



(51) International Patent Classification:
E21B 49/08 (2006.01)

(21) International Application Number:
PCT/US2017/032271

(22) International Filing Date:
11 May 2017 (11.05.2017)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
15/166,910 27 May 2016 (27.05.2016) US

(63) Related by continuation (CON) or continuation-in-part (CIP) to earlier application:
US 15/166,910 (CON)
Filed on 27 May 2016 (27.05.2016)

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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC,

(54) Title: WELL FLUID ANALYSIS SYSTEM

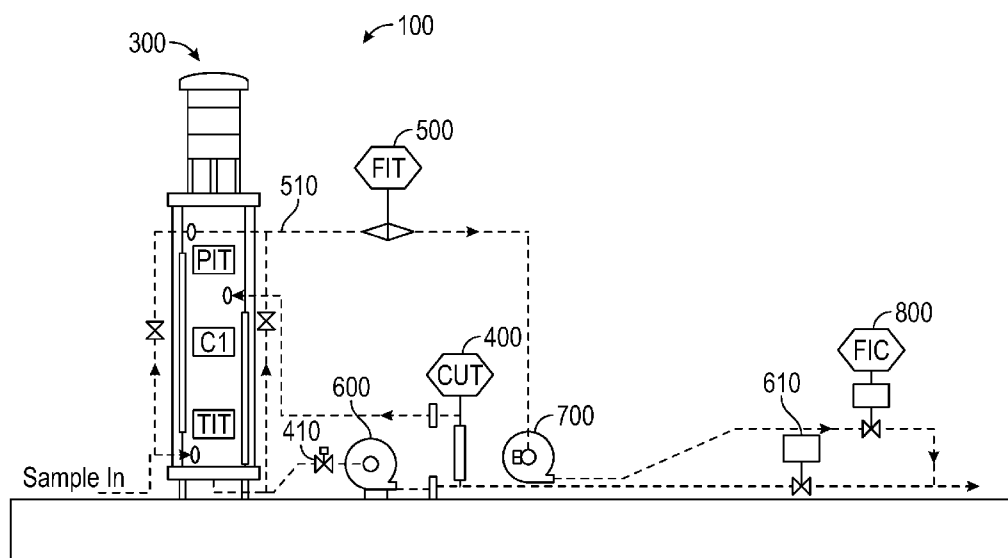


FIG. 1

(57) Abstract: An oil well production analyzing system receives production fluid samples from the oil well according to an automated sampling schedule. The fluid samples are taken from a pipeline through a sampling apparatus to obtain a representative sample. The representative sample flows into a circulation loop having a circulating pump, a water cut analyzer, and a cylindrical vessel, with interconnecting piping and actuated valves there between, with the actuated valves and the circulating pump controlled by a digital processor. Once a determination of the percentage of water and oil in the sample has been determined, the processor stops the circulating pump and activates a piston in the cylindrical vessel which sweeps the cylindrical vessel of any fluid contained in the vessel in preparation of receiving a subsequent fluid sample from the oil well.

SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR,
TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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

Published:

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

WELL FLUID ANALYSIS SYSTEM

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CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to and claims the benefit of U.S.S.N. 15/166,910 filed May 27, 2016, which is incorporated herein by reference in its entirety.

BACKGROUND

10 The present technology relates to a hydrocarbon well production analysis system. The present technology generally relates to the on-sight analysis of fluids produced from hydrocarbon producing wells and the measurement of flow rates of those fluids. In particular, the present technology relates to devices which provide real-time determination of the relative components of the fluids produced from hydrocarbon producing wells and the flow rates of each of the relative components, both instantaneous and over a particular
15 period of time.

 A determination of the percentage of water with respect to the volume of total liquids produced by the well -- the "water cut" -- is important for determination of the economic viability of a well because excessive water production increases lifting and separation expense, plus the produced water must be properly disposed. In addition, an
20 accurate real-time determination of water cut, when used in conjunction with other parameters such as oil gravity and gas liquid ratio, may be utilized to determine the real-time density of the produced fluid. Knowing the real-time density of the produced fluid may be utilized in conjunction with various devices, such as rod string load cells, to determine downhole pressures and real-time production rates. Knowing the water cut of
25 individual wells on a real time basis also facilitates field wide reservoir analysis and management. For example, in a water flood operation, the detection of a sudden increase in a well's water cut provides useful information regarding the effectiveness of the flood.

 The present well test systems typically require a relatively large test vessel into which the flow from a particular well may be directed by diverting the flow from the field
30 production system into the test system. The test system will allow produced gas to separate from the other produced fluids, and then typically allow oil and water to separate

by gravity separation over time. However, particularly with heavy crudes which may have gravities approaching that of water, gravity alone is not always sufficient. Emulsions also present difficulties in determining the relative percentages of water and oil in a well's production stream. Heat may be applied to the test vessel to assist in separating the oil and water or in breaking up oil and water emulsions. Flootation devices may be utilized which inject large quantities of small-diameter gas bubbles into streams of primarily water such that the gas bubbles attach to oil droplets suspended in the water stream. These separation devices are expensive and typically require a given volume of produced fluid to remain in the test vessel for sufficient time to allow oil and water separation. Before a successive well can be tested, the test system must be purged of produced fluids from the prior test.

It is known that separation of the free gas phase from the liquid phase in a sample is desired prior to making a water cut determination is made. The American Society for Testing and Materials ("ASTM") and the American Petroleum Institute ("API") have provided a Standard Test Method for Water and Sediment in Crude Oil by the Centrifuge Method (D 4007) which provides a laboratory procedure for making water cut determinations. This method is generally accurate because, among other reasons, free gas has already separated from the oil. However, this operation is time consuming and requires manual processing of the sample. It is not a method which may be replicated in the field for real time determination of water cut. Instead, the field determination of water cut will typically employ a number of various water cut meters. These meters utilize various operating principles and hardware to make the water cut determination, such as dielectric measurements using radio or microwave frequencies, optical detectors for detecting near infrared wavelengths, and gamma ray based instruments.

SUMMARY

The presently disclosed apparatus ascertains a relative percentage of water contained in a liquid phase of a fluid sample received from an oil well under real-time producing conditions. Embodiments of the disclosed apparatus include a sampling probe which acquires a representative sample of the fluid flowing through a well's production line.

The fluid sample may comprise a liquid phase and a gas phase, while the liquid

30 phase comprises an oil component and a water component. Gas separation may occur prior to taking the sample from the well's production line. Alternatively, embodiments of the present invention provide for gas separation to be achieved through the system itself.

In one embodiment of the disclosed systems, a pipe receives fluid received from the oil well. A representative sample of the produced fluid is acquired from a sampling
5 apparatus which has one or more probes installed through a wall of the pipe. The sample of the produced fluid flows into the sampling probe when a valve hydraulically connected to the outlet of the sampling probe opens. A circulating pump has an inlet hydraulically connected to the sampling probe. The circulating pump receives the sample of the produced fluid and discharges the sample to a cut analyzer connected to the pump
10 discharge. The cut analyzer ascertains the relative percentages of water and oil in the first portion of fluid as it is circulated through the analyzer.

The sampling apparatus will typically be downstream of an inline mixer. The sampling probe(s) of the sampling apparatus is installed through a wall of the pipe through which the fluid to be sampled is flowing. In one embodiment of the sampling
15 apparatus, a first probe is inserted through a wall of the pipe downstream of an inline mixer. The first probe comprises a first shaft having a first terminal end and a first outlet end. A portion of the first shaft spans substantially across the internal diameter of the pipe. The first shaft further has an internal axial passage which extends from adjacent the first terminal end through to the first outlet end. The first shaft also has a first upstream
20 face facing towards the inline mixer and a first downstream face facing away from the direction of the downstream mixer. The first upstream face of the sampling probe has a solid wall and the first downstream face has plurality of spaced-apart radial slots extending through from the first downstream face to the first axial passage.

The sampling apparatus may also have a second probe installed through a wall of
25 the pipe downstream of the outlet of the inline mixer. The second probe will substantially have the same structural elements as described above for the first probe. The first probe and the second probe may be installed such that the first probe and second probe are perpendicular to one another. With this configuration, a sample taken by the sampling apparatus will be representative of the fluid flowing through the pipe at the time
30 of the sampling.

As the sample of produced fluid is circulated through the system, it flows through a cut analyzer, through a vessel inlet and into a cylindrical vessel which is hydraulically connected to the cut analyzer. The liquid phase of the sample, and any remaining entrained or dissolved gas, flows out through an outlet of the cylindrical vessel, such that a circulation loop is defined as the fluid sample is circulated by the circulating pump through the cut analyzer and the cylindrical vessel.

