United States Patent Application Publication 20250251384
Kind Code A1
Publication Date August 07, 2025
Inventor(s) Stewart; Colin et al.

AUTOMATED ANALYSIS OF DRILLING FLUID

Abstract

A system includes a fluid conduit, a fluid chamber in communication with the fluid conduit, a rheology sensor in communication with the fluid chamber, and an electric temperature controller in communication with the fluid chamber. The fluid chamber is cooled in response to a first control signal from the electric temperature controller.

Inventors: **Stewart; Colin (Houston, TX), Fossdal; Truls (Sandsli, NO), Melz; Ragnar (Sandnes, NO), Connaughton; Jerry Thomas (Richmond, TX), Chizhov; Zakhar (Katy, TX), McPherson; Neil (Houston, TX), Sheladia; Rahul (Singapore, SG)**

Applicant: **Schlumberger Technology Corporation** (Sugar Land, TX)

Family ID: **64951218**

Appl. No.: **19/184855**

Filed: **April 21, 2025**

Related U.S. Application Data

parent US continuation 17980819 20221104 parent-grant-document US 12282010 child US 19184855
parent US continuation 16623383 20191216 ABANDONED US continuation PCT/US2018/040769 20180703 child US 17980819
us-provisional-application US 62529454 20170706

Publication Classification

Int. Cl.: **G01N33/28** (20060101); **G01N9/36** (20060101); **G01N11/00** (20060101); **G01N11/14** (20060101)

U.S. Cl.:

CPC **G01N33/2823** (20130101); **G01N9/36** (20130101); **G01N11/14** (20130101); G01N2011/0093 (20130101)

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of U.S. patent application Ser. No. 17/980,816 filed Nov. 4, 2022, now U.S. Pat. No. 12,282,010, which is a continuation of U.S. patent application Ser. No. 16/623,383 filed Dec. 16, 2019, which is a National Stage Entry of International Patent Application No. PCT/US2018/040769, filed on Jul. 3, 2018, which claims priority to U.S. Provisional Patent Application No. 62/529,454, filed on Jul. 6, 2017, the contents of which are incorporated by reference.

BACKGROUND
[0002] Drilling fluids are pumped the center of a down drill string when drilling a wellbore. The drilling fluid exits the drill string at the bit through nozzles and travels back up the annulus of the wellbore to the drilling equipment located at the surface. The fluids provide lubrication and cooling of the drilling. The fluid also carries cuttings out of the wellbore, controls wellbore pressure, and performs a number of other functions in connection with drilling the wellbore. To ensure that the properties of the drilling fluids are adequate, an engineer consistently checks the properties of the drilling fluid. For example, the viscosity of the drilling fluid must be high enough to carry the cuttings out of the wellbore while at the same time be low enough to allow the cuttings and entrained gas to escape the drilling fluids at the surface. Depending on the operation, the engineer may check the properties of the drilling fluid several times in a 24 hour period.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0003] The accompanying drawings illustrate a number of exemplary embodiments and are a part of the specification. Together with the following description, these drawings demonstrate and explain various principles of the instant disclosure.
[0004] FIG. **1** depicts a perspective view of an example of fluid testing apparatus in accordance with the present disclosure.
[0005] FIG. **2** depicts a schematic of an example of internal components of a fluid testing apparatus in accordance with the present disclosure.
[0006] FIG. **3** depicts a detailed view of a fluid chamber of the fluid testing apparatus in accordance with the present disclosure.
[0007] FIG. **4** depicts an example of a user interface of the fluid testing apparatus in accordance with the present disclosure.
[0008] FIG. **5** depicts a diagram of a system for adjusting a temperature of fluid samples in accordance with the present disclosure.
[0009] FIG. **6** depicts an example of a method for automated testing of the fluid samples at different temperatures in accordance with the present disclosure.
[0010] FIG. **7** depicts an example of components of a fluid testing apparatus with a side loop for controlling a temperature of fluid for density measurements in accordance with the present disclosure.
[0011] FIG. **8** depicts an example of components of a fluid testing apparatus without a density sensor in accordance with the present disclosure.
[0012] While the embodiments described herein are susceptible to various modifications and

alternative forms, specific embodiments have been shown by way of example in the drawings and will be described in detail herein. However, the exemplary embodiments described herein are not intended to be limited to the particular forms disclosed. Rather, the instant disclosure covers all modifications, equivalents, and alternatives falling within the scope of the appended claims.

DETAILED DESCRIPTION

[0013] Drilling fluid is circulated down the drill string, out the nozzles in the drill bit, and up the annulus of the wellbore. The drilling fluid can be used to remove cuttings from the bottom of the wellbore. The physical properties of the drilling mud are monitored during a drilling operation to determine whether the drilling mud is working adequately and to make any desired changes as drilling progresses.

