

**DOWNHOLE TOOLS AND OIL FIELD TUBULARS HAVING INTERNAL
SENSORS FOR WIRELESS EXTERNAL COMMUNICATION**

TECHNICAL FIELD OF THE INVENTION

[0001] This invention relates, in general, to equipment utilized in conjunction with operations performed in subterranean wells and, in particular, to downhole tools and oil field tubulars having internal sensors that are operable for wireless communication with an external data acquisition device.

BACKGROUND OF THE INVENTION

[0002] Without limiting the scope of the present invention, its background will be described with reference to downhole testing operations, as an example.

[0003] It is well known in the subterranean well drilling and completion art to perform tests on formations intersected by a wellbore. Such tests are typically performed in order to determine geological or other physical properties of the formation and the fluid contained therein. For example, parameters such as permeability, porosity, fluid resistivity, temperature, pressure and saturation pressure may be determined. These and other characteristics of the formation and fluid contained therein may be determined by performing tests on the formation before the well is completed.

[0004] One type of testing procedure that is commonly performed is obtaining fluid samples from the formation to, among other things, determine the composition of the formation fluid. In this procedure, it is important to obtain samples of the formation fluid that are representative of the fluid, as it exists in the formation. In a typical sampling procedure, samples of the formation fluid may be obtained by lowering a sampling tool having one or more sampling chambers into the wellbore on a conveyance such as a wireline, slick line, coiled tubing, jointed tubing or the like. When the sampling tool reaches the desired depth, one or more ports are opened to allow collection of the formation fluid. The ports may be actuated in variety of ways such as by electrical, hydraulic or mechanical methods. Once the ports are opened, formation fluid enters the sampling tool such that samples of the formation fluid may be obtained within the sampling chambers. After the samples have been collected, the sampling tool may be withdrawn from the wellbore and the formation fluid samples may be analyzed.

[0005] It has been found, however, that as the fluid samples are retrieved to the surface, the temperature of the fluid samples may decrease causing shrinkage of the fluid samples and a reduction in the pressure of the fluid samples. These changes can cause the fluid samples to reach or drop below saturation pressure creating the possibility of asphaltene deposition and flashing of entrained gasses present in the fluid samples. Once such a process occurs, the resulting fluid samples are no longer representative of the fluid present in the formation. Therefore, after a fluid sample has been retrieved to the surface, it would be desirable to determine if the integrity of the fluid sample has been maintained. In addition, it would be desirable to make such a determination without disturbing the fluid sample.

SUMMARY OF THE INVENTION

[0006] The present invention disclosed herein is directed to downhole tools and oil field tubulars having internal sensors that are operable for wireless communication with an external data acquisition device. For example, a sensor may be disposed in or relative to a sampling chamber of a sampling tool to obtain pressure, temperature and/or timing data associated with a fluid sample. The sensor may then be interrogated on the surface with a data acquisition device that is external to the sampling tool to retrieve the data from the sensor without disturbing the fluid sample.

[0007] In one aspect, the present invention is directed to a downhole tool. The downhole tool includes a housing assembly having an interior and an exterior. A sensor is disposed to the interior of the housing assembly. The sensor is operable to obtain data relative to a fluid parameter of a fluid disposed within the interior of the housing assembly and is operable to wirelessly transmit the data to a data acquisition device disposed to the exterior of the housing assembly responsive to interrogation by the data acquisition device.

[0008] In one embodiment, the interior of the housing assembly may be a fluid chamber of a downhole tester valve and the sensor may be disposed within the fluid chamber. In this embodiment, the downhole tester valve may include a mandrel assembly disposed within the housing assembly defining therebetween an operating fluid chamber, a biasing fluid chamber and a power fluid chamber. A valve assembly may be disposed within the housing assembly and may be operable between open and closed positions. A piston assembly may be operably associated with the valve assembly. The sensor may be disposed within at least one of the operating fluid chamber, the biasing fluid chamber and the power fluid chamber.

[0009] In another embodiment, the interior of the housing assembly may be a sampling chamber of a fluid sampler and the sensor may be disposed relative to the sampling chamber. In this embodiment, the fluid sampler may include an actuator operable to establish a fluid communication path between the exterior and the interior of the fluid sampler. A plurality of
5 sampling chambers may be operable to receive fluid samples. A self-contained pressure source in fluid communication with the sampling chambers may be operable to pressurize the fluid samples obtained in the sampling chambers to a pressure above saturation pressure.

[0010] In certain embodiments, the sensor may wirelessly communicate with the data acquisition device by one of radio frequency transmission and acoustic transmission. In
10 some embodiments, the sensor may be powered by at least one of electromagnetic field energy, acoustic energy, thermal energy and radioactive energy. In other embodiments, the fluid parameter may be at least one of pressure and temperature.

[0011] In another aspect, the present invention is directed to a downhole tester valve. The downhole tester valve includes a housing assembly and a mandrel assembly disposed
15 within the housing assembly defining therebetween an operating fluid chamber, a biasing fluid chamber and a power fluid chamber. A valve assembly is disposed within the housing assembly and is operable between open and closed positions. A piston assembly is operably associated with the valve assembly. A sensor is disposed within at least one of the operating fluid chamber, the biasing fluid chamber and the power fluid chamber. The sensor is
20 operable to obtain data relative to a fluid parameter and is operable to wirelessly transmit the data to a data acquisition device disposed to the exterior of the housing assembly responsive to interrogation by the data acquisition device.

[0012] In a further aspect, the present invention is directed to a fluid sampler. The fluid sampler includes a sampling chamber having an interior and an exterior. The sampling
25 chamber is operable to receive a fluid sample. An actuator is operable to establish a fluid communication path between the exterior and the interior of the sampling chamber. A self-contained pressure source is in fluid communication with the sampling chamber. The pressure source is operable to pressurize the fluid sample to a pressure above saturation pressure. A sensor is disposed to the interior of the sampling chamber. The sensor is
30 operable to obtain data relative to a fluid parameter of the fluid sample and is operable to wirelessly transmit the data to a data acquisition device disposed to the exterior of the sampling chamber responsive to interrogation by the data acquisition device.

