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— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

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(54) **Title**: SMART ELECTROCHEMICAL SENSOR FOR PIPELINE CORROSION MEASUREMENT

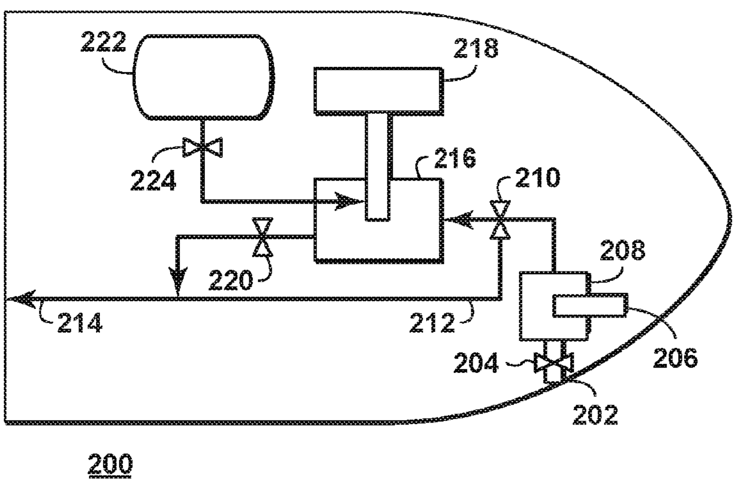

FIG. 2

(57) **Abstract**: A method of monitoring a pipeline, comprising positioning a probe device in the pipeline, passing the probe device along the pipeline, collecting at least one fluid sample at each of a plurality of locations along a length of the pipeline, passing each fluid sample into the probe device, and measuring at least one corrosion-related parameter of a fluid at a plurality of locations along the pipeline, wherein the at least one corrosion-related parameter is selected from a group consisting of: pH, temperature, pressure, viscosity, conductivity, salinity, deposits, and corrosivity.

WO 2017/039789 A1

SMART ELECTROCHEMICAL SENSOR FOR PIPELINE CORROSION MEASUREMENT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the priority benefit of United States Patent Application 62/212,297 filed August 31, 2015 entitled SMART ELECTROCHEMICAL SENSOR FOR PIPELINE CORROSION MEASUREMENT, the entirety of which is incorporated by reference herein.

BACKGROUND

[0002] Ensuring the integrity of oil and gas transport pipelines is a significant focus of the energy industry. Loss of integrity can result in significant adverse financial and environmental impact. Operating experience has shown that internal corrosion is the one of the main threats to pipeline integrity for flowlines and gathering lines carrying untreated produced fluids. The fluids transported through the pipelines may be inherently corrosive and may rapidly reduce the pipe wall thickness, thereby increasing the risk of a loss of pipeline integrity. Consequently, pipeline inspection and pipeline corrosion measurement are of importance to the industry.

[0003] Currently, the industry uses two types of corrosion detection sensors: movable and fixed. Movable pipeline inspection tools include tools such as in-line-inspection (ILI) tools or smart pigs travel inside the pipeline with fluid to assess the condition of pipelines. These tools may be equipped with sensors that measure the remaining wall thickness on the pipeline. The data provided by such inspection, however, is a lagging indicator of corrosion; corrosion must first occur and the wall thickness must first be reduced before corrosion may be detected. Furthermore, the time period between two consecutive inspections runs may be relatively long (e.g., more than 5 years), and substantial damage may progress in the interim. Early detection of corrosion would enable earlier corrective actions, more timely corrosion mitigation and/or intervention, and elimination and/or reduction of high consequence integrity loss events.

[0004] Fixed sensors may also be used for corrosion detection and/or measurement. Installation of fixed sensors or coupons along the pipeline length may provide real-time monitoring of pipeline conditions. Currently, corrosion coupons and/or corrosion rate measuring probes such as Electrical Resistance (ER) and Linear polarization Resistance (LPR) are used to measure corrosion rate in real-time, or at frequent interval in the pipeline at fixed location. These in-pipeline coupons/probes are only capable of providing corrosion information at a local point. However, pipeline corrosion may vary with location along the length due to topography and change in flow conditions in the pipeline. If fixed sensors are installed at a relatively less corrosive location in the pipeline, the sensors may present an inaccurate picture of the state of the pipeline. Identification of correct installation location may be critical in extracting appropriate information from these fixed sensors, but such information may be difficult to obtain. Consequently, a large number of such sensors may need to be mounted along the length of the pipeline to get accurate information on the state of the full pipeline.