As the sample is circulated, gas phase components which come out of solution are vented out of the cylindrical vessel through a gas outlet. The sample is circulated through the circulation loop until such time as the water cut analyzer reports consistent relative percentages of water and oil, as determined by specified tolerance values inputted into a processor which controls the system. Once the water cut analyzer reports consistent relative percentages of water and oil according to the pre-determined values, the processor stops the circulating pump and a piston within the cylindrical vessel displaces all fluids contained within the cylindrical vessel in preparation for receipt of the next sample.

The piston is moveable from a first position to a second position, wherein substantially all fluids contained within the cylindrical vessel are displaced from the cylindrical vessel as the piston moves from the first position to the second position. A first sensor is connected to the cylindrical vessel, where the first sensor ascertains when the piston is in the first position. A second sensor ascertains when the piston is in the second position.

In this embodiment, the fluid is swept from the sampling cylinder as the piston moves from a "raised" position to a "lowered" position. Fluid is discharged from the cylindrical vessel as the piston moves from the raised to the lowered position. It is to be noted that, as utilized within this disclosure, the terms "raised," "lowered," "top," "bottom," etc., are made with respect to the orientations of the piston and cylinder as depicted in the figures herein. However, the operation of the system is not dependent upon the components of the system being oriented as depicted in the drawings. Therefore, the use of the terms "raised," "lowered," "top," "bottom," etc. should be understood to be consistent with the a "raised" piston being in the initial position before it

sweeps a cylinder and a "lowered" piston being in its final position after it has swept the cylinder and cleared all fluid from the cylinder.

It is to be noted that the presently disclosed invention can utilize almost any of the types of devices for the eventual water cut determination. The presently disclosed invention improves the accuracy of these devices by providing a sample, on the fly at real-time conditions, where the sample is essentially gas free and, optionally, heated to API standard temperature for water cut determination. The inventor herein has found that PHASE DYNAMIC water cut analyzers, which utilize the difference between the electrical characteristics of the water and oil to determine water content, are acceptable for use for water cut determination, but other water cut analyzers may be utilized as well.

A vacuum pump may be connected to the cylindrical vessel to facilitate gas separation as the sample flows through the circulation loop. Alternatively, the vacuum may be applied from an external source, such as a field gas collection system.

Gas which has been evacuated from cylindrical vessel may be directed to a gathering line and measured through a gas flow meter, and if desired, a gas chromatograph to ascertain the gas stream constituents as discussed below. The gas flow meter may provide output to the processor as well.

The piston utilized in the cylindrical vessel may be configured with a piston head and seals which efficiently sweep the cylinder clear of all fluids contained within the cylinder, such that there is little or no mingling of samples as each sample is processed through the system. The cylinder wall may be lined with a material which is non-stick and capable of receiving high temperature fluids.

The sample may be heated within the cylindrical vessel to further effect separation of the gas phase and liquid phase and separation of the liquid phase components. The heating means will typically be of the electrical resistance type, such as heat blanketing wrapped about the cylindrical vessel. However, process heat might also be utilized with cylindrical vessel with a heat exchanger receiving process fluids such as steam or heated liquids. For such embodiments, the cylindrical vessel may be connected to one or more heat sensors which detect, or provide output to the processor which may be utilized to regulate the temperature of the fluid contained within system according to pre-set values.

It should be understood that all sensors utilized with embodiments of the device may be located outside of the cylindrical vessel, which greatly facilitates maintenance and repair. In addition, the sensors may be of the type which provide output signals compatible for receipt as input to a digital processor for either data collection or control purposes.

The piston in the cylindrical vessel may be actuated by a variety of actuation devices, including a low voltage servo motor. This motor may be actuated by the digital processor described above, such that a piston operating within the cylindrical vessel operates according to conditions which may be detected by, among other things, the position sensors and temperature sensors described above, as well as flow sensors which may be utilized in the system. Among other possible input received by the processor and in addition to the other devices listed herein, the processor may also receive load information from a polish rod load cell, pressure transducers detecting the pressure of the cylindrical vessel or downhole devices, water salinity from the water cut analyzer, gas flow rates from the gas flow meter, and other devices utilized in the industry.

The processor may therefore be utilized to manage the flow of a sample through the system, determining the time required to contain a satisfactory liquid sample for water cut determination, as well as controlling piston position, heat, etc. of the system. In these embodiments, the processor controls a plurality of solenoid operated valves to manage the flow of fluids through the system. In addition, the processor may, based upon the data received through the gas meter, gas analyzer, water cut analyzer, etc., calculate a real time fluid density. Once known, the real time fluid density may be utilized in conjunction with a rod string load analyzer to ascertain flow rates and downhole flowing pressure.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a general schematic of an embodiment of the analyzing apparatus.

Figure 2 shows an embodiment of a analyzing cylinder, piston and related components which may be used with the apparatus.

Figure 3 shows a process flow diagram for an embodiment of the present invention.

Figure 4 shows a perspective view of an embodiment of a cylinder which may be utilized in embodiments of the present invention.

Figure 5 shows a perspective view of an embodiment of a piston which may be utilized in embodiments of the present invention.

5 Figure 6 shows a side view of the piston of Figure 5.

Figure 7 shows a sectional view taken along line 7-7 of Figure 6.

Figure 8 shows a portion of an embodiment of the analyzing apparatus showing the location where a sample may be extracted.

Figure 9 shows a close-up view of a static mixer and a sampling apparatus.

10 Figure 10 shows an end view of the static mixer and sampling apparatus of Figure 9.

Figure 11 shows a perspective view of a sampling probe or quill which may be utilized in embodiments of the presently disclosed analyzing apparatus.

15 Figure 12 shows a side view of the sampling probe of Figure 11, showing a detailed view of the slots.

Figure 13 shows a front view of the sampling probe of Figure 11.

Figure 14 shows a section view taken along line 14-14 of Figure 13.

Figure 15 shows a top view of the sampling probe of Figure 11.

20 Figure 16 exemplifies an operator screen of a digital processor which provides data display and/or control of embodiments of the disclosed apparatus.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Figure 1 schematically depicts an embodiment of the presently disclosed hydrocarbon well production analysis system 100 according to the present invention. A fluid sampling system 200 for obtaining a representative fluid sample from pipeline 10 is described in further detail below. With respect to the hydrocarbon analysis system depicted in Figure 1, the major components of this embodiment include cylindrical vessel 300, water cut analyzer 400, gas flow meter 500, circulating pump 600, gas compressor 700, and flow control valve 800. A digital processor 1000, not shown in Figure 1, provides, among other things, control of the process flow of the analysis system and reporting of the analysis results. It is to be appreciated that the components of the

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production analysis system 100 may be relatively small, fitting within an instrument cabinet or mounted on a transportable skid for easy movement between locations. Flow volumes may be relatively small and interconnecting piping may be ½ inch stainless steel tubing.

5 Figure 2 schematically depicts an embodiment of a cylindrical vessel 300 which may be utilized with the present system. The cylindrical vessel may be fabricated from 316 stainless steel. The size of the vessel may change depending upon a variety of factors, such as the gas-oil ratio and viscosity of the test fluid or whether the test fluid is an emulsion. For test fluids requiring little residence time in the system, such as fluids
10 which have already been degasified and/or containing non-emulsified light gravity crude, the cylindrical vessel may be relatively small, perhaps having an outside diameter of 3 inches with an overall height (or length) of 36 inches, resulting in an approximate volume of 1.5 gallons of fluid. However, for low gravity crude (having a gravity approaching the gravity of the produced water), a larger cylindrical vessel will normally be desired. A
15 cylindrical vessel for these applications may have a diameter and height which provides a volume of 10 gallons of fluid or greater.

 The internal surface of cylindrical vessel 300 may be coated with a non-stick liner suitable for high temperature surface, which facilitates the removal of sample fluid from the cylindrical vessel 300. The cylindrical vessel 300 should be rated for a minimum of
20 300 psig, assuming a vacuum of 2.0 inches of water is applied to the vessel. The cylindrical vessel 300 may be equipped with a rupture disc (not shown). Cylindrical vessel 300 receives a fluid sample through inlet 302. Vent 304 provides for the outflow of gas phase components into a gas collection line 510 which may be transmitted to a gas flow meter 500.

