted herein, plugs 150, 152 may be positioned to close or to seal the ports 38, 40. The plugs 150, 152 may have any suitable structure, such as threaded plugs that threadably couple to the ports 38, 40. The plugs 150, 152 may remain in place during the rheology testing, as well as during regular cleaning operations (e.g., flushing operations). However, the plugs 150, 152 may be removed to enable access to the cross-drilled passageway 132, such as to clear blockages via cleaning rods. Advantageously, the configuration and the placement of the cross-drilled passageway 132 (e.g., straight or linear along an entirety of each portion 140, 144, rather than curved or complex shapes; access via the ports 38, 40 exposed on an outside of the fluid container 14) supports efficient, effectively cleaning operations in this manner. Further, the configuration and the placement of the cross-drilled passageway 132 may facilitate machining and manufacturing of the fluid container 14 with the cross-drilled passageway 132.

[0040] Additionally, as shown, the cross-drilled passageway 132 extends through a wall 160 (e.g., side wall) of the fluid container 14 (e.g., is surrounded by the wall 160 of the fluid container 14; both portions 140, 144 are within the wall 160 of the fluid container 14), which may provide a compact and/or secure structure for the fluid container 14 (e.g., one-piece at and/or below the defined level 134), as well as avoid use of a separate attachment that extends from the fluid container 14 between the desired level 134 and the outlet line 24, for example.

[0041] It should be appreciated that the cross-drilled passageway 132 may have other structural features and/or configurations. For example, the cross-drilled passageway 132 may not be open to the port 38 and/or the port 40 (e.g., the port 38 and/or the port 40 may not be present; the fluid container 14 is devoid of the port 38 and/or the port 40). In such cases, the cross-drilled passageway 132 (or at least some portions of the cross-drilled passageway 132) may not be accessible for cleaning via the cleaning rods, but instead may be cleaned via flushing operations and/or other techniques.

[0042] The processor(s) 112 may be processing circuitry that includes one or more processors configured to execute software, such as software for processing signals (e.g., sensor signals), inputs (e.g., keyed inputs from the operator), and/or controlling components of the fluid testing system 10. The memory device(s) 114 may include one or more memory devices (e.g., a volatile memory, such as random access memory [RAM], and/or a nonvolatile memory, such as read-only memory [ROM]) that may store a variety of information and may be used for various purposes. For example, the memory device(s) 114 may store processor-executable instructions (e.g., firmware or software) for the processor(s) 112 to execute, such as instructions for processing signals and/or controlling components of the fluid testing system 10. The controller 110 may also include other components, such as a communication device to transmit signals (e.g., data, information, control signals) via wireless and/or wired protocols. Further, the controller 110 may also include an output device to display information (e.g., status indicators) for visualization by the operator, provide audible alarms, and so forth.

[0043] FIG. 7 is a cross-sectional perspective view of an embodiment of a portion of the fluid testing system 10. As shown, the fluid container 14 is supported on the frame 20. The fluid container 14 is fluidly coupled to the inlet line 22 and the outlet line 24. The fluid container 14 defines an interior chamber 170 that holds the sample fluid during the rheology testing. The reference port 26 is open to a space 175 (e.g., a portion of the interior chamber 170 above the sample fluid within the fluid container 14; above the desired level 134 and above the level limit switch port 28) to enable removal of any gases above the sample fluid within the fluid container 14, as described herein. For example, the enclosure 12 is purged and pressurized to provide the first pressure within the enclosure 12. Further, the first pressure within the enclosure 12 exceeds the second pressure outside of the enclosure 12, wherein the reference port 26 is fluidly coupled to (e.g., exposed to) the second pressure at the outside of the enclosure 12. It should be appreciated that the second pressure may be atmospheric pressure.