[0005] Prior art technologies include U.S. Patent Publication No. 2003/0121338 for a pipeline pigging device for non-destructive inspection of the fluid environment in a pipeline. This disclosure includes a spherical, flowing fluid monitoring tool wherein the sensing element is at/near the surface of the sphere for directly measures the fluid characteristics as it flows along the line. Another prior art technology includes U.S. Patent Publication No. 2012/0279599 for an infrastructure corrosion analysis. This disclosure includes a pig-like device that collects pipeline wall corrosion data from a pipeline, analyzes the data, evaluates corrosion risk, and creates an implementation plan for the remediation of the pipeline. Still another prior art technology includes U.S. Patent No. 7,282,928 for a corrosion measurement field device with improved harmonic distortion analysis (HDA), linear polarization resistance measurement (LPR), electrochemical noise measurement (ECN) capability. This disclosure includes a corrosion measurement device that measures corrosion of a structure exposed to a fluid using a multi-electrode system and where a sinusoidal signal is transmitted into the fluid through one electrode and response evaluated using a second electrode.

[0006] Consequently, there exists a need for a sensor that is capable of providing early detection of pipeline corrosion without relying on an *ex post facto* corrosion analysis. There also exists a need for a sensor that is capable of providing corrosion information along a length of a pipeline without regard to topography and/or change in flow conditions in the pipeline. There further exists a need for a sensor that can provide accurate and timely information about the state of a pipeline.

SUMMARY

[0007] One embodiment includes a method of monitoring a pipeline, comprising positioning a probe device in the pipeline, passing the probe device along the pipeline, collecting at least one fluid sample at each of a plurality of locations along a length of the pipeline, passing each fluid sample into the probe device, and measuring at least one corrosion-related parameter of a fluid at a plurality of locations along the pipeline, wherein the at least one corrosion-related parameter is selected from a group consisting of: pH, temperature, pressure, viscosity, conductivity, salinity, deposits, and corrosivity.

[0008] Another embodiment includes an apparatus for monitoring a pipeline, comprising an electrochemical sensor device comprising: a body configured for passage along the pipeline, a fluid inlet on the electrochemical sensor device configured to collect at least one sample of a fluid, an electrochemical sensor disposed within the body and coupled to the fluid inlet, wherein the electrochemical sensor is configured to measure at least one corrosion-related parameter of the at least one sample.

[0009] Still another embodiment includes an apparatus for measuring a fluid in a pipeline, comprising a probe device, comprising a fluid sample collection section configured to collect at least one fluid sample, a fluid sample analysis section configured to analyze the fluid sample, a fluid sample disposal section configured to dispose of the fluid sample, wherein the probe device is configured for passage down the pipeline from a first location to a second location.

[0010] Unlike U.S. Patent Publication No. 2003/0121338, in some embodiments the present disclosure may not conduct measurements directly in the fluid. In disclosed embodiments, the fluid may be collected in a small reservoir in the tool and/or the sensor may be internally disposed. Unlike U.S. Patent Publication No. 2012/0279599, in some embodiments the present disclosure may not involve monitoring pipeline wall thickness and/or may only involve monitoring one or more corrosivity characteristics and/or parameters of the fluid. Unlike U.S. Patent No. 7,282,928, in some embodiments the present disclosure may not rely on transmitting a sinusoidal signal into the fluid for generating a response. Instead, disclosed embodiments may use a direct (non-oscillating) signal to generate a response. Unlike WO2014073969A2, in some embodiments the present disclosure may deploy the existing LPR and ER probe technologies on a pig/ robot which can travel in the pipeline. Therefore, the probes are not fixed to the equipment. Furthermore, our invention focuses on deploying suit of sensors in the pipeline to retrieve the information along the whole pipeline as they move through it.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The advantages of the present techniques are better understood by referring to the following detailed description and the attached drawings, in which:

[0012] **FIG. 1** is a schematic diagram of a first embodiment of a smart electrochemical sensor device for pipeline corrosion measurement.

[0013] **FIG. 2** is a schematic diagram of a second embodiment of a smart electrochemical sensor device for pipeline corrosion measurement.