25 Cylindrical vessel 300 has a piston 310 which may have o-ring seals 312. The o-ring seals 312 may be configured as double seals having an adjustable wear backing ring. Piston 310 may have a head portion 314 which has a profile which mates with the profile of the bottom 306 of cylindrical vessel 300, thereby providing for greater sweep efficiency of the cylindrical vessel 300 by piston 310. Piston 310 may be actuated by a
30 low voltage servo motor 330.

The cylindrical vessel 300 may be heated to promote separation of any free gas, and also to allow the liquid phase components to reach American Petroleum Institute ("API") standard temperatures for testing water cut through water cut analyzer 400. The means for heating the sampling cylinder 300 may comprise an electrical resistance heating element, such as in a heat blanket 326 or it utilize process heat in conjunction with a heat exchanger receiving process fluids such as steam or heated liquids. The cylindrical vessel 300 may be connected to one or more heat sensors 328 which detect the internal temperature of the cylindrical vessel 300.

Cylindrical vessel 300 has an outlet 324 which is hydraulically connected to the intake of circulating pump 600, which flow from the outlet controlled by solenoid operated valve 410. A sampling probe 332 may detect flowing liquid temperature at outlet 324 and provide this information to processor 1000.

The fluid sample is circulated through water cut analyzer 400 which determines the relative percentages of water and oil in the circulating liquid phase. Water cut analyzer 400 may provide data output to processor 1000. Once stable and consistent water cut information is detected by the water cut analyzer 400, the circulation of the liquid phase through the circuit may be ceased by the issuance of instructions to a motor controller for circulating pump 600. Once circulation has stopped, automated valve 410 is closed by instructions from processor 1000 and automated valve 610 is opened by instructions from processor 1000 for return of the liquid phase components to a group line. Upon the completion of the water cut analysis, piston 310 may be actuated by servo motor 330 to clear any remaining fluid inside cylindrical vessel 300 for discharge from the disclosed oil well production analyzing system 100 and discharge from the system as desired, such as by return to the group line and gathered with production from other wells.

Appropriate interconnect piping for the oil well production analyzing system 100 is one half-inch stainless steel tubing with fittings, utilizing stainless steel ASCO solenoid and check valves. The oil well production analyzing system 100 may be configured as a compact skid package to facilitate transportation and installation of the unit. For example, the entire system may be configured into a unit 40 inches long by 40 inches tall by 30 inches wide.

Figures 8 through 15 depicts an embodiment of a fluid sampling system 200 which may be utilized in combination with the presently disclosed well production analysis system 100. The fluid sampling system 200 provides representative fluid samples to the system 100. Figure 8 depicts a piping configuration 202 which may be
5 utilized in conjunction with embodiments of the well production analysis system 100. This piping configuration may include a mass flow meter 204 set within a bypass loop 206 into which the fluid sampling system 200 may be installed, where the sample is taken of fluid flowing through pipe 214.

Representative fluid samples are received through sampling line 210 by the
10 operation of actuated valve 212 which allows flow of the sample into the well production analysis system 100. Pipe 214 has a fluid flowing through it as depicted by the arrows. Pipe 214 has an internal diameter D_i . The sampling system 200 may be fabricated into the pipe 214 as a segment of the piping. Sampling system 200 has an inline mixer 216. Inline mixer 216 is a static mixer which allows for continuous blending of fluids within
15 pipe 214 utilizing the energy of the flow stream to generate the mixing. Inline mixer 216 has an inlet 218 and an outlet 220.

The fluid sampling system 200 has a probe 222 which is installed into a tee fitting or alternatively into a welded or threaded reinforced branch fitting, such as a WELDOLET or THREADOLET (not shown) which provides access through a wall 224
20 of the piping segment. The probe 222 is installed immediately adjacent to the outlet 220 of the inline mixer 216. The reinforced branch fitting or tee fitting may have threads which receive threads 226 of the head 228 of the probe 222. Head 228 may have attached a fitting 230 having $\frac{1}{2}$ inch MNPT (male national pipe thread) with a flared bevel on the opposite end of the threads 232 which make up into internal threads 234 at
25 the top of head 228. External threads 226 of head 228 may likewise be $\frac{1}{2}$ inch

Probe 222 has a shaft 236 which depends from head 228. The shaft 236 has a terminal end 238 and an outlet end 240. Terminal end 238 may be plugged as shown in Figure 14, but an axial passage 242 extends from a point immediately adjacent to the plugged end of terminal end 238 through to the outlet end 240 and out of head 228. As
30 shown in Figure 10, the portion of the shaft 236 extending from terminal end 238 to outlet end 240 spans substantially across the internal diameter D_i of the pipe 214.

Shaft 236 has an upstream face 242 which faces toward the outlet 220 of inline mixer 216. As shown in Figure 12, the upstream face 242 of shaft 236 is solid, i.e., the upstream face 242 has no openings penetrating into axial passage 242. Opposite upstream face 242 is downstream face 244. Downstream face 244 has a plurality of spaced-apart radial slots 246. Slots 246 may extend approximately through half of shaft 236. Each slot may be spaced 0.2 inches from an adjacent slot. Radial slots 246 penetrate through the wall of shaft 236 to provide a flow path to axial passage 242, such that a portion of a representative fluid sample enters into shaft 236 only by passing through slots 246 in the downstream face 244.

As shown in Figure 10, the fluid sampling system 200 may have a second probe 222 which is identical to the first probe described above. As further shown in Figure 10, the first probe 222 and the second probe 222 may be configured to be perpendicular to one another.

With the probe(s) 222 configured and installed as described above, a fluid sample taken from pipe 214 will flow into the axial passage 242 of shaft 236 through spaced-apart radial slots 246 on the downstream face 244 of the shaft, with the fluid sample taken along the entire diameter of pipe 214. If two probes 222 are configured as shown in Figure 10, the sample is being drawn from across a vertical and horizontal axis, each extending across nearly the entire internal diameter of the pipe 214 thereby collecting a sample along the entire flow profile, which is particularly useful for two phase fluid flow, such as a gas phase and a liquid phase, or in fluid flows where gravitational separation of individual components may occur, such as with some hydrocarbon fluids produced from different wells, or from different producing zones of a single well, where the hydrocarbons are combined into a single pipeline.

Because the radial slots 246 are on the downstream face 244 of the shaft 236, the sample will be acquired from fluid which has already flowed past the shaft and the radial slots will not be subject to plugging from any solids which may be entrained in the flowing fluid. This configuration further facilitates backwashing of the radial slots 246 when cleaning of the probe 222 is required.

The dimensions of sampling probe 222 may vary according the size of pipe 214. By way of example only, the total length of probe 222, without fitting 230, may be 4 ¼

inches, with shaft 226 having a length of 2 ½ inches extending below threads 226 of head 228. Shaft 226 may have an outside diameter of ½ inch. Radial slots 246 may extend into shaft 226 by ¼ inch, or half-way through the diameter. Radial slots 246 may be spaced by 0.190 inches from center to center — i.e., each slot spaced less than 0.2 inches
5 from an adjacent slot.

Figure 16 schematically shows a display from a digital processor 1000 which may be utilized with embodiments of the well production analyzing system 100. As exemplified by the schematic of Figure 16, the processor display may show a calculated gross daily production rate, daily oil rate, and water rate, which would be calculated by
10 the processor based upon input received from a load cell or other device. The processor 1000 may also display the water cut for a given sample, the temperatures of the fluid sample at the inlet of the device and the temperature of the liquid sample as it flows to the water cut analyzer 400. The processor may also display the current pressure and/or vacuum within the cylindrical vessel 300. Control of the well production analyzing
15 system 100 may also be performed at controls on the digital processor 1000, where the controls provide for manual or automated operation of the system, or allowing the system to be placed offline. The digital processor 1000 may provide a display which shows the status of the various components, such as the position of the piston 310 inside the cylindrical vessel 300.

It is to be appreciated that the cycling of the oil well production analyzing system 100 is controlled by the processor 1000 based upon real time conditions observed through the various sensors and controlled through the actuation of various end devices as determined appropriate by the processor. Thus, operation of the cylindrical vessel 300 0 and the various other control devices may be varied according to the observed conditions
25 and as desired for the particular field. For example, the timing of the sampling and volume of produced fluid tested for a particular well may be adjusted as necessary to obtain consistent and representative information.

While the above is a description of various embodiments of the present invention, further modifications may be employed without departing from the spirit and scope of the present invention. Thus the scope of the invention should not be limited according to
30 these factors, but according to the following appended claims.

All elements, parts and steps described herein are preferably included. It is to be understood that any of these elements, parts and steps may be replaced by other elements, parts and steps or deleted altogether as will be obvious to those skilled in the art.