[0014] The drilling fluid tests may measure physical characteristics of the drilling fluid, such as testing the fluid's rheology. Rheology tests may be performed with a rheology meter, such as a viscometer, a rheometer, or another type of sensor. These tests may be performed onsite at the wellbore, in a lab, or at another location. The fluid testing apparatus **100** depicted in FIG. **1** may complete a series of tests on the drilling fluid sequentially without further instructions from the user between tests. Other types of fluid property tests that may be performed with the fluid testing apparatus **100** include taking measurements of the mud weight, rheology, density, water-oil content, emulsion electrical stability, fluid conductivity, and particle size distribution. Based on the principles described in the present disclosure, a fluid testing apparatus **100** may perform at least one or more of the fluid property tests automatically at different temperatures.

[0015] The fluid testing apparatus **100** may include a housing **102**, a user interface **104**, and a bottle receiver **106**. A drilling fluid sample may be collected from the circulating drilling mud or from another location into a bottle **108**. The bottle **108** may be connect to the bottle receiver **106**. A fluid conduit may be suspended from the bottle receiver **106** and be submerged into the drilling fluid sample as the bottle **108** is connected to the bottle receiver **106**. A pump may actively convey at least a portion of the drilling fluid sample out of the bottle **108** into the fluid testing apparatus **100** where the tests may be performed.

[0016] The bottle **108** may be secured to the bottle receiver **106** through any appropriate type of interface. In some examples, the bottle receiver **106** has an internal thread that can be engaged with an external thread of the bottle **108**. In other examples, the bottle **108** is snapped into place, held in place through compression, otherwise interlocked with the bottle receiver **106**, or otherwise connected to the bottle receiver **106** though another type of attachment.

[0017] The user interface **104** may allow the user to instruct the fluid testing apparatus **100** to perform the tests. In some examples, the fluid testing apparatus **100** presents options for testing the drilling fluid sample through the user interface **104**. In some cases, the user may indicate the types of tests to be performed as well as parameters for performing those types of tests. For example, the user may instruct the fluid testing apparatus **100** to perform a viscosity test at multiple temperatures through the user interface **104**. The user may also specify the desired temperatures for those tests through the user interface **104**.

[0018] Any type of user interface **104** may be used in accordance with the principles described in the present disclosure. In some cases, the user interface **104** is a touch screen accessible from the housing **102** of the fluid testing apparatus **100**. In this type of example, the user may touch the touch screen to input information and provide instructions to the fluid testing apparatus **100**. In other examples, the fluid testing apparatus **100** may include a wireless receiver where the user can provide information and/or send instructions wirelessly to the fluid testing apparatus **100**. For example, the user may send the information and/or provide the instructions with a mobile device, an electric tablet, a laptop, a networked device, a desktop, a computing device, another type of device, or combinations thereof. In examples where the user can communicate with the fluid testing apparatus **100** wirelessly, the user may be located onsite or the user may be located at a remote location. In some cases, a mud engineer may be located at a remote location offsite and a local technician may fill the bottle **108** for the mud engineer so that the mud engineer does not have be onsite to evaluate the drilling mud and make recommendations. In yet another example, the user interface **104** may include a keyboard, a mouse, a button, a dial, a switch, a slider, another type of physical input mechanism, or combinations thereof to assist the user to input information or provide instructions to the fluid testing apparatus **100**. In some cases, the fluid testing apparatus **100** may include a microphone or a camera that allows the user to speak information to the fluid testing apparatus **100** and/or communicate with motion/hand gestures with the fluid testing apparatus **100**.

[0019] After inputting the information and instructing the fluid testing apparatus **100** to initiate the tests, the fluid testing apparatus **100** may complete the tests without further involvement from the user. The fluid testing apparatus **100** may automatically transition from one type of test to another as tests are completed. Further, the fluid testing apparatus **100** may automatically adjust the temperature of the drilling fluid sample between tests without involvement from the user. Often, the drilling mud is tested after circulating through the drill string in a hot, downhole environment. In those circumstances where the drilling mud is desired to be tested at a temperature lower than the current temperature of the drilling mud, the drilling mud has to be cooled off before the test can be performed. The fluid testing apparatus **100** may lower the drilling fluid sample's temperature and free the user to perform other tasks.

[0020] FIGS. **2** and **3** depict a schematic of an example of internal components of a fluid testing apparatus **100** in accordance with the present disclosure. FIG. **3** details a portion of the internal components depicted in FIG. **2**. In this example, the fluid testing apparatus **100** includes a bottle receiver **106**, a pump **200**, a fluid conduit **204**, a density sensor **216** connected to the fluid conduit **204**, a fluid chamber **218**, and a rheology sensor **220** connected to the fluid chamber **218**.