DETAILED DESCRIPTION

[0014] In the following detailed description section, specific embodiments of the present techniques are described. However, to the extent that the following description is specific to a particular embodiment or a particular use of the present techniques, this is intended to be for exemplary purposes only and simply provides a description of the exemplary embodiments. Accordingly, the techniques are not limited to the specific embodiments described herein, but rather, include all alternatives, modifications, and equivalents falling within the true spirit and scope of the appended claims.

[0015] At the outset, for ease of reference, certain terms used in this application and their meanings as used in this context are set forth. To the extent a term used herein is not defined herein, it should be given the broadest definition persons in the pertinent art have given that term as reflected in at least one printed publication or issued patent. Further, the present techniques are not limited by the usage of the terms shown herein, as all equivalents, synonyms, new developments, and terms or techniques that serve the same or a similar purpose are considered to be within the scope of the present claims.

[0016] As used herein, the term “fluid” may refer to gases, liquids, and/or combinations of gases and liquids, as well as to combinations of liquids and solids, and particularly to hydrocarbons.

[0017] As used herein, the term “hydrocarbon” refers to an organic compound that primarily includes the elements hydrogen and carbon, although nitrogen, sulfur, oxygen, metals, or any number of other elements may be present in small amounts. As used herein, hydrocarbons generally refer to components found in natural gas, oil, or chemical processing facilities.

[0018] As used herein with respect to fluid processing equipment, the term "inline" means sequentially within an identifiable common axis of orientation of flow.

[0019] As used herein, the term "substantial" when used in reference to a quantity or amount of a material, or a specific characteristic thereof, refers to an amount that is sufficient to provide an effect that the material or characteristic was intended to provide. The exact degree of deviation allowable may depend, in some cases, on the specific context.

[0020] As used herein, the terms "a" and "an," mean one or more when applied to any feature in embodiments of the present inventions described in the specification and claims. The use of "a" and "an" does not limit the meaning to a single feature unless such a limit is specifically stated.

[0021] As used herein, the definite article "the" preceding singular or plural nouns or noun phrases denotes a particular specified feature or particular specified features and may have a singular or plural connotation depending upon the context in which it is used.

[0022] This disclosure comprises mounting one or more sensing probes, e.g., LPR probes, on a device configured to travel along a pipeline and gather fluid corrosivity information. LPR allows corrosion-related metrics or parameters to be measured directly in real-time. The operating principle of LPR is based on measuring the flow of current between electrodes. When a metal/alloy electrode is immersed in an electrolytically conducting fluid of sufficient oxidizing power, it will corrode by an electrochemical mechanism. At anodic sites, metal will pass from the solid surface into the adjacent solution and, in so doing, leave a surplus of electrons at the metal surface. The excess electrons will flow to nearby sites, referred to as cathodic sites, where the excess electrons may be consumed by oxidizing species from the corrosive liquid. The corrosion current, i.e., the current generated by the flow of electrons from anodic to cathodic sites, may be used to compute a corrosion rate using a modified version of Faraday's Law. This disclosure may include distributing LPR probes around a device circumference to sample fluid and passing the device inline along a pipeline to sample different locations in the pipeline.

[0023] This disclosure includes a sensor capable of providing early detection of pipeline corrosion without relying on an *ex post facto* corrosion analysis, e.g., by sampling the fluid and not the pipeline wall. This disclosure includes a sensor capable of providing corrosion information along a length of a pipeline without regard to topography and/or change in flow conditions in the pipeline, e.g., by periodically obtaining samples at predetermined intervals along a length of pipeline and not remaining fixed. This disclosure includes a sensor that can provide accurate and timely information about the state of a pipeline, e.g., by providing real-time information about corrosive fluid conditions and/or parameters within a pipeline.

[0024] **FIG. 1** is a schematic diagram of a first embodiment of a smart electrochemical sensor device or probe device **100** for pipeline corrosion measurement. The device **100** may have a body diameter that is substantially the same diameter as the pipeline. The device **100** may have at least a portion of the body having a substantially cylindrical shape. The device **100** may have a conical first end similar to that of conventional cleaning pigs. Those of skill in the art will appreciate that suitable alternate embodiments are envisioned having differing shapes and/or diameters to create the desired flow characteristics, e.g., having fins, ridges, dimples, tails, etc., having a generally torpedo shape, a generally spherical shape, a generally oblate spheroid shape, a generally prolate spheroid shape, etc. Additionally, some embodiments may comprise propulsion mechanisms, e.g., propellers, jets, etc., on a second end distal from the first end for propelling or accelerating the passage of the device along a pipeline. Other propulsion mechanisms may permit the device **100** to roll, e.g., using gravity or drive wheels. Other embodiments may comprise drag mechanisms, e.g., parachutes, fins, rudders, ribs, etc., for slowing the passage of the device **100** in the pipeline and/or maintaining suitable orientation/alignment of the device in the pipeline.