Broadly, this writing discloses at least the following: An oil well production analyzing system receives production fluid samples from the oil well according to an automated sampling schedule. The fluid samples are taken from a pipeline through a sampling apparatus to obtain a representative sample. The representative sample flows into a circulation loop having a circulating pump, a water cut analyzer, and a cylindrical vessel, with interconnecting piping and actuated valves there between, with the actuated valves and the circulating pump controlled by a digital processor. Once a determination of the percentage of water and oil in the sample has been determined, the processor stops the circulating pump and activates a piston in the cylindrical vessel which sweeps the cylindrical vessel of any fluid contained in the vessel in preparation of receiving a subsequent fluid sample from the oil well.

This writing presents at least the following Concepts:

1. A system for ascertaining a relative percentage of water and a relative percentage of oil contained in a liquid phase of a fluid received from a well, the system comprising:

- 5 a pipe which receives the fluid received from the well;
a sampling apparatus comprising a first sampling probe extending through a wall of the pipe, the first sampling probe hydraulically connected to a first valve, where upon the opening of the first valve a first portion of the fluid enters the first sampling probe;
a circulating pump having a pump inlet and a pump discharge, wherein the inlet is
10 hydraulically connected to the first sampling probe and receives the first portion of the fluid upon the opening of the first valve;
a cut analyzer connected to the pump discharge, the cut analyzer capable of ascertaining the relative percentages of water and oil in the first portion of fluid;
a cylindrical vessel having a vessel inlet hydraulically connected to the cut
15 analyzer, and a vessel outlet, wherein a circulation loop is defined by the interconnected circulating pump, the cut analyzer and the cylindrical vessel;
a piston disposed within the cylindrical vessel, wherein, upon completion of ascertaining the relative percentages of water and oil in the first portion of fluid, the piston is moveable from a first position to a second position, wherein substantially all of
20 any fluid contained within the cylindrical vessel is displaced from the cylindrical vessel as the piston moves from the first position to the second position; and
a first sensor connected to the cylindrical vessel which ascertains when the piston is in the first position and a second sensor which ascertains when the piston is in the second position.

- 25 2. The system of concept 1 wherein the first sampling probe comprises a first shaft, wherein the first shaft comprises a first terminal end and a first outlet end, wherein a portion of the first shaft spans substantially across the internal diameter of the pipe, the first shaft further comprising a first axial passage extending from adjacent the first terminal end through to the first outlet end, the first shaft further comprising a first
30 upstream face facing an incoming flow of the fluid and a first downstream face in opposite relation to the first upstream face, wherein the first downstream face comprises a

first plurality of spaced-apart radial slots extending through from the first downstream face to the first axial passage, wherein the first portion of the fluid enters the first plurality of spaced-apart radial slots, enters the first axial passage and exits the first outlet end.

5 3. The system of concept 1 wherein the cylindrical vessel comprises a heater for heating the fluid.

 4. The system of concept 1 wherein the piston is actuated by a low voltage servo motor.

 5. The system of concept 1 further comprising a processor which receives input from the first sensor and the second sensor.

 6. The system of concept 5 wherein the processor provides output signals which cause the piston to move back and forth between the first position and the second position.

 7. The system of concept 6 wherein the piston moves back and forth between
15 the first position and the second position by a low voltage servo motor which receives the output signals from the processor.

 8. The system of concept 1 wherein the first valve is a solenoid operated valve which is instructed to open by a processor after any fluid contained in the cylindrical vessel is displaced from the cylindrical vessel.

20 9. The system of concept 1 wherein the cylindrical vessel comprises a gas outlet for discharging any gas phase present in the first portion of the fluid.

 10. The system of concept 9 wherein a vacuum pump is hydraulically connected to the gas outlet.

 11. A system for ascertaining a relative percentage of water and a relative
25 percentage of oil contained in a liquid phase of a fluid received from a well, the system comprising:

 a pipe which receives the fluid received from the well;

 a first sampling probe extending through a wall of the pipe, the first sampling probe hydraulically connected to a first solenoid operated valve, where upon the opening
30 of the first solenoid operated valve a first portion of the fluid enters the first sampling probe;

a circulation loop comprising a circulating pump, a cut analyzer, and a cylindrical vessel wherein a second solenoid operated valve controls flow from the circulating pump into the cut analyzer, and a third solenoid operated valve controls flow from the cylindrical vessel into the circulating pump, wherein the circulation loop is
5 hydraulically connected to the first sampling probe and receives the first portion of the fluid upon the opening of the first valve;

wherein the cut analyzer is capable of ascertaining the relative percentages of water and oil in the first portion of fluid as the first portion of fluid is circulated through the circulation loop;

10 a piston disposed within the cylindrical vessel, wherein, upon completion of ascertaining the relative percentages of water and oil in the first portion of fluid, the piston is moveable from a first position to a second position, wherein substantially all of any fluid contained within the cylindrical vessel is displaced from the cylindrical vessel as the piston moves from the first position to the second position; and

15 a first sensor connected to the cylindrical vessel which ascertains when the piston is in the first position and a second sensor which ascertains when the piston is in the second position.

12. The system of concept 11 further comprising a processor which receives input from the first sensor and the second sensor.

20 13. The system of concept 12 wherein the processor provides output signals which cause the piston to move back and forth between the first position and the second position.

14. The system of concept 12 wherein the processor provides instructions to the first solenoid operated valve, the second solenoid operated valve, and the third solenoid
25 operated valve when to open and close.

15. A system for ascertaining a relative percentage of water and a relative percentage of oil contained in a liquid phase of a fluid received from a well, the system comprising:

a pipe which receives the fluid received from the well;

a first solenoid operated valve hydraulically connected to the pipe where upon the opening of the first solenoid operated valve a first portion of the fluid is drawn into a cylindrical vessel by a circulating pump;

a cut analyzer hydraulically connected to the cylindrical vessel, the cut analyzer
5 capable of ascertaining the relative percentages of water and oil in the first portion of fluid;

a circulation loop wherein the first portion of the fluid is circulated by the circulating pump through the cut analyzer and the cylindrical vessel, the circulation loop comprising a second solenoid operated valve which, upon opening, the first portion of the
10 fluid is circulated through the circulation loop;

a piston disposed within the cylindrical vessel, wherein, upon completion of ascertaining the relative percentages of water and oil in the first portion of fluid, the piston is moveable from a first position to a second position, wherein substantially all of any fluid contained within the cylindrical vessel is displaced from the cylindrical vessel as
15 the piston moves from the first position to the second position;

a first sensor connected to the cylindrical vessel which ascertains when the piston is in the first position and a second sensor which ascertains when the piston is in the second position; and

a processor which receives input from the first sensor and the second sensor and
20 which provides instructions to the first solenoid operated valve and the second solenoid operated valve to open and close.

16. The system of concept 15 wherein the pipe which receives the fluid received from the well comprises a mass flow meter which transmits a mass flow rate to the processor.

25 17. The system of concept 15 wherein the piston moves back and forth between the first position and the second position by a low voltage servo motor which receives the output signals from the processor.

18. The system of concept 15 wherein the cylindrical vessel comprises a gas outlet for discharging any gas phase present in the first portion of the fluid.

30 19. The system of concept 18 wherein a vacuum pump is hydraulically connected to the gas outlet.

20. The system of concept 15 wherein the cylindrical vessel comprises a heater for heating the fluid.

5

What is claimed is:

1. A system for ascertaining a relative percentage of water and a relative percentage of oil contained in a liquid phase of a fluid received from a well, the system comprising:

- 5 a pipe which receives the fluid received from the well;
a sampling apparatus comprising a first sampling probe extending through a wall of the pipe, the first sampling probe hydraulically connected to a first valve, where upon the opening of the first valve a first portion of the fluid enters the first sampling probe;
a circulating pump having a pump inlet and a pump discharge, wherein the inlet is
10 hydraulically connected to the first sampling probe and receives the first portion of the fluid upon the opening of the first valve;
a cut analyzer connected to the pump discharge, the cut analyzer capable of ascertaining the relative percentages of water and oil in the first portion of fluid;
a cylindrical vessel having a vessel inlet hydraulically connected to the cut
15 analyzer, and a vessel outlet, wherein a circulation loop is defined by the interconnected circulating pump, the cut analyzer and the cylindrical vessel;
a piston disposed within the cylindrical vessel, wherein, upon completion of ascertaining the relative percentages of water and oil in the first portion of fluid, the piston is moveable from a first position to a second position, wherein substantially all of
20 any fluid contained within the cylindrical vessel is displaced from the cylindrical vessel as the piston moves from the first position to the second position; and
a first sensor connected to the cylindrical vessel which ascertains when the piston is in the first position and a second sensor which ascertains when the piston is in the second position.