[0013] In an additional aspect, the present invention is directed to an oil field tubular system. The oil field tubular system includes a plurality of oil field tubulars operably

coupled together. The oil field tubulars have an interior and an exterior. A sensor is disposed to the interior of the oil field tubulars. The sensor is operable to obtain data relative to a fluid parameter of a fluid disposed within the interior of the oil field tubulars and is operable to wirelessly transmit the data to a data acquisition device disposed to the exterior of the oil field tubulars responsive to interrogation by the data acquisition device.

[0014] In one embodiment, the oil field tubulars may be a surface flowline. In another embodiment, the oil field tubulars may be downhole tubulars.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] For a more complete understanding of the features and advantages of the present invention, reference is now made to the detailed description of the invention along with the accompanying figures in which corresponding numerals in the different figures refer to corresponding parts and in which:

[0016] Figure 1 is a schematic illustration of an offshore oil and gas platform during downhole testing and operating a plurality of internal sensors according to an embodiment of the present invention;

[0017] Figures 2A-G are quarter sectional views of a downhole tester valve including a plurality of internal sensors according to an embodiment of the present invention;

[0018] Figures 3A-C are block diagrams of internal sensors according to an embodiment of the present invention;

[0019] Figure 3D is a block diagram of a data acquisition device according to an embodiment of the present invention;

[0020] Figure 4 is a schematic illustration of a fluid sampler system including a plurality of internal sensors according to an embodiment of the present invention;

[0021] Figures 5A-5F are cross-sectional views of successive axial sections of a sampling chamber including a plurality of internal sensors according to an embodiment of the present invention;

[0022] Figure 6 is a schematic illustration of a surface well testing facility including a plurality of internal sensors according to an embodiment of the present invention; and

[0023] Figure 7 is a schematic illustration of a subsea well installation including a plurality of internal sensors according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0024] While the making and using of various embodiments of the present invention are discussed in detail below, it should be appreciated that the present invention provides many applicable inventive concepts, which can be embodied in a wide variety of specific contexts. The specific embodiments discussed herein are merely illustrative of specific ways to make and use the invention and do not delimit the scope of the invention.

[0025] Referring initially to figure 1, an offshore oil and gas platform operating internal sensors of the present invention during a well testing operation is schematically illustrated and generally designated 10. A semi-submersible platform 12 is centered over a submerged oil and gas formation 14 located below sea floor 16. A subsea conduit 18 extends from deck 20 of platform 12 to wellhead installation 22, including blowout preventers 24. Platform 12 has a hoisting apparatus 26 and a derrick 28 for raising and lowering pipe strings such as drill string 30. A wellbore 32 has been drilled through the various earth strata including formation 14. Wellbore 32 has a casing string 34 installed therein.

[0026] In the illustrated embodiment, a testing string 36 is shown disposed in wellbore 32, with blowout preventers 24 closed thereabout. Testing string 36 includes upper drill pipe string 30, which extends downward from platform 12 to wellhead 22. A hydraulically operated test tree 38 is positioned between upper drill pipe string 30 and intermediate pipe string 40. A slip joint 42 may be included in string 40 for enabling proper positioning of downhole equipment and to compensate for tubing length changes due to pressure and temperature changes. Below slip joint 42, intermediate string 40 extends downwardly to a downhole tester valve 44 including internal sensors of the present invention. Therebelow, is a lower pipe string 46 that extends to tubing seal assembly 48, which stabs into packer 50. When set, packer 50 isolates a wellbore annulus 52 from the lower portion of wellbore 54. Packer 50 may be any suitable packer well known to those skilled in the art. Tubing seal assembly 48 permits testing string 36 to communicate with lower wellbore 54 through a perforated tailpipe 56. In this manner, formation fluid from formation 14 may enter lower wellbore 54 through perforations 58 in casing 34 and be routed into testing string 36.

[0027] After packer 50 is set in wellbore 32, a formation test controlling the flow of fluid from formation 14 through testing string 36 may be conducted using variations in pressure affected in upper annulus 52 by pump 60 and control conduit 62, with associated relief valves (not shown). Formation pressure, temperature and recovery time may be measured during the flow test through the use of the internal sensors of the present invention positioned in downhole tester valve 44. In addition, internal sensors of the present invention

positioned in intermediate string 40 may be used to identify the formation of any hydrates during flow testing. In the illustrated embodiment, real time information about hydrate formation may be obtained by interrogating the internal sensors with data acquisition devices 64 that are operably associated with an umbilical assembly 66 that extends downhole from platform 12. Preferably, each data acquisition device 64 is located in communicable proximity to one or more of the internal sensors.

[0028] Even though figure 1 depicts the present invention in a vertical wellbore, it should be understood by those skilled in the art that the present invention is equally well suited for use in wellbores having other directional configurations including horizontal wellbores, deviated wellbores, slanted wells, lateral wells, multilateral wells and the like. Accordingly, it should be understood by those skilled in the art that the use of directional terms such as above, below, upper, lower, upward, downward, uphole, downhole and the like are used in relation to the illustrative embodiments as they are depicted in the figures, the upward direction being toward the top of the corresponding figure and the downward direction being toward the bottom of the corresponding figure, the uphole direction being toward the surface of the well and the downhole direction being toward the toe of the well.

[0029] Referring now to figures 2A-2G, therein is depicted an exemplary embodiment of a downhole tester valve 100 in accordance with an embodiment of the present invention. Downhole tester valve 100 includes an upper adaptor 102 having threads 104 at its upper end, whereby downhole tester valve 100 may be secured to drill pipe or other components within the testing string. Downhole tester valve 100 has a housing assembly 106 that is secured to upper adaptor 102 at its upper end. Housing assembly 106 is formed from a plurality of housing members that are threadedly, sealingly, weldably or otherwise secured together. Housing assembly 106 includes upper housing member 108, an upper housing connector 110, an upper intermediate housing member 112, an intermediate housing connector 114, a lower intermediate housing member 116, a lower housing connector 118 and a lower housing member 120. At its lower end, lower housing member 120 is secured to a lower adaptor 122 having threads 124 at its lower end, whereby downhole tester valve 100 may be secured to drill pipe or other components within the testing string. Even though a particular arrangement of tubulars has been described and depicted as forming housing assembly 106, it is understood by those skilled in the art that other arrangements of tubular components and the like could alternatively be used to form a housing assembly without departing from the principles of the present invention.