[0044] However, the first pressure within the enclosure 12 may reach the space 175 within the fluid container 14. For example, while portions of the fluid container 14 that are configured to contact the sample fluid remain infallible (e.g., one-piece and/or welded parts; devoid of fittings), and while the plugs 150, 152 may be positioned to close or to seal the ports 38, 40 located above the sample fluid, one or more openings (e.g., gaps; fluid passages) may exist above the sample fluid to enable the first pressure within the enclosure to reach the space 175 within the fluid container 14. For example, the one or more openings may be provided along, at, or proximate to a collar 174, such as through bearings that enable rotation of rotatable portions of the rheology sensor 16 (FIG. 1) that extend through the collar 174 into the fluid container 14 to facilitate testing the sample fluid.

[0045] Thus, the first pressure within the enclosure 12 may be applied to any gases in the space 175 within the fluid container 14 to drive any gases in the space 175 through the reference port 26 (e.g., out of the space 175 and through the reference port 26 to outside the enclosure 12). Accordingly, the first pressure within the enclosure 12 may block any gases from passing through the one or more openings from the space 175 within the fluid container 14, and further may force

any gases in the space 175 to flow through the reference port 26 to outside the enclosure 12. As noted herein, this may block (e.g., prevent) arcing, sparking, and fire conditions within the enclosure 12 and enable use of various types of equipment within the enclosure 12 (e.g., the rheology sensor 16 and the temperature control system 18 of FIG. 1).

[0046] As shown, the level limit switch port 28 is open to the interior chamber 170. The reference port 26 and the level limit switch port 28 are open to the interior chamber 170 at locations above the desired level 134 (e.g., along the vertical axis 30; relative to a gravity vector). Accordingly, the reference port 26 and the level limit switch port 28 may include fittings (e.g., threaded connections) and so forth, while portions of the fluid container 14 that are configured to contact the sample fluid remain infallible (e.g., one-piece and/or welded parts; devoid of fittings). Further, the reference port 26 is positioned above the level limit switch port 28 relative to the vertical axis 30 (e.g., relative to a gravity vector; relative to the sample fluid in the fluid container 14).

[0047] The level limit switch port 28 may support the level limit sensor (e.g., capacitance sensor) to detect occurrence of the high level of the sample fluid (e.g., above the defined level 134). The level limit sensor may provide signals indicative of the occurrence of the high level of the sample fluid to the controller 110 of FIG. 6, and then the controller 110 may initiate certain actions. The level limit sensor may not be used to achieve the defined level 134 of the sample fluid, but instead may be used only as a “high-high” switch that indicates improper operation of the fluid testing system 10 (e.g., that the fluid testing system 10 is not maintaining or is unable to achieve the positive level via the opening 130).

[0048] Thus, in response to detection of the high level of the sample fluid, the controller 110 may shut-down the fill pump 116 and/or suction pump 118 to enable maintenance operations. However, it should be appreciated that additionally or alternatively, the controller 110 may take any other actions to stop the rheology testing, such as adjust the fill pump rate of the fill pump 116 of FIG. 6 (e.g., stop or reduce the fill pump rate), adjust the suction pump rate of the suction pump 118 of

FIG. 6 (e.g., stop or increase the suction pump rate), block operation of the rheology sensor 16 of FIG. 1, discard test results generated by the rheology sensor 16 of FIG. 1 during the high level of the sample fluid, initiate a cleaning process to flush the fluid testing system 10, and/or any combination thereof.

[0049] Further, as described herein, the opening 130 to the cross-drilled passageway 132 may enable removal of the sample fluid and provide the positive level (e.g., automatically; without feedback from any sensors that monitor a level of the sample fluid in the fluid container 14). As shown, a temperature sensor 172 may extend into the interior chamber 170 from the collar 174 (e.g., from a location above the sample fluid relative to the vertical axis 30), and the temperature sensor 172 may monitor the temperature of the sample fluid to facilitate conducting the rheology testing at particular temperatures (e.g., via feedback loop; according to the testing protocols).

[0050] FIG. 8 is a perspective rear view of an embodiment of the fluid container 14 of the fluid testing system 10, as well as a corresponding schematic diagram of the fluid container 14 of the fluid testing system 10. As shown, the fluid container 14 includes the cross-drilled passageway 132 with the ports 38, 40, as well as the level limit switch port 28. The opening 130 to the cross-drilled passageway 132 defines and/or is placed at the defined level 134 that is appropriate for the rheology testing of the sample fluid. The level limit switch port 28 also defines and/or is placed at a level switch shut off level 180. In operation, the sample fluid may flow through the cross-drilled passageway 132 to the outlet line 24 to provide the positive level for the sample fluid.