- 25 2. The system of claim 1 wherein the first sampling probe comprises a first shaft, wherein the first shaft comprises a first terminal end and a first outlet end, wherein a portion of the first shaft spans substantially across the internal diameter of the pipe, the first shaft further comprising a first axial passage extending from adjacent the first terminal end through to the first outlet end, the first shaft further comprising a first
30 upstream face facing an incoming flow of the fluid and a first downstream face in opposite relation to the first upstream face, wherein the first downstream face comprises a

first plurality of spaced-apart radial slots extending through from the first downstream face to the first axial passage, wherein the first portion of the fluid enters the first plurality of spaced-apart radial slots, enters the first axial passage and exits the first outlet end.

5 3. The system of claim 1 wherein the cylindrical vessel comprises a heater for heating the fluid.

 4. The system of claim 1 wherein the piston is actuated by a low voltage servo motor.

 5. The system of claim 1 further comprising a processor which receives input
10 from the first sensor and the second sensor.

 6. The system of claim 5 wherein the processor provides output signals which cause the piston to move back and forth between the first position and the second position.

 7. The system of claim 6 wherein the piston moves back and forth between
15 the first position and the second position by a low voltage servo motor which receives the output signals from the processor.

 8. The system of claim 1 wherein the first valve is a solenoid operated valve which is instructed to open by a processor after any fluid contained in the cylindrical vessel is displaced from the cylindrical vessel.

20 9. The system of claim 1 wherein the cylindrical vessel comprises a gas outlet for discharging any gas phase present in the first portion of the fluid.

 10. The system of claim 9 wherein a vacuum pump is hydraulically connected to the gas outlet.

 11. A system for ascertaining a relative percentage of water and a relative
25 percentage of oil contained in a liquid phase of a fluid received from a well, the system comprising:

 a pipe which receives the fluid received from the well;

 a first sampling probe extending through a wall of the pipe, the first sampling probe hydraulically connected to a first solenoid operated valve, where upon the opening
30 of the first solenoid operated valve a first portion of the fluid enters the first sampling probe;

a circulation loop comprising a circulating pump, a cut analyzer, and a cylindrical vessel wherein a second solenoid operated valve controls flow from the circulating pump into the cut analyzer, and a third solenoid operated valve controls flow from the cylindrical vessel into the circulating pump, wherein the circulation loop is
5 hydraulically connected to the first sampling probe and receives the first portion of the fluid upon the opening of the first valve;

wherein the cut analyzer is capable of ascertaining the relative percentages of water and oil in the first portion of fluid as the first portion of fluid is circulated through the circulation loop;

10 a piston disposed within the cylindrical vessel, wherein, upon completion of ascertaining the relative percentages of water and oil in the first portion of fluid, the piston is moveable from a first position to a second position, wherein substantially all of any fluid contained within the cylindrical vessel is displaced from the cylindrical vessel as the piston moves from the first position to the second position; and

15 a first sensor connected to the cylindrical vessel which ascertains when the piston is in the first position and a second sensor which ascertains when the piston is in the second position.

12. The system of claim 11 further comprising a processor which receives input from the first sensor and the second sensor.

20 13. The system of claim 12 wherein the processor provides output signals which cause the piston to move back and forth between the first position and the second position.

14. The system of claim 12 wherein the processor provides instructions to the first solenoid operated valve, the second solenoid operated valve, and the third solenoid
25 operated valve when to open and close.

15. A system for ascertaining a relative percentage of water and a relative percentage of oil contained in a liquid phase of a fluid received from a well, the system comprising:

a pipe which receives the fluid received from the well;

a first solenoid operated valve hydraulically connected to the pipe where upon the opening of the first solenoid operated valve a first portion of the fluid is drawn into a cylindrical vessel by a circulating pump;

a cut analyzer hydraulically connected to the cylindrical vessel, the cut analyzer
5 capable of ascertaining the relative percentages of water and oil in the first portion of fluid;

a circulation loop wherein the first portion of the fluid is circulated by the circulating pump through the cut analyzer and the cylindrical vessel, the circulation loop comprising a second solenoid operated valve which, upon opening, the first portion of the
10 fluid is circulated through the circulation loop;

a piston disposed within the cylindrical vessel, wherein, upon completion of ascertaining the relative percentages of water and oil in the first portion of fluid, the piston is moveable from a first position to a second position, wherein substantially all of any fluid contained within the cylindrical vessel is displaced from the cylindrical vessel as
15 the piston moves from the first position to the second position;

a first sensor connected to the cylindrical vessel which ascertains when the piston is in the first position and a second sensor which ascertains when the piston is in the second position; and

a processor which receives input from the first sensor and the second sensor and
20 which provides instructions to the first solenoid operated valve and the second solenoid operated valve to open and close.

16. The system of claim 15 wherein the pipe which receives the fluid received from the well comprises a mass flow meter which transmits a mass flow rate to the processor.

25 17. The system of claim 15 wherein the piston moves back and forth between the first position and the second position by a low voltage servo motor which receives the output signals from the processor.

18. The system of claim 15 wherein the cylindrical vessel comprises a gas outlet for discharging any gas phase present in the first portion of the fluid.

30 19. The system of claim 18 wherein a vacuum pump is hydraulically connected to the gas outlet.