[0030] Generally positioned within upper housing member 108 is a valve assembly 126. Valve assembly 126 includes an upper cage support 128, a ball cage 130, an upper annular seat 132 that is downwardly biased by one or more springs 134, a pair of operating pins 136 (only one being visible in figure 2B), a rotating ball member 138, a lower annular seat 140 and a lower cage support 142. Together, the components of valve assembly 126 cooperate to open and close the central pathway 144 of downhole tester valve 100 to selectively allow and prevent fluid flow therethrough.

[0031] Generally positioned within upper intermediate housing member 112 is a piston assembly 146. Piston assembly 146 includes a valve operating member 148 that is coupled at its upper end (see figure 2B) to operating pins 136 of valve assembly 126. Piston assembly 146 also includes a check valve assembly 150, a snap sleeve 152, a split ring 154 and a collet assembly 156 that is securably coupled at its lower end to intermediate housing connector 114. In the illustrated embodiment, check valve assembly 150 is slidably and sealingly positioned between valve operating member 148 and upper intermediate housing member 112. Check valve assembly 150 includes a pair of oppositely disposed check valves 158, 160, having a fluid passageway 162 therebetween that may be referred to as a bypass passageway. Check valves 158, 160 each have a stem that is extendable outwardly from check valve assembly 150. In the illustrated embodiment, split ring 154 is received in a radially reduced section of valve operating member 148. A gap exists between split ring 154 and the lower surface of check valve assembly 150 and likewise, gap exists between split ring 154 and an upper shoulder of a snap sleeve 152. Collet assembly 156 includes a plurality of collet fingers 164, only one being visible in the figure 2D. Each collet finger 164 has a detent 166. Snap sleeve 152 includes a pair of annular grooves 168, 170 that are designed to selectively and releasably cooperate with detents 166 of collet fingers 164.

[0032] Generally positioned within lower intermediate housing member 116 is an upper mandrel 172. In the illustrated embodiment, upper mandrel 172 is threadedly and sealably coupled to intermediate housing connector 114 at its upper end and sealably coupled to lower housing connector 118 at its lower end. Generally positioned within lower housing member 120 is a lower mandrel 174. In the illustrated embodiment, lower mandrel 174 is sealably coupled to lower housing connector 118 at its upper end and threadedly and sealably coupled to lower adaptor 122 at its lower end. Together, upper mandrel 172 and lower mandrel 174 may be referred to herein as a mandrel assembly. Even though a particular arrangement of tubulars has been described and depicted as forming the mandrel assembly, it is understood by those skilled in the art that other arrangements of tubular components and the like could

alternatively be used to form a mandrel assembly without departing from the principles of the present invention.

[0033] Together, lower intermediate housing member 116 and upper mandrel 172 define a generally annular operating fluid chamber 176, which extends between a lower surface of intermediate housing connector 114 and an upper surface of a floating piston 178 that is disposed between lower intermediate housing member 116 and upper mandrel 172. Preferably, operating fluid chamber 176 contains an operating fluid in the form of a substantially incompressible fluid such as an oil including hydraulic fluid. Lower intermediate housing member 116 and upper mandrel 172 also define a generally annular power fluid chamber 180, which extends between a lower surface of floating piston 178 and an upper surface of lower housing connector 118. Power fluid chamber 180 is aligned with one or more housing ports 182 that extend through lower intermediate housing member 116 to provide fluid communication with annulus fluid pressure. In the illustrated embodiment, a housing port 182 is depicted in dashed lines as it is not actually located in the illustrated cross section but instead is circumferentially offset from the illustrated view. Together, lower housing member 120 and lower mandrel 174 define a generally annular biasing fluid chamber 184, which extends between a lower surface of floating piston 186 that is disposed between lower housing member 120 and lower mandrel 174 and an upper surface of lower adaptor 122. Preferably, biasing fluid chamber 184 contains a biasing fluid in the form of a compressible fluid such as a gas and more preferably, biasing fluid chamber 184 contains an inert gas such as nitrogen.

[0034] Downhole tester valve 100 includes an operating fluid communication network. In valve 100, operating fluid is used not only to actuate the valve assembly between open and closed positions but also for rapid charging of the biasing fluid after shifting the valve assembly from the closed position to the open position. The operating fluid communication network includes a plurality of fluid passageways that are formed in various section of housing assembly 106. In the illustrated embodiment, operating fluid used to downwardly shift piston assembly 146 and open valve assembly 126 has a communication path from operating fluid chamber 176 through fluid passageway 188 in intermediate housing connector 114 and fluid passageway 190 in upper intermediate housing member 112. The operating fluid is then operable to act on an upper surface of check valve assembly 150 of piston assembly 146.

[0035] After the operating fluid has downwardly shifted piston assembly 146 causing valve assembly 126 to open, the operating fluid has a communication path through fluid

passageway 162 in check valve assembly 150, through the annular region between upper intermediate housing member 112 and valve operating member 148, through fluid passageway 192 in intermediate housing connector 114 (a portion of which is depicted in dashed lines in figures 2D and 2E), through fluid passageway 194 in lower intermediate housing member 116 (a portion of which is depicted in dashed lines in figures 2E and 2F) and through fluid passageway 196 in lower housing connector 118 (a portion of which is depicted in dashed lines in figure 2F). The operating fluid is then operable to act on an upper surface of floating piston 186.

[0036] After the operating fluid has charged the biasing fluid and annulus pressure is reduced, the operating fluid has a communication path through fluid passageway 196 in lower housing connector 118 (a portion of which is depicted in dashed lines in figure 2F), through fluid passageway 194 in lower intermediate housing member 116 (a portion of which is depicted in dashed lines in figures 2F and 2E), through fluid passageway 192 in intermediate housing connector 114 (a portion of which is depicted in dashed lines in figures 2E and 2D) and through the annular region between upper intermediate housing member 112 and valve operating member 148. The operating fluid is then operable to act on a lower surface of check valve assembly 150.