[0021] The bottle receiver **106** may be any appropriate attachment to the exterior of the fluid testing apparatus **100** to which the bottle **108** may be connected and which includes a mechanism for removing the drilling fluid sample **230** from the bottle **108**. In the depicted example, a portion of the fluid conduit **204** is suspended from the bottle receiver **106** at a distance so that the inlet **206** is submerged within the drilling fluid sample **230** when the bottle **108** is attached. A filter **202** is connected to the drilling fluid conduit **204** and surrounds the inlet **206** so that solid particles and/or unwanted debris is prevented from entering the fluid conduit **204**.

[0022] A first portion **210** of the fluid conduit **204** connects the inlet **206** to a pump **200**. The pump **200** may be used to pull at least a portion of the drilling fluid sample **230** from the bottle **108** into fluid conduit **204**. In some examples, the pump **200** is a peristaltic pump. But, any appropriate type of pump may be used in accordance with the principles described in the present disclosure.

[0023] A second portion **212** of the fluid conduit **204** may connect the fluid conduit **204** to the pump **200** and a density sensor. In some cases, the pump **200** is at a higher elevation than the density sensor **216**. In this type of example, the pump **200** may release the drilling fluid sample **230** and allow gravity to push the drilling fluid sample **230** to the density sensor **216**. In other examples, the pump **200** may actively push the drilling fluid sample **230** through the density sensor **216**.

[0024] Any appropriate type of density sensor **216** may be used. In one example, the density sensor **216** may be a coriolis density meter that measures a characteristic of the drilling fluid sample **230** as the fluid passes through it. Coriolis density meters may measure the movement/vibrations of internal components of the density meter. These movements may be measured as the drilling fluid sample **230** passes through the density sensor **216**. This frequency correlates to the drilling fluid sample's density.

[0025] A third portion **214** of the fluid conduit **204** connects the fluid conduit **204** from the density sensor **216** to a fluid chamber **218**. The fluid chamber **218** may include a chamber wall **236** that defines an opening **242**. An outlet **208** of the fluid chamber **218** may terminate in the opening **242** of the fluid chamber **218** and direct the drilling fluid sample **230** into the fluid chamber **218**.

[0026] A level detection sensor **222** may send a signal to the pump **200** to stop pumping in the

drilling fluid sample **230** when the fluid level **232** is at an appropriate height. Any appropriate type of level detection sensor **222** may be used. A non-exhaustive list of level detection sensors that may be used include ultrasonic sensors, fluid conductivity sensors, capacitance sensors, induction sensors, microwave sensors, laser sensors, float switches, thermal flow switches, hydrostatic pressure sensors, radar based sensors, magnetostrictive sensors, optical sensors, load cell sensors, other types of sensors, time of flight sensors, other types of sensors, or combinations thereof.
[0027] While each of the above level detection sensors may be used in some applications, many some of the above mentioned level detection sensors may not be as effective as other types of sensors for certain types of drilling fluids. In some examples, a thermal dispersion level detection sensor is incorporated into the fluid chamber **218** and may be effective for a wide variety of different types of drilling fluids. The thermal dispersion level detection sensor can be effective for determining the level of fluids regardless of the fluid's di-electric strength, tendency to create optical disturbances, and other characteristics of drilling fluids that make level detection challenging.
[0028] Thermal dispersion technology is generally used to measure characteristics of a fluid's flow rate. Generally, fluids are cooler when flowing than when in a static condition. Conventionally, thermal dispersion technology analyzes the temperature of a fluid to determine the flow rate or another characteristic of the fluid. In examples where thermal dispersion technology is used in the fluid testing apparatus **100**, thermal dispersion technology can be repurposed to determine a fluid level **232**.
[0029] Level detection with thermal dispersion technology may be accomplished by actively moving the drilling fluid sample **230** as it enters into the fluid chamber **218** and measuring temperature differences at various heights along the fluid chamber **218**. In some examples, a rotor **248** may cause the drilling fluid sample **230** to rotate within the fluid chamber **218** as it fills. The rotation of the drilling fluid sample **230** caused by the rotor **248** may create a cooling effect on the portions of the chamber wall **236** in direct contact with the fluid. A fluid level **232** may be determined by comparing the temperature differences along the fluid chamber's wall and identifying the fluid level **232** at the height were the temperature difference occurs.
[0030] In the example of FIGS. **2** and **3**, the level detection sensor **222** includes a first level detector **224**, a second level detector **226**, and a third level detector **228**. In some cases, each of the first level detector **224**, second level detector **226**, and third level detector **228** are thermal dispersion level detectors. In other examples, at least one of these detectors is a different type of sensor. For those level detectors that are thermal level detectors, each may include two or more level thermometers that detect the temperature of the chamber wall **236**, the temperature adjacent to the exterior of the chamber wall **236**, the temperature adjacent to the interior of the chamber wall **236**, or combinations thereof. Each of the level thermometers of the level detector may be at adjacent each other, but at different heights. When the lower of the two thermometers is a different temperature than the higher thermometer, the level detector may send signal to stop the pump **200**. This temperature difference may indicate that the fluid level **232** is between the lower and higher thermometers.
[0031] The second level detector **226** may be used as a back-up if the first level detector **224** fails to operate properly. In this situation, the second level detector **226** may cause a signal to be sent to stop the pump **200**.
[0032] The third level detector **228** may be used to indicate the fluid level **232** is too high. In some examples, a rheology sensor **220** or other components of the fluid testing apparatus **100** are incorporated into the fluid chamber **218** above the operating fluid level **234**. If the fluid level **232** gets too high, the drilling fluid sample **230** may get into these components and interfere with their operation. In one such example, a rotary bearing of a viscometer may be above the operating fluid level **234** in the fluid chamber **218** and if the fluid level **232** exceeds the fluid operating level, the drilling fluid sample **230** may get into the rotary bearings. In some cases, the viscometer's rotary