20. The system of claim 15 wherein the cylindrical vessel comprises a heater for heating the fluid.

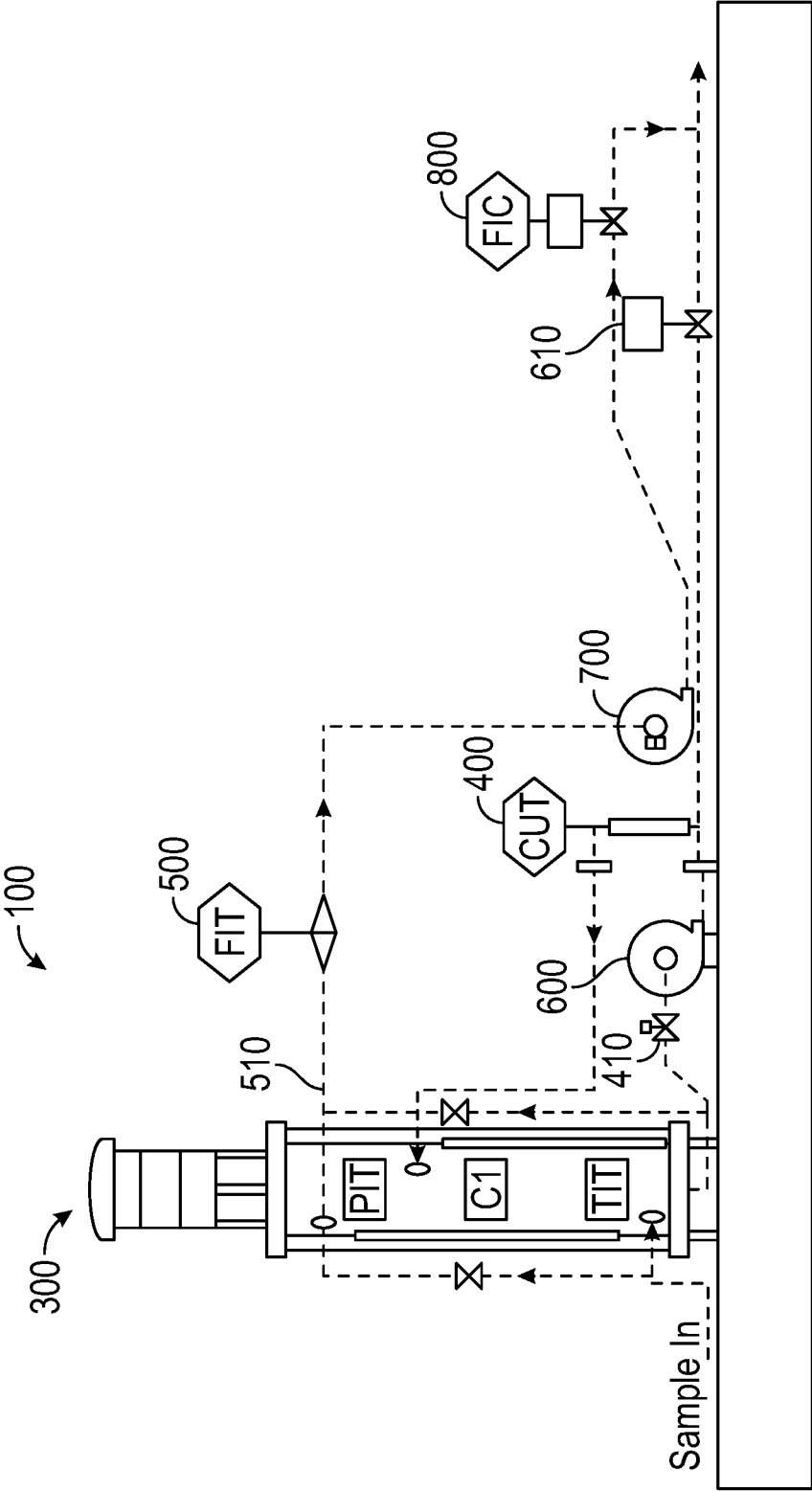


FIG. 1

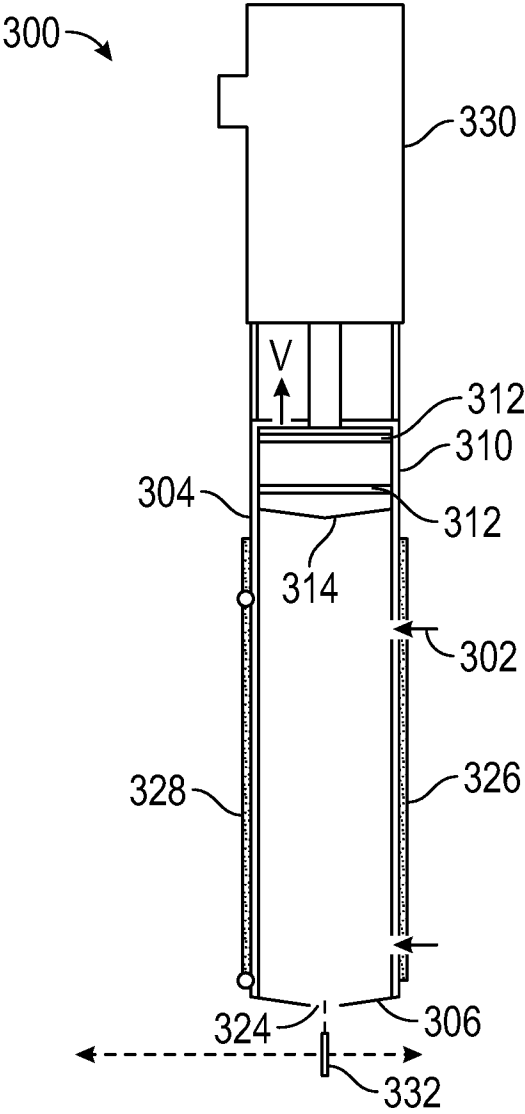


FIG. 2

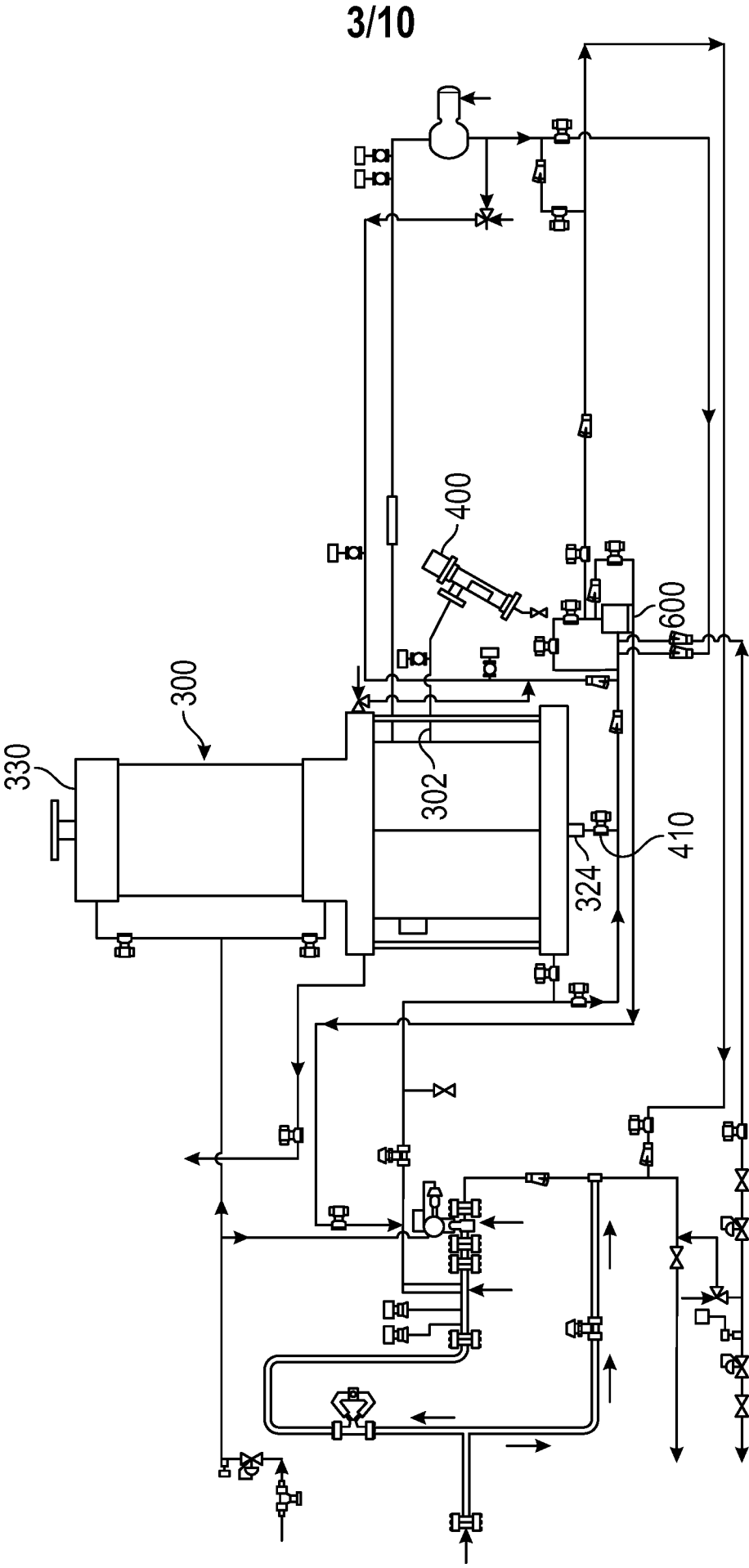


FIG. 3

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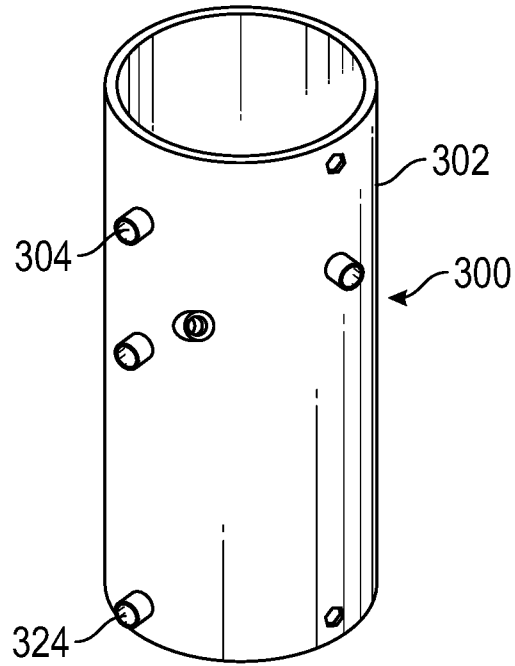