[0037] In addition, the operating fluid communication network of downhole tester valve 100 includes a metered fluid pathway between operating fluid chamber 176 and the upper side of floating piston 186. In the illustrated embodiment, a fluid pathway 198 in intermediate housing connector 114 includes a metering section 200 having a fluid resistance assembly such as an orifice disposed therein to limit the rate at which operating fluid can pass therethrough. Fluid pathway 198 is in fluid communication with fluid pathway 202 in lower intermediate housing member 116 (as best seen in figures 2E and 2F), which is in fluid communication with fluid passageway 204 in lower housing connector 118 (as best seen in figures 2F and 2G). The operating fluid is then operable to act on an upper surface of floating piston 186.

[0038] In the illustrated embodiment, downhole tester valve 100 includes a plurality of internal sensors 210, 212, 214, 216, 218. Specifically, internal sensor 210 is positioned in the annular region between upper intermediate housing member 112 and valve operating member 148. Internal sensor 212 is positioned in operation fluid chamber 176. Internal sensor 214 is positioned in power fluid chamber 180. Internal sensor 216 is positioned in the metered fluid pathway between metering section 200 and the upper surface of floating piston 186. Internal sensor 218 is positioned in biasing fluid chamber 184. As illustrated, internal sensors 210,

212, 214, 216, 218 are positioned in the various pressure regions of downhole tester valve 100. This configuration can be particularly beneficial following redressing of downhole tester valve 100 between downhole testing operations. For example, prior to using downhole tester valve 100 in a testing operation, it is desirable to cycle downhole tester valve 100 through its various positions to determine if downhole tester valve 100 is functioning properly. One way to determine whether downhole tester valve 100 is functioning properly is to monitor the pressure transitions in the various pressure regions and the timing of such pressure transitions as downhole tester valve 100 is operated through its various positions. By placing a data acquisition device in communicable proximity to each of the internal sensors 210, 212, 214, 216, 218 during this functional testing procedure, the pressure in each of the pressure regions of downhole tester valve 100 can be monitor. Importantly, this pressure analysis does not impact the operation of downhole tester valve 100 nor does it require physically attaching gauges or monitors to downhole tester valve 100 as internal sensors 210, 212, 214, 216, 218 are operable to wirelessly communicate with the data acquisition device or devices.

[0039] Referring next to figures 3A-3C, therein are depicted block diagrams of sensor assemblies that may be used as the internal sensors described above and the internal sensors described below. Sensor assembly 300, of figure 3A, includes a sensor 302 and a transceiver 304. For example, sensor 302 may be a temperature gauge, a pressure gauge or other fluid parameter gauge. In the illustrated embodiment, transceiver 304 using a wireless, noncontact means, such as radio frequency electromagnetic fields, to transfer data obtained by sensor 302 to a data acquisition device that interrogates sensor assembly 300. In this embodiment, sensor assembly 300 does not require a battery as sensor 302 and transceiver 304 are powered by the electromagnetic fields generated by the data acquisition device that is reading the data. In this configuration, the data relative to the fluid parameter being measured is preferably obtained at the time the data acquisition device interrogates sensor assembly 300. In other words, the data acquisition device generates an electromagnetic field that is received by a radio frequency electromagnetic field coil of sensor 302, transceiver 304 or both. This prompts sensor 302 to obtain the desired data, which is returned to the data acquisition device by transceiver 304.

[0040] Sensor assembly 310, of figure 3B, includes a sensor 312, a transceiver 314 and a charger 316. For example, sensor 312 may be a temperature gauge, a pressure gauge or other fluid parameter gauge. Transceiver 314 may generate acoustic signals that are read by the data acquisition device. In this embodiment, sensor assembly 310 does not require a

battery as power for sensor 312 and transceiver 314 is provided by charger 316. Charger 316 is powered by the data acquisition device. For example, charger 316 may be charged responsive to energy generated by the data acquisition device in the form of acoustic energy, thermal energy, radioactive energy or the like. Charger 316 converts the energy to electrical energy to operate sensor 312 and transceiver 314. In this configuration, the data relative to the fluid parameter being measured is preferably obtained at the time the data acquisition device interrogates sensor assembly 310. In other words, the data acquisition device generates energy that is received by charger 316 and converted to electricity. This prompts sensor 312 to obtain the desired data, which is returned to the data acquisition device by transceiver 314.

[0041] Sensor assembly 320, of figure 3C, includes a sensor 322 and a transceiver 324. Sensor 322 may be a temperature gauge, a pressure gauge or other fluid parameter gauge. Transceiver 324 may communicate with a data acquisition device via radio frequency electromagnetic fields, acoustic signals or the like. In this embodiment, sensor assembly 320 is powered by a battery 326. In addition, sensor assembly 320 has a microprocessor 328 associated therewith providing command and control over sensor assembly 320. Likewise, sensor assembly 320 includes a memory 330, which provides for storing information for later transmission, if desired. In the illustrated embodiment, sensor assembly 320 is operable to obtain data regarding fluid parameters when sensor assembly 320 is remote from the data acquisition device. For example, sensor assembly 320 may be installed in a downhole testing tool, such as the downhole tester valve described above, and used to obtain fluid parameter data during a downhole testing operation. Upon retrieval to the surface, sensor assembly 320 may be interrogated with a data acquisition device to receive the stored data via a wireless communication means. For example, pressure, temperature and time data may be stored throughout a testing operation and during retrieval of the testing tools such that pressure and temperature profiles for an entire testing operation may be analyzed.