bearings are finely tuned to obtain precise measurement readings. Drilling fluid in these finely tuned bearings may cause the viscometer's measurement outputs to be inaccurate. When activated, the third level detector **228** may cause a message to be communicated to the user that the equipment needs to be checked before proceeding with the tests. In some examples, the third level detector **228** may also send a signal to the stop the pump **200**.

[0033] In the example of FIGS. **2** and **3**, the rheology sensor **220** is a viscometer. The rheology sensor **220** may include a rotor **248** that is suspended into the opening **242** of the fluid chamber **218** to make contact and/or be submerged into the drilling fluid sample **230** when the fluid chamber **218** is filled. In some examples, the rotor **248** is an outer cylinder that rotates about a bob (not shown), which in an inner cylinder. The drilling fluid sample **230** is filled within the annulus between the rotor **248** and the bob. When activated, the rotor **248** rotates at known velocities and creates shear stress on the bob through the drilling fluid sample **230**. A torsion spring restrains the movement of the bob and measures the shear stress. The viscometer may run the tests at any appropriate rotor speed (rotations per minute or RPM). In some cases, the tests are taken at 600, 300, 200, 100, 6 and 3 RPM.

[0034] An electric temperature controller may be in communication with the fluid chamber **218**. Any appropriate type of electric temperature controller may be used in accordance with the principles described in the present disclosure. In some examples, the electric temperature controller includes a thermoelectric material **256** (e.g. Peltier device) that has the characteristic of generating an electric current in response to a temperature differential. The thermoelectric material **256** may include a first side **258** in contact with the outside surface **238** of the fluid chamber **218**. In some cases, the thermoelectric material **256** includes a second side **260** that is opposite the first side **258** and is in contact with a heat sink **268**.

[0035] The thermoelectric material **256** may be part of an electric circuit that can pass an electric current through the thermoelectric material **256** to produce both a heated region **262** and a cooling region **264** within the thermoelectric material **256** simultaneously. A polarity switch may be incorporated into the circuit to change the direction that the electric current passes through the thermoelectric material **256**. When the electric current passes through the thermoelectric material **256** in a first direction, the heated region **262** is produced adjacent to the fluid chamber **218** and the cooling region **264** is produced adjacent to the heat sink **268**. When the heated region **262** is actively produced adjacent to the fluid chamber **218**, the electric temperature controller actively heats the fluid chamber **218**. In some cases, when the heated region **262** is produced adjacent to the fluid chamber **218**, the fluid chamber's temperature is raised to a higher temperature or the fluid chamber's temperature may be maintained to be at a desired temperature for executing a test on the drilling fluid sample **230**. In situations where the electric current passes through the thermoelectric material **256** in a second direction that is opposite of the first direction, the heated region **262** is produced adjacent to the fluid chamber **218** and the heated region **262** is produced adjacent to the heat sink **268**. In those situations where the cooling region **264** is actively produced adjacent to the fluid chamber **218**, the drilling fluid sample's temperature is lowered to a cooler temperature or the drilling fluid sample's temperature may be maintained to be at a desired temperature for executing a test on the drilling fluid sample **230**.

[0036] The temperature of the heated region **262** and the cooling region **264** may be controlled with a pulse width modulator. The pulse width modulator may switch the electric circuit on and off at a frequency rate that produces an average current flow. The longer the pulse width modulator causes electric current to flow through the thermoelectric material **256** compared to the periods where the flow of electric current is stopped, the higher the total power supplied to the thermoelectric material **256** resulting in a higher temperature being produced in the heated region **262** and a lower temperature in the cooling region **264**. The difference in temperatures between the heated region **262** and the cooling region **264** may be lowered by increasing the periods of time that the electric current is stopped from flowing through the thermoelectric material **256**. The pulse width modulator may cause the thermoelectric material **256** to adjustably heat or cool the fluid chamber **218** to each of the desired temperatures for each of the tests that are to be performed with the fluid chamber **218**.