FIG. 4

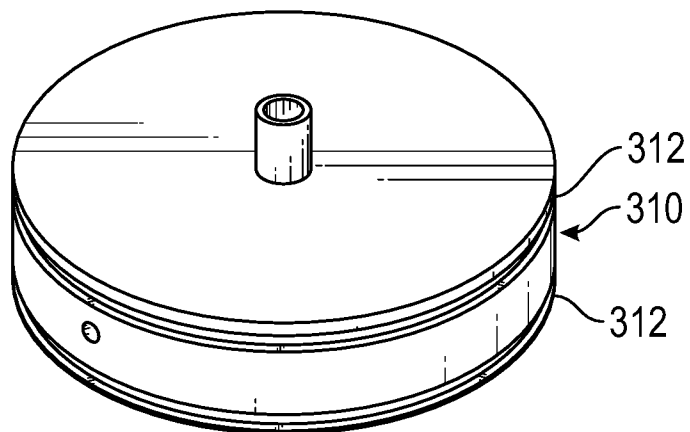


FIG. 5

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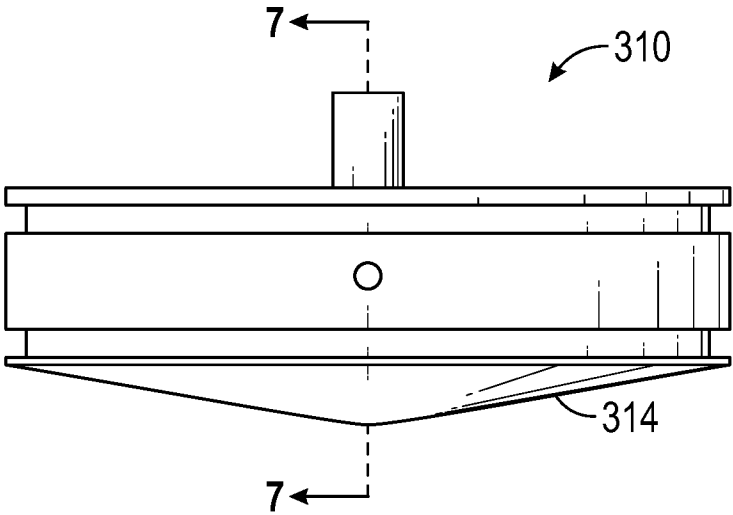


FIG. 6

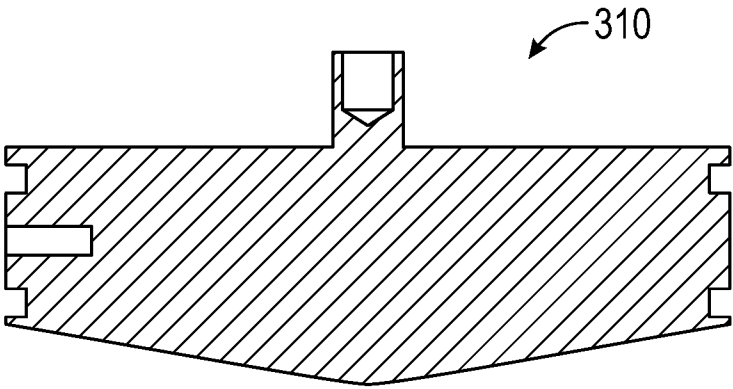


FIG. 7

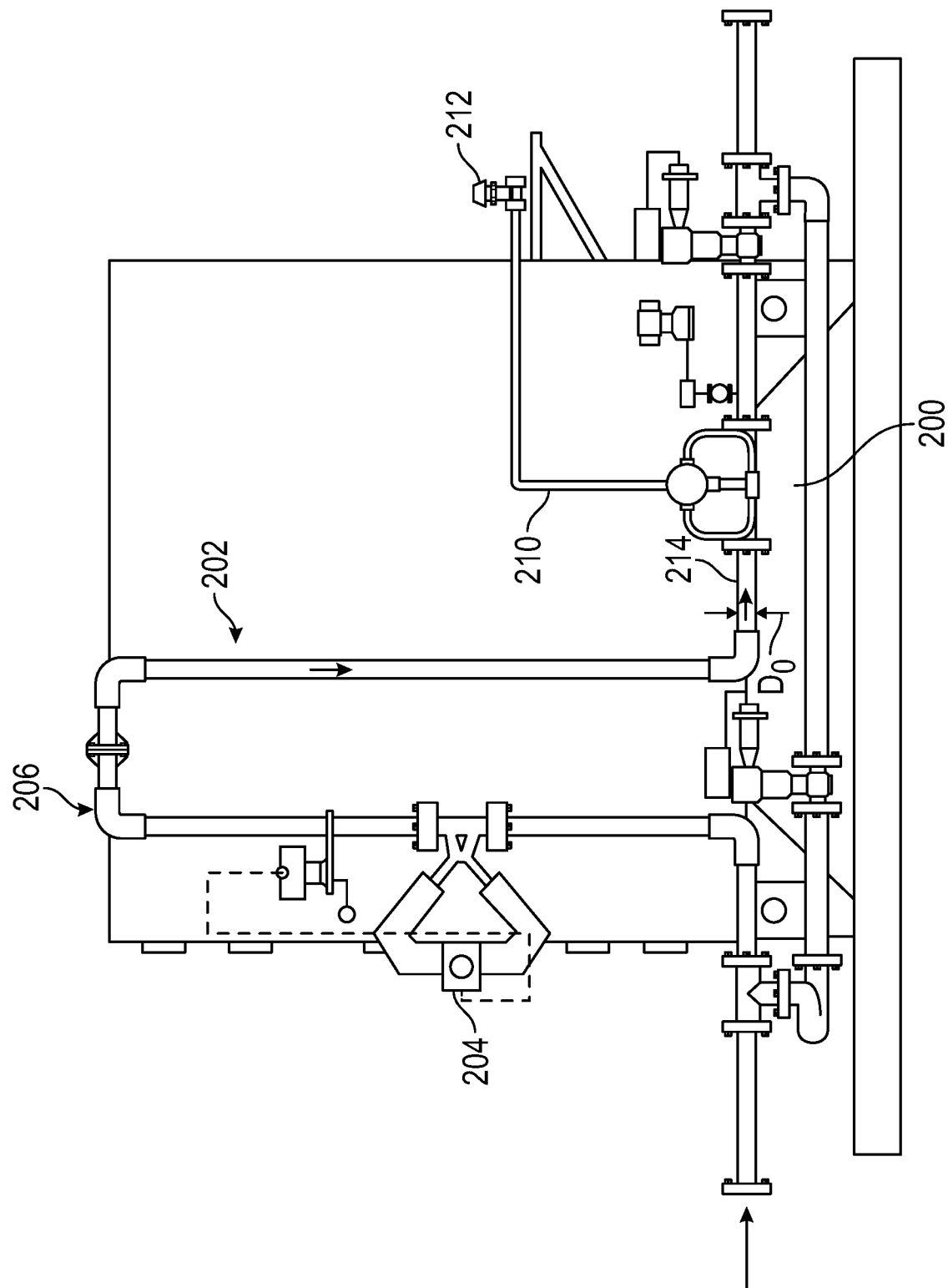


FIG. 8

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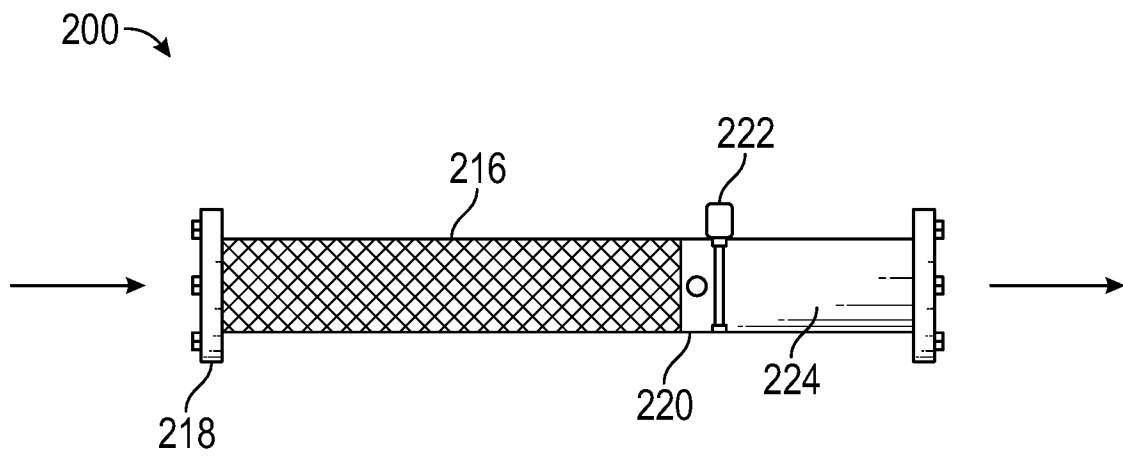