[0042] Referring next to figure 3D, therein is depicted a block diagram of a data acquisition device that is generally designated 340. Data acquisition device 340 includes a microprocessor 342 that provides command and control for data acquisition device 340. Data acquisition device 340 also has a transceiver 344 for wireless communication with a transceiver of a sensor assembly. For example, transceiver 344 may communicate with sensor assembly 300 discussed above, using radio frequency electromagnetic fields. Alternatively, transceiver 344 may communicate with sensor assembly 310 discussed above, using acoustic signals. In the illustrated embodiment, data acquisition device 340 includes an

energy generator 346. For example, energy generator 346 may generate energy in the form of acoustic energy, thermal energy, radioactive energy or the like which may be harnessed by a sensor assembly including charger 316. Preferably, data acquisition device 340 is a handheld device that has an internal power source such as a battery 348. Data acquisition device 340 further includes memory 350 for storing data received from a sensor assembly.

[0043] Referring next to figure 4, therein is representatively illustrated a fluid sampler system 400 operating internal sensors of the present invention. A fluid sampler 402 is being run in a wellbore 404 that is depicted as having a casing string 406 secured therein with cement 408. Although wellbore 404 is depicted as being cased and cemented, it could alternatively be uncased or open hole. Fluid sampler 402 includes a cable connector 410 that enables fluid sampler 402 to be coupled to or operably associated with a wireline conveyance 412 that is used to run, retrieve and position fluid sampler 402 in wellbore 404. Wireline conveyance 412 may be a single strand or multistrand wire, cable or braided line, which may be referred to as a slickline or may include one or more electric conductors, which may be referred to as an e-line or electric line. Even though fluid sampler 402 is depicted as being connected directly to cable connector 410, those skilled in the art will understand that fluid sampler 402 could alternatively be coupled within a larger tool string that is being positioned within wellbore 404 via wireline conveyance 412 or could be conveyed via coiled tubing, jointed tubing or the like.

[0044] In the illustrated embodiment, fluid sampler 402 includes an actuator assembly 414, a sampler assembly 416 and a self-contained pressure source assembly 418. Preferably, sampler assembly 416 includes multiple sampling chambers, such as two, three or four sampling chambers. In coiled tubing or jointed tubing conveyed embodiments, sampler assembly 416 may include nine or more sampling chambers. In order to route the fluid samples into the desired sampling chamber, fluid sampler 402 includes a manifold assembly 420 positioned between actuator assembly 414 and sampler assembly 416. Valving or other fluid flow control circuitry within manifold assembly 420 may be used to enable fluid samples to be taken in all of the sampling chambers simultaneously or to allow fluid samples to be sequentially taken into the various sampling chambers. In slickline conveyed embodiments, actuator assembly 414 preferably includes timing circuitry such as a mechanical or electrical clock, which is used to determine when the fluid sample or samples will be taken. Alternatively, a pressure signal or other wireless input signal could be used to initiate operation of actuator assembly 414. In electric line conveyed embodiments, actuator

assembly 414 preferably includes electrical circuitry operable to communicate with surface systems via the electric line to initiate operation of actuator assembly 414.

[0045] After the fluid samples are taken, in order to route pressure into the desired sampling chamber, fluid sampler 402 includes a manifold assembly 422 positioned between sampler assembly 416 and self-contained pressure source 418. Self-contained pressure source 418 may include one or more pressure chambers that initially contain a pressurized fluid, such as a compressed gas or liquid, and preferably contain compressed nitrogen at between about 10,000 psi and 20,000 psi. Those skilled in the art will understand that other fluids or combinations of fluids and/or other pressures both higher and lower could be used, if desired. Depending on the number of sampling chambers and the number of pressure chambers, valving or other fluid flow control circuitry within manifold assembly 422 may be operated such that self-contained pressure source 418 serves as a common pressure source to simultaneously pressurize all sampling chambers or may be operated such that self-contained pressure source 418 independently pressurizes certain sampling chambers sequentially. In the case of multiple sampling chambers and multiple pressure chambers, manifold assembly 422 may be operated such that pressure from certain pressure chambers of self-contained pressure source 418 is routed to certain sampling chambers. As described below, internal sensors of the present invention positioned in the sampling chambers may be used to quickly determine whether sample integrity has been maintained during the testing and retrieval of the fluid samples. For example, pressure and temperature data for the fluid samples may be obtained upon retrieval to the surface from the internal sensors using a data acquisition device placed in communicable proximity to the internal sensors.

[0046] Referring now to figures 5A-5F a fluid sampling chamber for use in a fluid sampler that embodies principles of the present invention is representatively illustrated and generally designated 500. Preferably, one or more of sampling chambers 500 are positioned in a sampler assembly 416 that is coupled to an actuator assembly 420 and a self-contained pressure source assembly 418 as described above.

[0047] As described more fully below, a passage 510 in an upper portion of sampling chamber 500 (see figure 5A) is placed in communication with the exterior of fluid sampler 402 when the fluid sampling operation is initiated. Passage 510 is in communication with a sample chamber 514 via a check valve 516. Check valve 516 permits fluid to flow from passage 510 into sample chamber 514, but prevents fluid from escaping from sample chamber 514 to passage 510.

[0048] A debris trap piston 518 is disposed within housing assembly 502 and separates sample chamber 514 from a meter fluid chamber 520. When a fluid sample is received in sample chamber 514, debris trap piston 518 is displaced downwardly relative to housing assembly 502 to expand sample chamber 514. Prior to such downward displacement of debris trap piston 518, however, fluid flows through sample chamber 514 and passageway 522 of piston 518 into debris chamber 526 of debris trap piston 518. The fluid received in debris chamber 526 is prevented from escaping back into sample chamber 514 due to the relative cross sectional areas of passageway 522 and debris chamber 526 as well as the pressure maintained on debris chamber 526 from sample chamber 514 via passageway 522. An optional check valve (not pictured) may be disposed within passageway 522 if desired. In this manner, the fluid initially received into sample chamber 514 is trapped in debris chamber 526. Debris chamber 526 thus permits this initially received fluid to be isolated from the fluid sample later received in sample chamber 514. Debris trap piston 518 includes a magnetic locator 524 used as a reference to determine the level of displacement of debris trap piston 518 and thus the volume within sample chamber 514 after a sample has been obtained.