[0051] FIG. 9 is a series of side views of embodiments of portions of the fluid testing system 10. In particular, FIG. 9 illustrates various features described herein, such as the fluid container 14, the rheology sensor 16, the frame 20, the inlet line 22, the outlet line 24, the reference port 26, the level limit switch port 28 that defines the level switch shut off level 180, and the opening 130 that extends to the cross-drilled passageway 132 of FIG. 6.

[0052] The fluid testing system 10 described herein may have various other features, such as a coating along the interior chamber 170 of the fluid container 14 and/or an insulation layer about the fluid container 14. A pressure gauge may be positioned along the outlet line 24 (e.g., between the cross-drilled passageway 132 and the suction pump 118) to monitor a pressure along the outlet line 24, which may indicate operational aspects and/or maintenance needs of the fluid testing system 10.

[0053] The fluid testing system 10 may run a series of tests in an automated manner, such as to run a first rheology test on a first aliquot of the sample fluid at a first temperature, run a second rheology test on the first aliquot of the sample fluid at a second temperature, and remove the first aliquot of the sample fluid from the fluid container 14 (e.g., by operating the fill pump 116 in reverse to empty the fluid container 14). Then, the fluid testing system 10 may add a second aliquot of the sample fluid to the fluid container 14 (e.g., by turning on the suction pump 118 at the suction pump rate and then turning on the fill pump 116 at the fill pump rate to provide the sample fluid into the fluid container 14, wherein the sample fluid reaches and stays as the defined level 134 via the cross-drilled passageway 132 and the suction pump 118, as described herein). Then, the fluid testing system 10 may run a third rheology test on the second aliquot of the sample fluid at the first temperature, run a fourth rheology test on the second aliquot of the sample fluid at the second temperature, remove the second aliquot of the sample fluid from the fluid container 14 (e.g., by operating the fill pump 116 in reverse to empty the fluid container 14), perform a cleaning (e.g., flushing operation) by routing cleaning fluid through the fluid container 14, and then continuing with further testing of additional aliquots of the sample fluid.

[0054] It should be appreciated that the fluid container 14 may be emptied via various techniques, but running the fill pump 116 in reverse as described herein may be an efficient way to provide a new aliquot to the fluid container 14 (e.g., remove and then fill, versus diluting an old aliquot with fresh sample fluid via forward circulation). Results of the rheology tests may be stored (e.g., in a storage device), displayed (e.g., via a display device for visualization by an operator),

communicated (e.g., to a remote device), and/or utilized for control actions. For example, the control actions may include providing control signals to stop the drilling operations, control signals to adjust a filter and/or associated filter process for the sample fluid prior to use in the drilling operations, and/or control signals to adjust valves and/or other devices to add components (e.g., water, chemical compounds) to the sample fluid to cause the sample fluid to match target characteristics. It should be appreciated that the fluid testing system 10 may be utilized to test any of a variety of fluids at any of a variety of locations. Further, the fluid testing system 10 may omit certain features (e.g., the enclosure 12) depending on characteristics of a fluid and/or a location.

[0055] FIG. 10 is a flow diagram of an embodiment of a method 200 of operating a fluid testing system, such as the fluid testing system 10 of FIG. 1. The method 200 disclosed herein includes various steps represented by blocks. It should be noted that at least some of the blocks of the method 200 may be performed as an automated procedure, such as via instructions from the controller 110 of FIG. 6. Although the flow diagram illustrates the blocks in a certain sequence, it should be understood that the blocks may be performed in any suitable order and certain blocks may be carried out simultaneously, where appropriate. Further, certain blocks may be omitted and/or other blocks may be added.

[0056] In block 202, the method 200 may include operating a fill pump to provide fluid to a fluid container. In block 204, the method 200 may include operating a suction pump to remove the fluid from the fluid container. In particular, the method 200 may include operating the suction pump that is coupled to a cross-drilled passageway of the fluid container to remove the fluid from the fluid container in a manner that provides a positive level for the fluid in the fluid container.