[0037] The fluid chamber **218** may be made of a thermally conductive material that spreads the temperature produced by first side **258** of the thermoelectric material **256**. In this embodiments, the fluid chamber **218** is made of aluminum, but the fluid chamber **218** may be made of other types of thermally conductive materials. A non-exhaustive list of thermally conductive materials that may be used to make the fluid chamber **218** include aluminum, copper, gold, magnesium, beryllium, tungsten, other metals, mixtures thereof, alloys thereof, or combinations thereof. In some cases, the fluid chamber **218** is entirely made of a material that has a substantially consistent thermal conductivity. In other examples, the inside surface of the chamber wall **236** is lined with a material with a different thermal conductivity than other materials that makes up a different portion of the fluid chamber **218**.

[0038] The contact surface **240** of the outside surface **238** of the fluid chamber **218** that is adjacent to the thermoelectric material **256** may include a smooth surface roughness that is in thermal contact with the thermoelectric material **256**. In some examples, the contact surface **240** includes a polished surface. Further, in some embodiments, the contact surface **240** includes a smoother finish that other portions of the outside surface **238** of the fluid chamber **218**. The smooth finish of the contact surface **240** may reduce gaps between the thermoelectric material **256** and the outside surface **238** of the fluid chamber **218**. In some examples, a thermally conductive paste may be used to fill the gaps between the contact surface **240** and the thermoelectric material **256**. Even in examples where the contact surface **240** has a smooth finish, the contact surface **240** may still have small gaps that can minimize the thermal transfer between the thermoelectric material **256** and the fluid chamber **218** and the thermally conductive paste may be used in these examples to increase the thermal transfer.

[0039] The outside surface **238** of the fluid chamber **218** may be at least partially surrounded with an insulation layer **244**. The insulation layer **244** may minimize ambient conditions that would otherwise heat or cool the fluid chamber **218**. For example, the insulation layer **244** may prevent an ambient temperature outside of the fluid chamber **218** from heating or cooling the fluid chamber **218** away from the desired temperature for executing a rheology test. In some cases, the insulation layer **244** may prevent the formation of condensation on the outside of the fluid chamber **218**, which can cause unwanted cooling of the fluid chamber **218** when bringing the drilling fluid sample **230** to a higher temperature or trying to maintain the drilling fluid sample **230** at a higher temperature.

[0040] The fluid chamber **218** may include at least one fluid thermometer **250** that measures the temperature of the drilling fluid sample **230**. The fluid chamber **218** may also include at least one equipment thermometer **252** that may measure the temperature of at least one piece of equipment associated with the drilling fluid sample **230**. For example, the equipment thermometer **252** may measure the temperature of the material forming the fluid chamber **218**. Temperature measurements of the fluid chamber's material may prevent overheating of the fluid chamber **218**.

[0041] The heat sink **268** may be made of a thermally conductive material and include fins **270** that increase the surface area of the heat sink **268**. The fins **270** can be used to exchange temperature with a fluid medium, such as air or a liquid. In examples where the heated region **262** is produced on the second side **260**, the heat generated by the heated region **262** can spread throughout the heat sink **268** and be transferred through the fins **270** into the fluid medium. In some cases, a fan **272** is positioned adjacent to the heat sink **268** to cause air to flow through the fins **270** to increase the rate at which the heat is dissipated into the air. In other examples, a water or another type of liquid may be passed over the fins **270** as the fluid medium. In this example, the liquid medium does not make contact with the fluid chamber **218**, but instead makes contact with the fins **270** of the heat sink **268**.