[0049] Meter fluid chamber 520 initially contains a metering fluid, such as a hydraulic fluid, silicone oil or the like. A flow restrictor 534 and a check valve 536 control flow between chamber 520 and an atmospheric chamber 538 that initially contains a gas at a relatively low pressure such as air at atmospheric pressure. A collapsible piston assembly 540 includes a prong 542, which initially maintains check valve 544 off seat, so that flow in both directions is permitted through check valve 544 between chambers 520, 538. When elevated pressure is applied to chamber 538, however, as described more fully below, piston assembly 540 collapses axially, and prong 542 will no longer maintain check valve 544 off seat, thereby preventing flow from chamber 520 to chamber 538.

[0050] A piston 546 disposed within housing 502 separates chamber 538 from a longitudinally extending atmospheric chamber 548 that initially contains a gas at a relatively low pressure such as air at atmospheric pressure. Piston 546 includes a magnetic locator 547 used as a reference to determine the level of displacement of piston 546 and thus the volume within chamber 538 after a sample has been obtained. Piston 546 included a piercing assembly 550 at its lower end. In the illustrated embodiment, piercing assembly 550 is spring mounted within piston 546 and includes a needle 554. Needle 554 has a sharp point at its lower end and may have a smooth outer surface or may have an outer surface that is fluted, channeled, knurled or otherwise irregular. As discussed more fully below, needle 554

is used to actuate the pressure delivery subsystem of the fluid sampler when piston 546 is sufficiently displaced relative to housing assembly 502.

[0051] Below atmospheric chamber 548 and disposed within the longitudinal passageway of housing assembly 502 is a valving assembly 556. Valving assembly 556 includes a pressure disk holder 558 that receives a pressure disk therein that is depicted as rupture disk 560, however, other types of pressure disks that provide a seal, such as a metal-to-metal seal, with pressure disk holder 558 could also be used including a pressure membrane or other piercable member. Rupture disk 560 is held within pressure disk holder 558 by hold down ring 562 and gland 564 that is threadably coupled to pressure disk holder 558. Valving assembly 556 also includes a check valve 566. Valving assembly 556 initially prevents communication between chamber 548 and a passage 580 in a lower portion of sampling chamber 500. After actuation of the pressure delivery subsystem by needle 554, check valve 566 permits fluid flow from passage 580 to chamber 548, but prevents fluid flow from chamber 548 to passage 580. Preferably, passageway 580 is placed in fluid communication with pressure from the self-contained pressure source via the manifold therebetween.

[0052] In the illustrated embodiment, sampling chamber 500 includes a plurality of internal sensors 582, 584, 586, 588. Specifically, internal sensor 582 is positioned in sample chamber 514. Internal sensor 584 is positioned in metering fluid chamber 520. Internal sensor 586 is positioned in atmospheric chamber 538. Internal sensor 588 is positioned in atmospheric chamber 548. As illustrated, internal sensors 582, 584, 586, 588 are positioned in the various pressure regions of sampling chamber 500.

[0053] In operation, once the fluid sampler has been run downhole via the wireline conveyance to the desired location and is in its operable configuration, a fluid sample can be obtained into one or more of the sample chambers 514 by operating the actuator. Fluid enters passage 510 in the upper portion of each of the desired sampling chambers 500. For clarity, the operation of only one of the sampling chambers 500 after receipt of a fluid sample therein is described below. The fluid sample flows from passage 510 through check valve 516 to sample chamber 514. It is noted that check valve 516 may include a restrictor pin 568 to prevent excessive travel of ball member 570 and over compression or recoil of spiral wound compression spring 572. An initial volume of the fluid sample is trapped in debris chamber 526 of piston 518 as described above. Downward displacement of piston 518 is slowed by the metering fluid in chamber 520 flowing through restrictor 534. This prevents pressure in

the fluid sample received in sample chamber 514 from dropping below its saturation pressure.

[0054] As piston 518 displaces downward, the metering fluid in chamber 520 flows through restrictor 534 into chamber 538. At this point, prong 542 maintains check valve 544 off seat. The metering fluid received in chamber 538 causes piston 546 to displace downwardly. Eventually, needle 554 pierces rupture disk 560, which actuates valving assembly 556. Actuation of valving assembly 556 permits pressure from the self-contained pressure source to be applied to chamber 548. Specifically, once rupture disk 560 is pierced, the pressure from the self-contained pressure source passes through passage 580 and valving assembly 556 including moving check valve 566 off seat. In the illustrated embodiment, a restrictor pin 574 prevents excessive travel of check valve 566 and over compression or recoil of spiral wound compression spring 576. Pressurization of chamber 548 also results in pressure being applied to chambers 538, 520 and thus to sample chamber 514.

[0055] When the pressure from the self-contained pressure source is applied to chamber 538, pins 578 are sheared allowing piston assembly 540 to collapse such that prong 542 no longer maintains check valve 544 off seat. Check valve 544 then prevents pressure from escaping from chamber 520 and sample chamber 514. Check valve 516 also prevents escape of pressure from sample chamber 514. In this manner, the fluid sample received in sample chamber 514 is pressurized such that the fluid sample may be retrieved to the surface without degradation by maintaining the pressure of the fluid sample above its saturation pressure, thereby obtaining a fluid sample that is representative of the fluids present in the formation. Upon retrieval to the surface, the internal sensors 582, 584, 586, 588 may be interrogated by a data acquisition device to determine the current pressures in the various pressure regions. If suitable pressure data is provided from internal sensors 582, 584, 586, 588, the sample integrity has likely been maintained. If the pressure data provided from internal sensors 582, 584, 586, 588 is not suitable, another sampling run may immediately be made into the wellbore. Alternatively or additionally, in certain embodiments, pressure and/or temperature profile data may be obtained from internal sensors 582, 584, 586, 588.