[0025] The device **100** comprises an inlet port **102** in a fluid sample collection section for collecting a fluid sample. In some embodiments, the port **102** may be wire framed with/without spring-loaded components, e.g., arms, flaps, caps, etc., for restricting sampling periods, e.g., limiting sampling to predetermined times, periodicities, locations, etc. The port **102** is depicted on a radially inwardly disposed location on a conical head end of the device **100** in order to collect a sample of fluid that is (1) substantially in front of the device **100**, (2) relatively close to the pipeline wall, and (3) generally representative of the fluid passing along the pipeline wall (not depicted). Other locations for the port **102** may be suitably employed within the scope of this disclosure to obtain the desired fluid sample characteristics as would be understood by those of skill of the art and are considered within the scope of this disclosure. Some embodiments may utilize filters, screens, baffles, or other mechanisms disposed on or in conjunction with the port **102** to obtain a representative sample suitably representative of the fluid for which sampling is desired.

[0026] An internally disposed power source **104** is coupled to an LPR probe **106** in a fluid sample analysis section of the device **100**. The port **102** is coupled to and configured to pass a fluid sample to the LPR probe **106**. An outlet port **108** is coupled to the LPR probe **106** and is configured to dispose of a fluid sample following sampling at the LPR probe **106**, e.g., via an internally disposed passage having an outlet located in a fluid sample disposal section positioned at a second tail end of the device **100**. In some embodiments, the outlet port **108** is configured to act as or in conjunction with a propulsion mechanism as discussed above, e.g., by positioning the outlet port **108** such that the outlet port **108** emits a propulsion fluid between the device **100** and a pipeline wall (not depicted). While depicted as having a singular internal sampling system, other embodiments may include a plurality of internal sampling systems sharing the same ports **102**, **108**, LPR probe **106**, and/or power source **104** or having one or more such components configured to operate independently, e.g., for redundancy, for sampling different fluids and/or corrosion-related parameters, etc., within the scope of this disclosure.

[0027] In operation, the device **100** may be positioned in a pipeline at a first location. The device **100** may pass along a pipeline and may collect one or more fluid samples via the outlet port **108**. The fluid samples may pass to the LPR probe **106** where each of the fluid samples may be measured for at least one corrosion-related parameter, e.g., pH, temperature, pressure, viscosity, conductivity, salinity, deposits, corrosivity, etc., that may be used to determine a corrosion index for the pipeline. In LPR, the measurements may show decay characteristic, e.g., due to capacitive effects. This delay or time lag may vary depending on the specific characteristics of the metal/environment system. Since the decay characteristic is asymptotic, systems with ‘capacitive inertia’ may closely approach equilibrium in 0-5 minutes, 0-10 minutes, 0-15 minutes, 0-30 minutes, 5-10 minutes, 5-15 minutes, 5-30 minutes, 10-15 minutes, 10-30 minutes, or 15-30 minutes. Frequency of sampling and measurement may be varied based on the properties of the fluid to be sampled and/or measured parameters and may be optimized using a control system configured to control the sampling frequency, e.g., by controlling the opening/closing frequency of the ports **102** and/or **108** based on a timer, a location, or another metric to obtained the desired operating characteristics for the device **100**. In some embodiments, the device **100** may be equipped with components configured to periodically clean the LPR probe **106** either chemically or mechanically depending on fluid properties to avoid fouling of sensors. The device **100** may be removed from the pipeline at a second location, e.g., downstream along a pipeline. The second location may be remote from the first location by a separation of between 0-1 kilometers (km), 0-10 km, 0-50 km, 0-100 km, 10-50 km, 10-100 km, 50-100 km, a distance greater than 1 km, 10 km, 50 km, or 100 km, as optionally determined, e.g., based on the power available to the power source **104**, based on global positioning system (GPS) availability, based on topological and/or geographic limitations, etc.