[0042] FIG. **4** depicts an example of a user interface **104** of the fluid testing apparatus **100** in accordance with the present disclosure. In this example, the user interface **104** presents a format for the user to instruct the fluid testing apparatus **100** about performing the tests. In this example, the format includes sample origin options **400** to select the origin of drilling fluid sample **230**, temperature set point options **402** for each of the tests, and duration options **404** for each of the tests. Additionally, the user interface **104** presents controls for sending instructions to the fluid testing apparatus **100**.
[0043] In this example, the user is provided with five temperature set point for performing tests. While the illustrated example depicts five different temperatures for conducting the tests, any appropriate temperature values may be presented to the user as well as any appropriate number of temperature set point options may be presented.
[0044] In the depicted example, the test durations are depicted as a ten second option or a ten minute option. But, any appropriate test duration may be presented in accordance with the principles disclosed herein. Further, any appropriate number of test duration options **404** may be presented through the user interface **104**.
[0045] While the example of FIG. **4** depicts the format presenting a limited number of options that the user can select, in other examples the format presents open fields where the user may specify the values for temperature, test durations, or other testing parameters. Also, some examples may provide the user an ability to add any number of tests to the executed by the fluid testing apparatus **100**.
[0046] The controls provided in the depicted example include a start command **406**, a stop command **408**, a repeat command **410**, and a reset command **412**. The start command **406** may be selected by the user when he or she desires to start the tests. In some examples, in response to sending the start command **406**, the fluid testing apparatus **100** executes each of the tests in a sequence without having to have additional involvement from the user. In some examples, the testing sequence includes performing the first test at the lowest selected temperature set point and performing the second test at the second lowest selected temperature set point and so forth until final test is performed at the highest selected temperature set point.
[0047] FIG. **5** depicts a diagram of a system **500** for testing drilling fluid samples. The system **500** includes a processor **515**, an I/O controller **520**, memory **525**, a user interface **526**, a polarity switch **530**, a rheology sensor **535**, and an electric temperature controller **540**. These components may communicate wirelessly, through hard wired connections, or combinations thereof. The memory **525** of the system may include a test temperature determiner **545**, a temperature adjuster **550**, a temperature verifier **555**, a test initiator **560**, and a test conclusion determiner **565**. The temperature adjuster **550** includes a pulse width modulator **570**, and a polarity changer **575**.
[0048] The processor **515** may include an intelligent hardware device, (e.g., a general-purpose processor, a digital signal processor (DSP), a central processing unit (CPU), a microcontroller, an application-specific integrated circuit (ASIC), a field-programmable gate array (FPGA), a programmable logic device, a discrete gate or transistor logic component, a discrete hardware component, or any combination thereof). In some cases, the processor **515** may be configured to operate a memory array using a memory controller. In other cases, a memory controller may be integrated into the processor **515**. The processor **515** may be configured to execute computer-readable instructions stored in a memory to perform various functions (e.g., functions or tasks supporting the evaluation of prescribed optical devices).
[0049] The I/O controller **520** may represent or interact with a modem, a keyboard, a mouse, a touchscreen, or a similar device. In some cases, the I/O controller **520** may be implemented as part of the processor. In some cases, a user may interact with the system via the I/O controller **520** or via hardware components controlled by the I/O controller **520**. The I/O controller **520** may be in communication with any appropriate input and any appropriate output.
[0050] The memory **525** may include random access memory (RAM) and read only memory

(ROM). The memory **525** may store computer-readable, computer-executable software including instructions that, when executed, cause the processor to perform various functions described herein. In some cases, the memory **525** may contain, among other things, a basic input/output system (BIOS) which may control basic hardware and/or software operation such as the interaction with peripheral components or devices.

[0051] The test temperature determiner **545** represents programmed instructions that cause the processor **515** to determine the temperature at which a test is to be performed. In some examples, the test temperature is determined by accessing information the user inputted into the user interface.

[0052] The temperature adjuster **550** represents programmed instructions that cause the processor **515** to adjust the temperature of the drilling fluid sample. Part of the process of adjusting the temperature may include determining the current temperature of the drilling fluid sample and determining whether the desired temperature for the next test is higher or lower than the current temperature of the drilling fluid sample. Based on whether the temperature of the drilling fluid sample is to be increased or decreased, the polarity changer **575** may cause the processor **515** to send an instruction to the polarity switch **530** to direct electric current through the thermoelectric material in the appropriate direction. The pulse width modulator **570** may send an instruction to the electric temperature controller **540** to adjust the strength of the electric current to run through the thermoelectric material. When the temperature of the drilling fluid sample is being actively changed, the pulse width modulator **570** may cause the signal strength to be greater than when the signal strength is intended to just maintain the drilling fluid sample at its current temperature for testing.

[0053] The temperature verifier **555** represents programmed instructions that cause the processor **515** to determine the current temperature of the drilling fluid sample. This information can be consulted by the temperature adjuster **550** to determine when to change the signal strength from actively changing the temperature of the drilling fluid sample to maintaining the temperature of the drilling fluid sample.

[0054] The test initiator **560** represents programmed instructions that cause the processor **515** to cause the test to be performed with the rheology sensor **535**. The test initiator **560** may also consult information from the temperature verifier **555** to determine if the drilling fluid sample is at the appropriate temperature for executing the test.

[0055] The test conclusion determiner **565** represents programmed instructions that cause the processor **515** to determine when a test is completed. In some examples, the test conclusion determiner **565** sends a signal to the temperature adjuster at the conclusion of a test at a first temperature. In response, the temperature adjuster **550** may start the process for changing the temperature of the drilling fluid sample for the next test at a different desired temperature.