[0056] Referring next to figure 6, therein is depicted a surface well testing facility operating internal sensors of the present invention that is schematically illustrated and generally designated 600. Surface well testing facility 600 includes a wellhead 602 and a surface test tree 604 connected to wellhead 602. Surface test tree 604 includes a plurality of valves for controlling fluid flow into or out of the well. A flow line 606 extends from surface test tree 604 to transport a multiphase well fluid produced from the well for

processing. In the illustrated embodiment, flow line 606 includes a heater 608. In addition, flow line 606 includes a choke manifold 610 which includes one or more valves that are used to accurately throttle the flow from the well so that the fluid pressure downstream from choke manifold 610 is reduced to a desired pressure.

5 [0057] Downstream from choke manifold 610 is a separator 612 in which the various constituents of the well fluid are separated. In the illustrated embodiment, separator 612 is depicted as a system for handling a three-phase fluid; namely, a fluid having a gas constituent, an oil constituent and a water constituent. Separator 612 includes a gas line 614 discharging from the top of separator 612, an oil line 616 discharging from an intermediate
10 portion of separator 612 and a water line 618 discharging near the bottom of separator 612. An orifice-type gas flow meter 620 is disposed in gas line 614, a volumetric oil flow meter 622 is disposed in oil line 616 and a volumetric water flow meter 624 is disposed in water line 618. Preferably, water line 618 is directed to a tank or other facility in which the water may be treated for later disposal.

15 [0058] In the illustrated embodiment, the oil constituent in oil line 616 is directed to an oil burner 626. Preferably, oil burner 626 is positioned at a distal end of a boom. One or more flow control component such as pumps, valves, regulators and the like (not pictured), may be positioned in oil line 616. In the illustrated embodiment, the gas constituent in gas line 614 is directed to a flare 628 through which the gas constituent is flared to the
20 atmosphere. Preferably, gas line 616 includes flow control components such as one or more valves, regulators and the like (not pictured).

[0059] Typically, the surface well testing facility is a temporary facility that is used only during the well testing phase. As such, the tubulars used to transport the formation fluid throughout the facility are commonly assembled, disassembled and reassembled numerous
25 times resulting in the tubular system having a potentially irregular flow path which may tend to get plugged by the dirty fluid that is initially produced in a well testing operation. Use of internal sensors (not visible in figure 6) and one or more data acquisition devices makes locating a blockage in the tubular system safer and more efficient. In the illustrated embodiment, a plurality of data acquisition devices 630 have been positioned in
30 communicative proximity to internal sensors disposed within flow line 606. As discussed above, the internal sensors may be interrogated by data acquisition devices 630 to obtain data gathered by the internal sensors. In the illustrated example, if the flow rate into separator 612 declines, the various internal sensors location along flow line 606 may be interrogated to determine the location of a pressure drop and therefore the blockage in flow line 606.

[0060] Referring next to figure 7, therein is depicted a subsea well installation operating internal sensors of the present invention that is schematically illustrated and generally designated 700. Subsea well installation 700 includes a subsea test tree 702 that is positioned within a blowout preventer (BOP) stack 704 installed on the ocean floor. BOP stack 704 includes two pipe rams 706 and two shear rams 708 that are configured and controlled according to conventional practice. Subsea test tree 702 has been lowered into BOP stack 704 through a tubular riser 710 extending upwardly therefrom. A fluted wedge 712 attached below subsea test tree 702 permits accurate positioned of subsea test tree 702 within BOP stack 704. In the illustrated embodiment, a retainer valve 714 is attached above subsea test tree 702 and remains within riser 710 when subsea test tree 702 is positioned within BOP stack 704.

[0061] Subsea test tree 702 includes a latch head assembly 716, a ramlock assembly 718 and a valve assembly 720. Ramlock assembly 718 is interconnected axially between latch head assembly 716 and valve assembly 720 to axially separate these components from one another. As used herein, the term ramlock assembly is used to indicate one or more members, which are configured in such a way as to permit sealing engagement with conventional pipe rams. For example, as shown in figure 7, ramlock assembly 718 is shown in sealing engagement with both of the pipe rams 706 as pipe rams 706 have been previously actuated to extend inwardly to engage ramlock assembly 718. As illustrated, latch head assembly 716 and valve assembly 720 have diameters which are greater than that which may be sealingly engaged by conventional pipe rams, therefore, ramlock assembly 718 provides for sealing engagement of the pipe rams 706 between latch head assembly 716 and valve assembly 720.

[0062] Valve assembly 720 is positioned between pipe rams 706 and wedge 712 such that when pipe rams 706 are closed about ramlock assembly 718, valve assembly 720 is isolated from an annulus 722 above pipe rams 706. Pipe rams 706 isolate annulus 722 from an annulus 724 below pipe rams 706 and surrounding valve assembly 720. As used herein, the term valve assembly is used to indicate an assembly including one or more valves, which are operative to selectively permit and prevent fluid flow through a flow passage formed through the valve assembly. For example, valve assembly 720 of figure 7 includes two safety valves (not visible), which are operative to control fluid flow through a tubular string 726. Retainer valve 714, latch head assembly 716, ramlock assembly 718 and valve assembly 720 are all interconnected within and are part of tubular string 726. Tubular string

726 has a flow passage formed therethrough and the valves in valve assembly 720 may be actuated to permit or prevent fluid flow therethrough.

[0063] As used herein, the term latch head assembly is used to indicate one or more members which permit decoupling of one portion of tubular string 726 from another portion thereof. For example, in the representatively illustrated subsea test tree 702, latch head assembly 716 may be actuated to decouple an upper portion 728 of tubular string 726 from a lower portion 730 of tubular string 726. Thus, in the event of an emergency, pipe rams 706 may be closed on ramlock assembly 718, the valves in valve assembly 720 may be closed, and upper portion 728 of tubular string 726 may be retrieved, or otherwise displaced away from lower portion 730. Closure of pipe rams 706 on ramlock assembly 718 and closure of the valves in valve assembly 720 isolates the well therebelow from fluid communication with riser 710. Actuation of retainer valve 714, latch head assembly 716 and valve assembly 720 is controlled via an umbilical assembly 732 that may include one or more hydraulic lines, electric lines, fiber optic lines and the like.