[0028] In some embodiments, the device **100** may further comprise a chemical dispersing section configured to disperse a chemical, e.g., a corrosion inhibiting chemical, into the pipeline, e.g., in response to a parameter measurement exceeding a predetermined set point. The device may dispose corrosion inhibitor or biocide if the residual of corrosion inhibitor or biocide is below threshold. Threshold value of corrosion inhibitor is defined based on fluid corrosivity or corrosion rate at that location which depends on the corrosion allowance used during pipeline design. Typical value of threshold corrosion rate may be lower than 20 mils per year (mpy), e.g., between 0-20 mpy, 0-10 mpy, 0-5 mpy, etc. Suitable corrosion inhibitors may include chemicals such as quaternary ammonium salt, quaternary amine, imidazoline, or other similar compounds. In some cases, emulsifier may be added in the fluid to remove free water, or pH buffering agent may be added to maintain pH at desired value in the pipeline.

[0029] In some embodiments, the device **100** may further comprises one or more location sensors, e.g., a GPS sensor, for determining the position of the device **100**. The device **100** may further comprise computer equipment configured to record the location of the device **100** at a particular time, e.g., in order to record particular regions of concern within the pipeline for future monitoring, in order to disperse corrosion inhibiting chemicals, etc.

[0030] **FIG. 2** is a schematic diagram of a second embodiment of a smart electrochemical sensor device **200** for pipeline corrosion measurement. The components of the device **200** may be substantially the same as the corresponding components of the device **100** of FIG. 1 except as otherwise noted. The device **200** has an inlet port **202** and an inlet valve **204** configured to start and stop fluid sample collection, e.g., as directed by a control system (not depicted) configured to control sampling periodicity. A conductivity measuring probe **206** is disposed in a fluid reservoir **208**. A three-way valve **210** is configured to pass a fluid sample from the fluid reservoir along a bypass **212** to the outlet port **214** or along an inlet line to the LPR probe **216**. An internally disposed power source **218** is coupled to the LPR probe **216**. An outlet valve **220** is configured to pass the fluid sample from the LPR probe to the outlet port **214**. In some embodiments, the outlet valve **220** is directed by a control system (not depicted) configured to control sampling periodicity. A probe cleaning equipment **222** is disposed in a cleaning section on the device **200** and configured to store a probe cleaning liquid. A cleaning liquid valve **224** is disposed on a line coupling the probe cleaning equipment **222** to the LPR probe **216**. In some embodiments, the probe cleaning equipment **222** comprises chemical cleaning equipment, e.g., one or more nozzles and pumps configured to pass the probe cleaning liquid to the LPR probe in order to periodically clean the LPR probe **216** and thus avoid fouling of the sensors. Mechanical cleaning equipment (not depicted) may be disposed on the device **200** and used alternately or additionally for substantially the same purpose as understood by those of skill in the art.

[0031] While the present techniques may be susceptible to various modifications and alternative forms, the exemplary embodiments discussed herein have been shown only by way of example. However, it should again be understood that the techniques disclosed herein are not intended to be limited to the particular embodiments disclosed. Indeed, the present techniques include all alternatives, modifications, combinations, permutations, and equivalents falling within the true spirit and scope of the appended claims.

CLAIMS

What is claimed is:

1. A method of monitoring a pipeline, comprising:

positioning a probe device in the pipeline;

passing the probe device along the pipeline;

collecting at least one fluid sample at each of a plurality of locations along a length of the pipeline;

passing each fluid sample into the probe device; and

measuring at least one parameter of each fluid sample using an electrochemical sensor disposed within the probe device, wherein the at least one parameter is selected from a group consisting of: pH, temperature, pressure, viscosity, conductivity, salinity, deposits, and corrosivity.

2. The method of claim 1, wherein measuring the at least one parameter comprises performing linear polarization resistance (LPR) analysis, electrical resistance (ER) analysis, or both.

3. The method of claim 1 or claim 2, wherein the length of the pipeline is at least 1 kilometer.

4. The method of any of claims 1-3, further comprising:

delivering at least one chemical in the pipeline based at least in part on results from measuring the at least one parameter, a location of the probe device in the pipeline, or a combination thereof.

5. The method of any of claims 1-4, further comprising:

cleaning at least one sensor on the probe using cleaning equipment disposed on the probe.

6. An apparatus for monitoring a pipeline, comprising:

an electrochemical sensor device comprising:

a body configured for passage along the pipeline;

a fluid inlet on the electrochemical sensor device configured to collect at least one sample of a fluid;

an electrochemical sensor disposed within the body and coupled to the fluid inlet, wherein the electrochemical sensor is configured to measure at least one corrosion-related parameter of the at least one sample.