[0057] As described herein, the suction pump may be turned on prior to the fill pump in certain cases, such as to apply suction at the cross-drilled passageway to prepare to remove the fluid from the fluid container. Further, the fill pump may be turned off after some period of time that is sufficient to provide an aliquot of the fluid at a defined level (e.g., that is automatically provided via the positive level). In

some such cases, the suction pump may continue to operate to maintain the aliquot of the fluid at the defined level during a rheology test on the aliquot of the fluid. However, it is also envisioned that the suction pump may be turned off at any suitable time, such as after the fill pump is turned off and prior to performance of the rheology test on the aliquot of the fluid.

[0058] In block 206, the method 200 may include performing a rheology test on an aliquot of the fluid in the fluid container. For example, once the positive level is achieved via operating the fill pump in block 202 and the suction pump in block 204, a rheology sensor may be controlled and operated to complete rheology testing on the aliquot of the fluid. The rheology test may include one or more tests to measure one or more parameters of the fluid. For example, the one or more parameters may include viscosity, density, and/or any other desirable parameters.

[0059] It should be appreciated that it may be desirable to perform the rheology test at one or more particular temperatures (e.g., temperature or temperature range). Accordingly, block 206 of the method 200 may also include receiving signals from a temperature sensor, wherein the signals indicate a temperature of the aliquot of the fluid. In such cases, block 206 of the method 200 may also include operating a temperature control system to adjust the temperature of the aliquot of the fluid and performing the rheology test at the one or more particular temperatures (e.g., as prescribed by testing protocols).

[0060] In block 208, the method 200 may include operating the fill pump in reverse to drain the fluid from the fluid container. While this may be an efficient way to drain the fluid from the fluid container, it should be appreciated that the fluid may be drained from the fluid container via any suitable technique. In any case, once the fluid is drained from the fluid container, the method 200 may return to block 202 and repeat blocks 202-206 to test an additional aliquot of fluid. Indeed, the blocks 202-208 of the method 200 may be repeated multiple times to test multiple aliquots of fluid. It should be appreciated that cleaning operations may be carried out between draining and filling steps or at any other suitable time. For

example, the cleaning operations may include flushing the fluid container, inserting a cleaning rod into the cross-drilled passageway, and/or any other suitable steps.

[0061] It should be appreciated that the method 200 may include one or more steps related to purging, pressurizing, and/or removing any gases (e.g., flammable gases) from a space above the fluid in the fluid container, as described herein. For example, the method 200 may begin with forming the enclosure (e.g., closing and sealing the enclosure) and then purging and pressurizing the enclosure via a flow of compressed air into the enclosure prior to the block 202. Further, during the blocks 202-208, pressure within the enclosure may enter the space above the fluid in the fluid container and may force any gases produced by the fluid to exit the fluid container via a reference port open to the space and positioned above the fluid in the fluid container. In this way, the method 200 may enable performing the rheology test as set forth in the block 206, even for the fluid that may release the gases within the fluid chamber and even with the fluid chamber and fluid testing equipment positioned within the enclosure.

[0062] As noted herein, embodiments of the present disclosure relate to a fluid testing system that may be capable of and/or certified to (e.g., according to ATEX, UKEX, IECex standards) receive sample fluid (e.g., drilling fluid) and/or other fluid (e.g., cleaning fluid) that may be flammable (e.g., capable of releasing flammable gases/vapors). In particular, the fluid testing system may be utilized onsite (e.g., a well site) and may include a fluid container within an enclosure. The fluid testing system may be configured to provide fluid (e.g., flammable fluid) to the fluid container within the enclosure, wherein the fluid container is infallible (e.g., continuous, one-piece construction and weldments; devoid of fittings) in portions that contain (e.g., contact) the fluid. To block gases that may be produced by the fluid (e.g., any gases that escape from the fluid into a space above the fluid in the fluid container) from reaching a portion of the enclosure that surrounds the fluid container (and thus from reaching electrically-powered equipment within the portion of the enclosure), the enclosure may be purged and pressurized (e.g., to a first pressure), and a reference port may extend from the space above the fluid in the fluid container to outside the enclosure (e.g., at a second, lower pressure; an

atmospheric pressure). In this way, the fluid testing system may bring or move the fluid through a purged and pressurized enclosure for purposes of analysis of the fluid and/or cleaning with the fluid (e.g., cleaning the fluid container), for example.