[0064] A lower portion of tubular string 726 extends into well 734. Internal sensors (not pictured) of the present invention positioned in tubular string 726 may be used to identify the formation of any hydrates during flow testing. In the illustrated embodiment, real time information about hydrate formation may be obtained by interrogating the internal sensors with data acquisition devices 736 that are operably associated with umbilical assembly 732. Preferably, each data acquisition devices 736 is located in communicable proximity to one or more of the internal sensors. In the illustrated embodiment, data acquisition device 736 are depicted as being positioned proximate the connection between joints of tubular string 726 as the internal sensors have been positioned in the interior of the connections.

[0065] While this invention has been described with reference to illustrative embodiments, this description is not intended to be construed in a limiting sense. Various modifications and combinations of the illustrative embodiments as well as other embodiments of the invention will be apparent to persons skilled in the art upon reference to the description. It is therefore, intended that the appended claims encompass any such modifications or embodiments.

What is claimed is:

1. A downhole tool comprising:
a housing assembly having an interior and an exterior; and
a sensor disposed to the interior of the housing assembly, the sensor operable to
5 obtain data relative to a fluid parameter of a fluid disposed within the interior of the housing
assembly and operable to wirelessly transmit the data to a data acquisition device disposed to
the exterior of the housing assembly responsive to interrogation by the data acquisition
device.
- 10 2. The downhole tool as recited in claim 1 wherein the interior of the housing
assembly further comprises a fluid chamber of a downhole tester valve and wherein the
sensor is disposed within the fluid chamber.
3. The downhole tool as recited in claim 2 wherein the downhole tester valve
15 further comprises:
a mandrel assembly disposed within the housing assembly defining therebetween an
operating fluid chamber, a biasing fluid chamber and a power fluid chamber;
a valve assembly disposed within the housing assembly operable between open and
closed positions; and
20 a piston assembly operably associated with the valve assembly;
wherein, the sensor is disposed within at least one of the operating fluid chamber, the
biasing fluid chamber and the power fluid chamber.
- 25 4. The downhole tool as recited in claim 1 wherein the interior of the housing
assembly further comprises a sampling chamber of a fluid sampler and wherein the sensor is
disposed relative to the sampling chamber.

5. The downhole tool as recited in claim 4 wherein the fluid sampler further comprises:

an actuator operable to establish a fluid communication path between the exterior and the interior of the fluid sampler;

5 a plurality of sampling chambers operable to receive fluid samples; and

a self-contained pressure source in fluid communication with the sampling chambers operable to pressurize the fluid samples obtained in the sampling chambers to a pressure above saturation pressure.

10 6. The downhole tool as recited in claim 1 wherein the sensor wirelessly communicates with the data acquisition device by one of radio frequency transmission and acoustic transmission.

7. The downhole tool as recited in claim 1 wherein the sensor is powered by at
15 least one of electromagnetic field energy, acoustic energy, thermal energy and radioactive energy.

8. The downhole tool as recited in claim 1 wherein the fluid parameter is at least one of pressure and temperature.

20

9. A downhole tester valve comprising:

a housing assembly;

a mandrel assembly disposed within the housing assembly defining therebetween an operating fluid chamber, a biasing fluid chamber and a power fluid chamber;

25 a valve assembly disposed within the housing assembly operable between open and closed positions;

a piston assembly operably associated with the valve assembly; and

30 a sensor disposed within at least one of the operating fluid chamber, the biasing fluid chamber and the power fluid chamber, the sensor operable to obtain data relative to a fluid parameter and operable to wirelessly transmit the data to a data acquisition device disposed to the exterior of the housing assembly responsive to interrogation by the data acquisition device.

10. The downhole tester valve as recited in claim 9 wherein the sensor wirelessly communicates with the data acquisition device by one of radio frequency transmission and acoustic transmission.

11. The downhole tester valve as recited in claim 9 wherein the sensor is powered by at least one of electromagnetic field energy, acoustic energy, thermal energy and radioactive energy.

12. The downhole tester valve as recited in claim 9 wherein the fluid parameter is at least one of pressure and temperature.

13. A fluid sampler comprising:
a sampling chamber having an interior and an exterior, the sampling chamber operable to receive a fluid sample;
an actuator operable to establish a fluid communication path between the exterior and the interior of the sampling chamber;
a self-contained pressure source in fluid communication with the sampling chamber, the pressure source operable to pressurize the fluid sample to a pressure above saturation pressure; and
a sensor disposed to the interior of the sampling chamber, the sensor operable to obtain data relative to a fluid parameter of the fluid sample and operable to wirelessly transmit the data to a data acquisition device disposed to the exterior of the sampling chamber responsive to interrogation by the data acquisition device.

14. The fluid sampler as recited in claim 13 wherein the sensor wirelessly communicates with the data acquisition device by one of radio frequency transmission and acoustic transmission.

15. The fluid sampler as recited in claim 13 wherein the sensor is powered by at least one of electromagnetic field energy, acoustic energy, thermal energy and radioactive energy.

16. The fluid sampler as recited in claim 13 wherein the fluid parameter is at least one of pressure and temperature.

17. An oil field tubular system comprising:

a plurality of oil field tubulars operably coupled together, the oil field tubulars having an interior and an exterior; and

5 a sensor disposed to the interior of the oil field tubulars, the sensor operable to obtain data relative to a fluid parameter of a fluid disposed within the interior of the oil field tubulars and operable to wirelessly transmit the data to a data acquisition device disposed to the exterior of the oil field tubulars responsive to interrogation by the data acquisition device.

10 18. The oil field tubular system as recited in claim 17 wherein the oil field tubulars further comprise a surface flowline.

19. The oil field tubular system as recited in claim 17 wherein the oil field tubulars further comprise downhole tubulars.

15 20. The oil field tubular system as recited in claim 17 wherein the sensor wirelessly communicates with the data acquisition device by one of radio frequency transmission and acoustic transmission.

20 21. The oil field tubular system as recited in claim 17 wherein the sensor is powered by at least one of electromagnetic field energy, acoustic energy, thermal energy and radioactive energy.

22. The oil field tubular system as recited in claim 17 wherein the fluid parameter is at least one of pressure and temperature.