[0056] FIG. **6** depicts an example of a method **600** for automated testing of the fluid samples at different temperatures in accordance with the present disclosure. In this example, the method **600** includes supplying a drilling fluid sample into a fluid chamber, receiving **610** instructions to test the drilling fluid sample at two or more temperatures, bringing **615** the temperature of the drilling fluid sample to a first temperature of the two or more temperatures through the fluid chamber with an electric temperature controller, testing **620** the drilling fluid sample at the first temperature with a rheology sensor incorporated into the fluid chamber, automatically bringing **625** the temperature of the drilling fluid sample to a second temperature after a conclusion of a test at the first temperature with the electric temperature controller, and testing **630** the drilling fluid sample at the second temperature with the rheology sensor. At least some of the portions of this method may be carried out in accordance with the principles described in the present disclosure.

[0057] FIG. **7** depicts an example of components of a fluid testing apparatus **100** with a side loop **800** for controlling a temperature of fluid for density measurements in accordance with the present disclosure. In the depicted example, a side loop **800** is incorporated into the fluid testing apparatus

100. A second pump **806** and the density sensor **216** is incorporated into the side loop **800**. The second pump **806** may cause a portion of the drilling fluid sample **230** to enter into the side loop **800** from the fluid chamber **218** when the drilling fluid is at a desired temperature for testing the density of the drilling fluid sample **230**.

[0058] In some examples, the user interface presents the user with options to test the rheology of the drilling fluid sample **230**, to test the density of the drilling fluid sample **230**, or combinations thereof. The user may instruct the fluid testing apparatus **100** to test the drilling fluid at the same temperature at which the rheology sensor **220** tests the drilling fluid sample **230**. In other examples, the density of the drilling fluid sample **230** may be tested at a temperature that is different from at least one of the tests conducted with the rheology sensor **220**. In some cases, the electric heating controller brings the drilling fluid sample **230** to a temperature for tests performed by either the rheology sensor **220**, the density sensor **216**, another type of sensor incorporated into the fluid chamber **218**, or combinations thereof. In the example of FIG. **8**, the fluid testing apparatus **100** does not include a density sensor **216** in accordance with the present disclosure.

[0059] While the fluid testing apparatus has been described above as having a bottle receiver for connection to a bottle containing the drilling fluid sample, in some examples, no bottle receiver is incorporated into the fluid testing apparatus. For example, the user may pour the drilling fluid sample into a tank incorporated into the fluid testing apparatus. In some examples where the drilling fluid sample is incorporated into the fluid testing apparatus, a filter may be incorporated into an outlet of the tank to filter out sand, debris, other types of solids, or combinations thereof. In some cases, the user may pour the drilling fluid sample directly into the fluid chamber connected to the viscometer or other rheology sensor.

[0060] In one embodiment, a system includes a fluid conduit, a fluid chamber in communication with the fluid conduit, a rheology sensor in communication with the fluid chamber, and an electric temperature controller in communication with the fluid chamber. The fluid chamber is cooled in response to a first control signal from the electric temperature controller.

[0061] A method includes receiving instructions to test a drilling fluid sample at two or more temperatures, bringing a temperature of the drilling fluid sample to a first temperature of the two or more temperatures with an electric temperature controller, testing the drilling fluid sample at the first temperature with a fluid property sensor, automatically bringing the temperature of the drilling fluid sample to a second temperature after a conclusion of a test at the first temperature with the electric temperature controller, and testing the drilling fluid sample at the second temperature.

[0062] An apparatus includes a fluid chamber where the fluid chamber includes a chamber wall and an opening defined by the chamber wall. The apparatus also includes a rheology sensor in communication with the fluid chamber. The rheology sensor includes a rotor protruding into the opening where the rotor is supported at a depth within the opening to contact a fluid sample when the fluid chamber is filled with a fluid to an operating level. Further, the apparatus includes at least one thermal dispersion sensor that detects a level of the fluid sample when the rotor causes the fluid sample to move within the fluid chamber and an electric temperature controller in communication with the fluid chamber that is configured to control a temperature of the fluid sample within the fluid chamber.

[0063] The foregoing description, for purpose of explanation, has been described with reference to specific embodiments. However, the illustrative discussions above are not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations are possible in view of the above teachings. The embodiments were chosen and described in order to best explain the principles of the present systems and methods and their practical applications, to thereby enable others skilled in the art to best utilize the present systems and methods and various embodiments with various modifications as may be suited to the particular use contemplated.

[0064] Unless otherwise noted, the terms “a” or “an,” as used in the specification and claims, are to be construed as meaning “at least one of.” In addition, for ease of use, the words “including” and “having,” as used in the specification and claims, are interchangeable with and have the same meaning as the word “comprising.” In addition, the term “based on” as used in the specification and the claims is to be construed as meaning “based at least upon.”