7. The apparatus of claim 6, wherein the electrochemical sensor device further comprises:

a location sensor, and

a memory configured to store a location of the electrochemical sensor device in response to measuring at least one corrosion-related parameter, sensing a location of the electrochemical sensor device, or a combination thereof.

8. The apparatus of claim 6 or claim 7, wherein the electrochemical sensor device further comprises:

a fluid reservoir having a fluid reservoir inlet and a fluid reservoir outlet, wherein the fluid reservoir is configured to retain the sample of the fluid;

an inlet valve coupled to the fluid reservoir inlet; and

an outlet valve coupled to the fluid reservoir outlet.

9. The apparatus of any of claims 6-8, wherein the body has a diameter that is substantially the same diameter as the pipeline, and wherein at least a portion of the body has a substantially cylindrical shape.

10. The apparatus of claim 9, wherein the body comprises a conically shaped first end configured to lead the probe device along the pipeline, and wherein the fluid inlet is disposed on the first end of the body.

11. The apparatus of claim 9, wherein the electrochemical sensor device further comprises:

a propulsion mechanism disposed on a tail end of the electrochemical sensor device.

12. The apparatus of any of claims 6-11, wherein the electrochemical sensor device further comprises:

a plurality of electrochemical sensors configured to measure at least one corrosion-related parameter of the fluid.

13. The apparatus of any of claims 6-12, wherein the electrochemical sensor device further comprises: a cleaning fluid reservoir configured to retain a sensor cleaning fluid; and

a cleaning fluid dispenser coupled to the cleaning fluid reservoir on a first end and coupled to the sensor on a second end, and configured to pass the sensor cleaning fluid from the cleaning fluid reservoir to the sensor.

14. The apparatus of any of claims 6-13, wherein the electrochemical sensor device further comprises: a chemical reservoir configured to retain a corrosion inhibiting chemical; and

a chemical dispensing port coupled to the chemical reservoir, and configured to dispense the corrosion inhibiting chemical into the pipeline.

15. An apparatus for measuring a fluid in a pipeline, comprising:

a probe device, comprising:

a fluid sample collection section configured to collect at least one fluid sample;

a fluid sample analysis section configured to analyze the fluid sample;

a fluid sample disposal section configured to dispose of the fluid sample;

wherein the probe device is configured for passage down the pipeline from a first location to a second location.

16. The apparatus of claim 15, wherein the probe device comprises:

a head end;

a center section coupled to the head end; and

a tail end coupled to the center section, wherein the head end is distal from the tail end, and wherein:

the fluid sample collection section comprises at least a portion of the head end, the center section, or both; and

the fluid sample analysis section comprises at least a portion of the center section.

17. The apparatus of claim 15 or claim 16, wherein the fluid sample collection section is configured to periodically collect a plurality of fluid samples, and wherein the fluid sample disposal section comprises a reservoir for retaining one or more fluid samples for subsequent analysis.

18. The device of any of claims 15-17, wherein the probe further comprises:

a cleaning section configured to clean at least a portion of the fluid sample analysis section.

19. The device of any of claims 15-18, wherein the probe further comprises:

a chemical dispersing section configured to disperse a chemical into the pipeline.

20. The device of any of claims 15-19, wherein the fluid sample analysis section comprises at least one sensor for analyzing the fluid sample for at least one corrosion-related parameter selected from a group consisting of: pH, temperature, pressure, viscosity, conductivity, salinity, deposits, and corrosivity.