[0063] In order to confirm that the fluid testing system is capable of receiving the fluid that may be flammable and/or to achieve certification (e.g., meet or pass ATEX, UKEX, IECex standards), certain tests may be carried out on the fluid testing system. For example, during manufacturing and/or prior to field use, at least one fluid testing system (e.g., one enclosure with a respective fluid container and other equipment therein) may be subjected to an overpressure test. During the overpressure test, a test pressure of at least five times a maximum operating pressure specified for normal service may be applied within the enclosure for a period of time (e.g., 2 minutes, plus or minus 10 seconds). In certain embodiment, a minimum test pressure (e.g., 1000 Pascals) may also be set, such that the test pressure is at least five times the maximum operating pressure specified for normal service and is also at least more than the minimum test pressure. Further, a maximum test pressure should be reached within a portion of the period of time (e.g., 5 seconds), and a high temperature may also be applied to the enclosure. The fluid testing system may be considered to pass the overpressure test if no permanent deformation occurs (e.g., to the enclosure or equipment therein), and also if the fluid testing system also passes an infallibility test.

[0064] The infallibility test may be carried out by flushing and pressurizing the enclosure with helium (e.g., pure helium; 95 percent volume by volume) to at least the maximum operation pressure. A helium leak detector may be utilized to monitor for leaks from the enclosure (e.g., leaks are indicated by an increase in helium outside of the enclosure, as compared to an initial or ambient helium reading). The fluid testing system may be considered to pass the infallibility test if no leaks from the enclosure are detected. (e.g., to the enclosure or equipment therein), and also if the fluid testing system also passes an infallibility test. It should be appreciated that other fluids (e.g., gases other than helium; liquids, such as water) may be utilized in the infallibility test.

[0065] While the disclosure may be susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and have been described in detail herein. However, it should be understood that the disclosure is not intended to be limited to the particular forms disclosed. Rather, the disclosure is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the disclosure as defined by the following appended claims. Any features shown in FIGS. 1-10 or described with reference to FIGS. 1-10 may be combined in any suitable manner.

[0066] The techniques presented and claimed herein are referenced and applied to material objects and concrete examples of a practical nature that demonstrably improve the present technical field and, as such, are not abstract, intangible or purely theoretical. Further, if any claims appended to the end of this specification contain one or more elements designated as "means for (perform)ing (a function)..." or "step for (perform)ing (a function)...", it is intended that such elements are to be interpreted under 35 U.S.C. 112(f). However, for any claims containing elements designated in any other manner, it is intended that such elements are not to be interpreted under 35 U.S.C. 112(f).

CLAIMS

1. A fluid testing system, comprising:
an enclosure;
a fluid container within the enclosure;
a passageway formed in a wall of the fluid container; and
a suction pump coupled to the passageway and configured to pump a sample fluid through the passageway to provide a positive level for the sample fluid in an interior chamber of the fluid container.
2. The fluid testing system of claim 1, wherein the passageway comprises a first portion and a second portion that intersect one another to provide a cross-drilled passageway formed in the wall of the fluid container.
3. The fluid testing system of claim 2, wherein the first portion extends radially through the wall of the fluid container, and the second portion extends vertically through the wall of the fluid container.
4. The fluid testing system of claim 1, comprising a rheology sensor within the enclosure and coupled to the fluid container, wherein the rheology sensor is configured to detect rheology parameters of a sample fluid within the fluid container and the positive level corresponds to a target level for the rheology sensor.
5. The fluid testing system of claim 1, comprising an outlet line that extends through the enclosure to couple the passageway to the suction pump.
6. The fluid testing system of claim 1, comprising a fill pump coupled to the interior chamber of the fluid container and configured to pump the sample fluid into the interior chamber of the fluid container.
7. The fluid testing system of claim 6, comprising an inlet line that extends through the enclosure to couple the interior chamber to the fill pump.