Claims

1. A system, comprising: a fluid conduit; a fluid chamber in communication with the fluid conduit; a rheology sensor in communication with the fluid chamber; an electric temperature controller in communication with the fluid chamber; wherein the fluid chamber is cooled in response to a first control signal from the electric temperature controller.
2. The system of claim 1, wherein the fluid chamber is heated in response to a second control signal from the electric temperature controller.
3. The system of claim 2, wherein the second control signal has an opposite polarity than the first control signal.
4. The system of claim 1, further comprising a density sensor in communication with the fluid conduit.
5. The system of claim 4, further comprising: an inlet of the fluid conduit; and an outlet of the fluid conduit in communication with the fluid chamber; wherein the density sensor is positioned between the inlet and the outlet.
6. The system of claim 1, wherein the electric temperature controller includes a thermoelectric material that produces a heated region and a cooling region simultaneously.
7. The system of claim 6, wherein the electric temperature controller includes a pulse width modulator to control a signal strength sent through the thermoelectric material.
8. The system of claim 6, wherein the electric temperature controller includes a heat sink in communication with the thermoelectric material.
9. The system of claim 6, further comprising: a polarity switch in communication with the thermoelectric material; wherein when the polarity switch directs electricity in a first direction through the thermoelectric material, the heated region is produced on a first side of the thermoelectric material and the cooling region is produced on a second side of the thermoelectric material; wherein when the polarity switch directs electricity in a second direction, opposite to the first direction, through the thermoelectric material, the heated region is produced on the second side of the thermoelectric material and the cooling region is produced on the first side of the thermoelectric material.
10. The system of claim 1, further comprising: a processor; memory in communication with the processor, wherein the processor includes programmed instructions to: receive input to test a fluid sample in the fluid chamber with the rheology sensor at two or more different temperatures; with the electric temperature controller, bring a temperature of the fluid sample to a first temperature of the two or more different temperatures; test the fluid sample with the rheology sensor at the first temperature; automatically, with the electric temperature controller, bring the temperature of the fluid sample to a second of the two or more different temperatures; and test the fluid sample with the rheology sensor at the first temperature.
11. The system of claim 1, further including at least one level detection sensor incorporated into the fluid chamber.
12. The system of claim 11, wherein the at least one level detection sensor is a thermal dispersion sensor.
13. The system of claim 1, further including an insulation layer covering an outside surface of the fluid chamber.
14. A method, comprising: receiving instructions to test a drilling fluid sample at two or more temperatures; bringing a temperature of the drilling fluid sample to a first temperature of the two or

more temperatures with an electric temperature controller; testing the drilling fluid sample at the first temperature with a fluid property sensor; automatically bringing the temperature of the drilling fluid sample to a second temperature after a conclusion of a test at the first temperature with the electric temperature controller; and testing the drilling fluid sample at the second temperature.

15. The method of claim 14, wherein bringing the temperature of the drilling fluid sample to the first temperature or the second temperature includes applying a control signal to a thermoelectric material in thermal contact with the drilling fluid sample.

16. The method of claim 14, further including: supplying the drilling fluid sample into a fluid chamber; and detecting a drilling fluid level within the fluid chamber with a thermal dispersion sensor incorporated into the fluid chamber.

17. An apparatus, comprising: a fluid chamber, the fluid chamber including: a chamber wall; and an opening defined by the chamber wall; a rheology sensor in communication with the fluid chamber, the rheology sensor further including: a rotor protruding into the opening; the rotor being supported at a depth within the opening to contact a fluid sample when the fluid chamber is filled with a fluid to an operating level; at least one thermal dispersion sensor that detects a level of the fluid sample when the rotor causes the fluid sample to move within the fluid chamber; an electric temperature controller in communication with the fluid chamber that is configured to control a temperature of the fluid sample within the fluid chamber.

18. The apparatus of claim 17, wherein the electric temperature controller further includes: at thermoelectric material; a first side of the thermoelectric material being in contact with an outside surface of the fluid chamber; and a second side of the thermoelectric material being in contact with a heat sink.

19. The apparatus of claim 18, wherein the thermoelectric material has a characteristic of: producing a heated region adjacent to the fluid chamber and a producing a cooling region adjacent to the heat sink in response to a first control signal applied across the thermoelectric material; and producing the heated region adjacent to the heat sink and a producing the cooling region adjacent to the fluid chamber in response to a second control signal applied across the thermoelectric material when the second control signal has an opposite polarity to the first control signal.

20. The apparatus of claim 18, further comprising: a processor; memory in communication with the processor, wherein the processor includes programmed instructions to: receive input to test the fluid sample in the fluid chamber with the rheology sensor at multiple temperatures; automatically bring and maintain the temperature of the fluid sample to each of the multiple temperatures; and automatically test the fluid sample with the rheology sensor at each of the multiple temperatures.