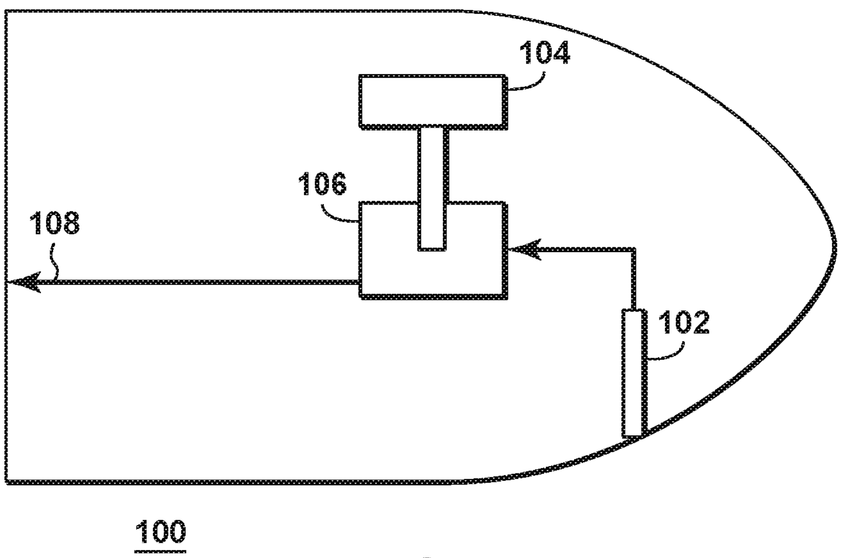
104
106
108
102
100

FIG. 1

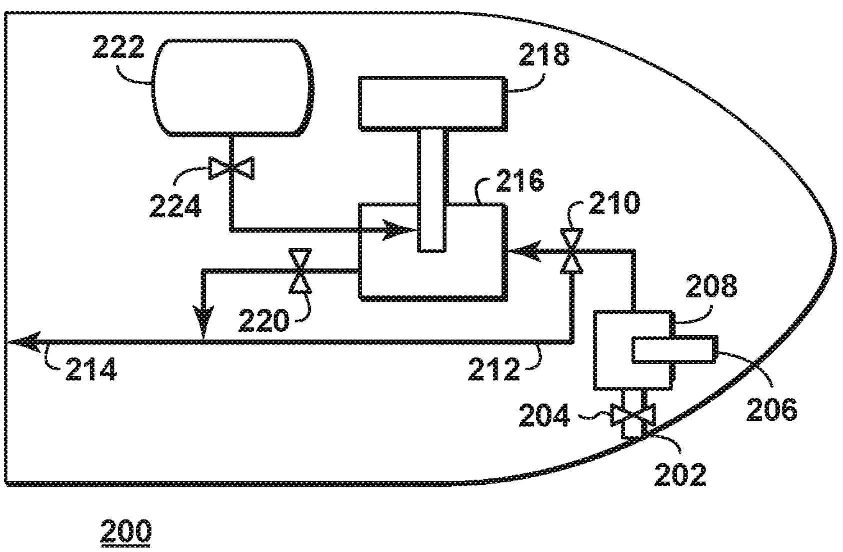
222
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FIG. 2

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/038600

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01N17/04
ADD.

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)
G01N E21B

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	GB 2 338 307 A (COPIPE SYSTEMS LIMITED [GB]; CORMON LIMITED [GB]) 15 December 1999 (1999-12-15) page 5, line 1 - page 6, line 3; figures -----	1-20
A	US 2005/168208 A1 (POTS BERT [US] ET AL) 4 August 2005 (2005-08-04) paragraph [0004] - paragraph [0006] -----	1-20
Y	US 2007/119244 A1 (GOODWIN ANTHONY R [US] ET AL) 31 May 2007 (2007-05-31) paragraph [0001] - paragraph [0010]; figures -----	1-20
A	US 6 871 713 B2 (MEISTER MATTHIAS [DE] ET AL) 29 March 2005 (2005-03-29) column 8, line 51 - column 9, line 7 ----- -/--	1-20

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
27 September 2016	05/10/2016

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1

INTERNATIONAL SEARCH REPORT

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2009/052235 A1 (SCHLUMBERGER CA LTD [CA]; SCHLUMBERGER TECHNOLOGY BV [NL]; PRAD RES &) 23 April 2009 (2009-04-23) paragraph [0001] - paragraph [0005] -----	1-20

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2016/038600

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
GB 2338307	A	15-12-1999	GB	2338307	A	15-12-1999
			NO	992798	A	13-12-1999
US 2005168208	A1	04-08-2005	AU	2005210467	A1	18-08-2005
			CA	2555092	A1	18-08-2005
			EA	200601396	A1	29-12-2006
			EG	24696	A	25-05-2010
			EP	1709216	A1	11-10-2006
			NO	337787	B1	20-06-2016
			US	2005168208	A1	04-08-2005
			WO	2005075708	A1	18-08-2005
			ZA	200605873	B	30-01-2008
US 2007119244	A1	31-05-2007	CA	2594086	A1	22-06-2008
			GB	2445043	A	25-06-2008
			US	2007119244	A1	31-05-2007
US 6871713	B2	29-03-2005	NONE			
WO 2009052235	A1	23-04-2009	CA	2702868	A1	23-04-2009
			WO	2009052235	A1	23-04-2009