8. The fluid testing system of claim 6, comprising a controller configured to:
provide control signals to initiate operation of the suction pump at a first time;
provide additional control signals to initiate operation of the fill pump to pump the sample fluid into the interior chamber of the fluid container at a second time subsequent to the first time;
provide further control signals to shut off the operation of the fill pump to block delivery of the sample fluid into the interior chamber of the fluid container at a third time subsequent to the second time; and
continue to provide the control signals to operate the suction pump after the third time to continue to withdraw the sample fluid from the interior chamber of the fluid container into the passageway to maintain the positive level for the sample fluid in the interior chamber of the fluid container.
9. The fluid testing system of claim 8, wherein the controller is configured to:
determine that the sample fluid is at a desired level that corresponds to the positive level in response to expiration of the third time and without receipt of signals from a level switch.
10. The fluid testing system of claim 1, wherein a first end of the passageway is open to an outer surface of the fluid container, and a plug is removably coupled to the first end of the passageway to selectively cover the first end of the passageway.
11. The fluid testing system of claim 1, wherein at least a portion of the passageway extends vertically within the wall of the fluid container.
12. The fluid testing system of claim 1, comprising:
a level switch positioned vertically above the positive level for the sample fluid; and
a controller configured to:

determine that the sample fluid is at a level switch level in the interior chamber of the fluid container based on a signal from the level switch; and

in response to determining that the sample fluid is at the level switch level:

adjust operation of the suction pump to increase a removal rate of the sample fluid from the interior chamber of the fluid container;

adjust operation of a fill pump to decrease a fill rate of the sample fluid into the interior chamber of the fluid container;

or both.

13. The fluid testing system of claim 1, comprising:

a reference port open to a space within the fluid container, wherein the space is above the sample fluid in the interior chamber of the fluid container, and the reference port is fluidly coupled to a vent outside of the enclosure;

wherein the enclosure is purged and pressurized such that a pressure within the enclosure directs any gases in the space within the fluid container to pass through the reference port to the vent outside of the enclosure.

14. A fluid testing system, comprising:

a fluid container;

a passageway within a side wall of the fluid container, wherein at least a vertical portion of the passageway extends vertically within the side wall of the fluid container; and

a suction pump coupled to the passageway and configured to pump a sample fluid through the passageway to provide a positive level for the sample fluid in an interior chamber of the fluid container.

15. The fluid testing system of claim 14, wherein the vertical portion and a radial portion of the passageway intersect one another to provide a cross-drilled passageway formed in the wall of the fluid container.

16. The fluid testing system of claim 15, wherein respective first ends of the vertical portion and the radial portion are open at an outer surface of the fluid container.

17. The fluid testing system of claim 14, comprising an enclosure and an outlet line that extends through the enclosure to couple the passageway to the suction pump.

18. The fluid testing system of claim 14, comprising a controller configured to:
provide control signals to initiate operation of the suction pump at a first time;
provide additional control signals to also initiate operation of a fill pump to pump the sample fluid into the interior chamber of the fluid container at a second time subsequent to the first time;
provide further control signals to shut off the operation of the fill pump to block delivery of the sample fluid into the interior chamber of the fluid container at a third time subsequent to the second time; and
continue to provide the control signals to operate the suction pump after the third time to continue to withdraw the sample fluid from the interior chamber of the fluid container into the passageway to maintain the positive level for the sample fluid in the interior chamber of the fluid container.

19. A method of operating a fluid testing system, the method comprising:
controlling, via a controller, a fill pump to pump a sample fluid into an interior chamber of a fluid container; and
controlling, via the controller, a suction pump to withdraw the sample fluid from the interior chamber of the fluid container via a passageway that includes a vertical portion that extends vertically within a wall of the fluid container to provide a positive level for the sample fluid in the interior chamber of the fluid container.

20. The method of claim 19, comprising controlling, via the controller, a rheology sensor to detect rheology parameters of the sample fluid at the positive level in the interior chamber of the fluid container with the sample fluid.