FIG. 9

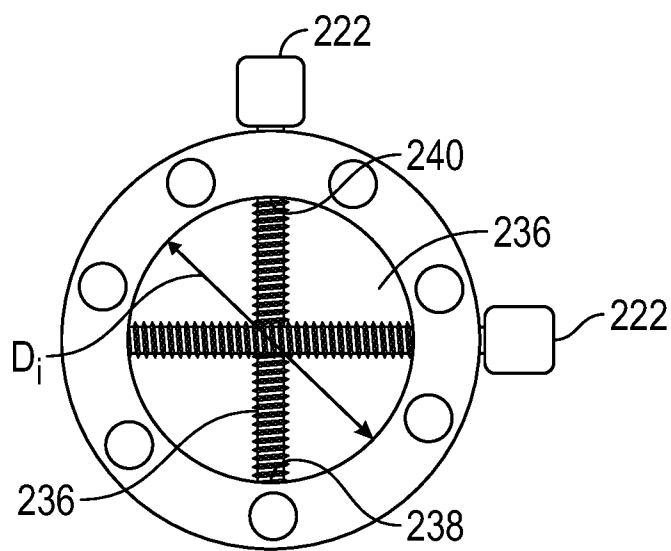


FIG. 10

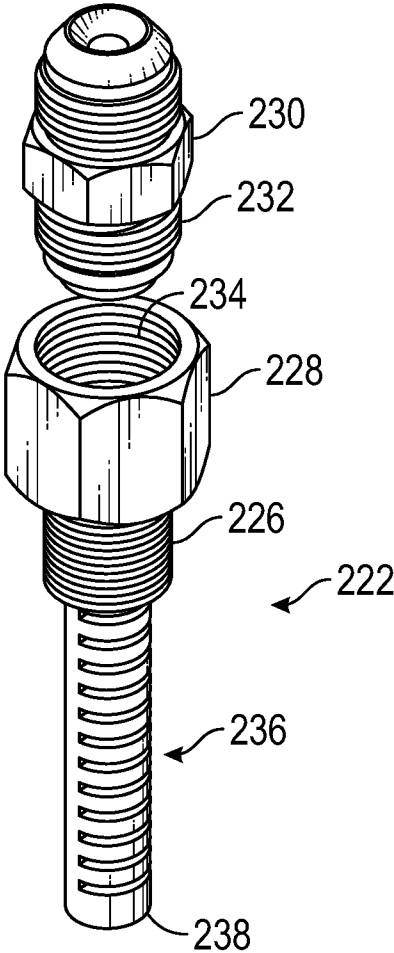


FIG. 11

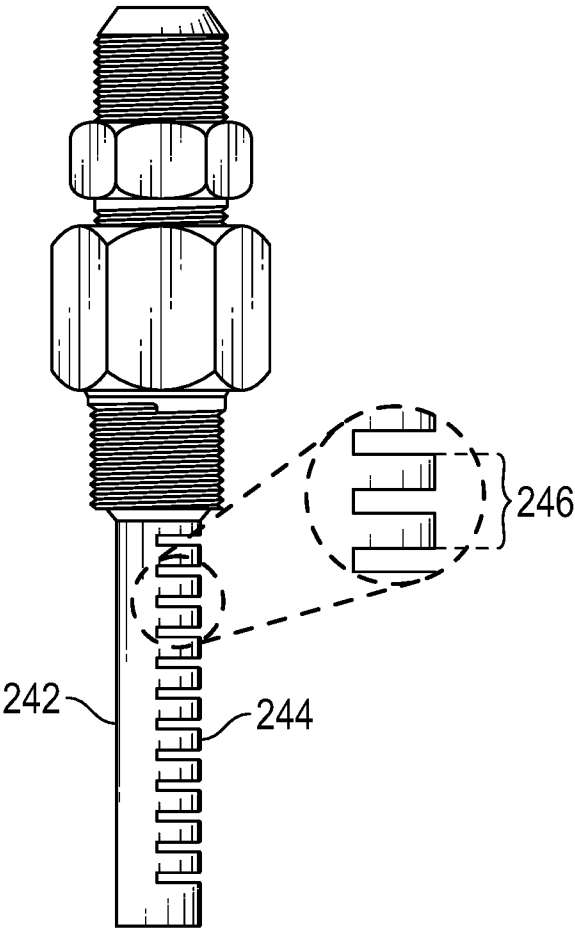


FIG. 12

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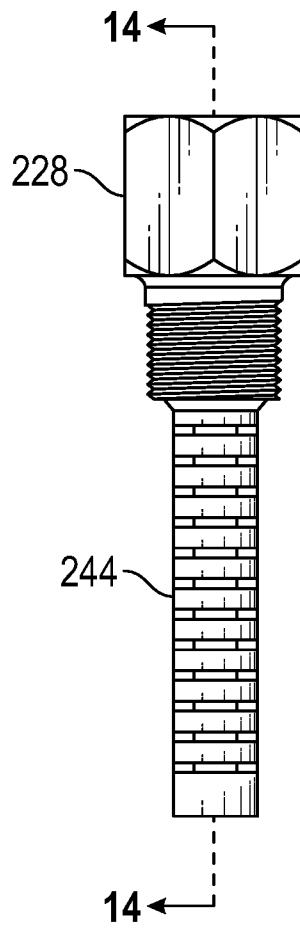


FIG. 13

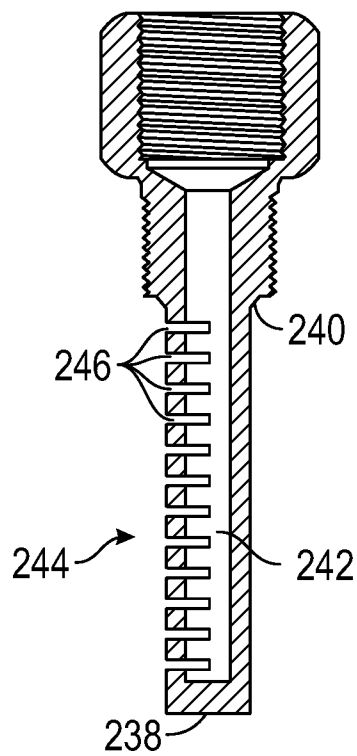


FIG. 14

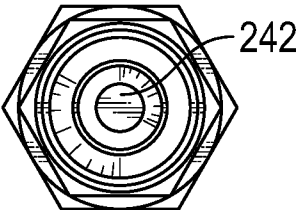


FIG. 15

1000 →

Total Fluid Volume		BPD Gross		
Total Oil Volume		BPD Net Oil		
Total Water Volume		BPD Water		
Inlet Sample		TEMP F 150.0		
Sample TEMP		TEMP F 200.0		
Sample Cut 0-100%		Cut% 90.0%		
Sample Cylinder		PSIG 0.0" WC		
Piston-1		Sample	Sample	
P-UP	P-Down	Displace	Auto	Manuel
Piston-2				
Level	P-Down			
Fluid Process		On-Line	Off-Line	

FIG. 16

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/032271**A. CLASSIFICATION OF SUBJECT MATTER****E21B 49/08(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

E21B 49/08; G01F 1/78; G01N 33/24; G01F 1/74; B01D 19/00; C09K 8/00

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: water cut, sample fluid, gas, probe, valve, pump, piston, processor, analysis

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2015-0198039 A1 (MARSHALL, DAN W.) 16 July 2015 See paragraphs [0019]-[0030]; claims 1-18; and figures 1-4.	1-20
Y	US 2014-0020462 A1 (HALLIBURTON ENERGY SERVICES, INC.) 23 January 2014 See paragraphs [0052]-[0061]; and figures 7, 9.	1-20
A	US 2010-0145634 A1 (PINGUET et al.) 10 June 2010 See paragraphs [0033]-[0053]; and figures 1, 2A-2B, 3.	1-20
A	US 2007-0204750 A1 (LIU et al.) 06 September 2007 See paragraphs [0016]-[0025]; and figures 1-3.	1-20
A	WO 2014-078853 A1 (INVENSYS SYSTEMS, INC.) 22 May 2014 See paragraphs [0024]-[0038]; and figures 2-6.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

28 July 2017 (28.07.2017)

Date of mailing of the international search report

01 August 2017 (01.08.2017)

Name and mailing address of the ISA/KR

International Application Division

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2017/032271

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WO 2014-078853 A1	22/05/2014	CA 2846656 A1 CN 103959019 A CN 103959019 B EP 2920558 A1 EP 2920558 A4 RU 2014-111212 A RU 2577257 C2 US 2014-0137642 A1 US 2014-0137643 A1 US 9512709 B2 US 9562427 B2	19/05/2014 30/07/2014 22/03/2017 23/09/2015 11/01/2017 27/09/2015 10/03/2016 22/05/2014 22/05/2014 06/12/2016 07/02/2017