US 20140069656A1

(19) **United States**

(12) **Patent Application Publication**

Arp

(10) **Pub. No.: US 2014/0069656 A1**

(43) **Pub. Date: Mar. 13, 2014**

(54) **SYSTEMS AND METHODS FOR DETECTING LEAKS IN SUBSEA CEMENT AND WELLBORE EQUIPMENT**

(75) Inventor: **David Arp**, Fort Collins, CO (US)

(73) Assignee: **Arp Inc.**, Fort Collins, CO (US)

(21) Appl. No.: **13/573,353**

(22) Filed: **Sep. 11, 2012**

Publication Classification

(51) **Int. Cl.**

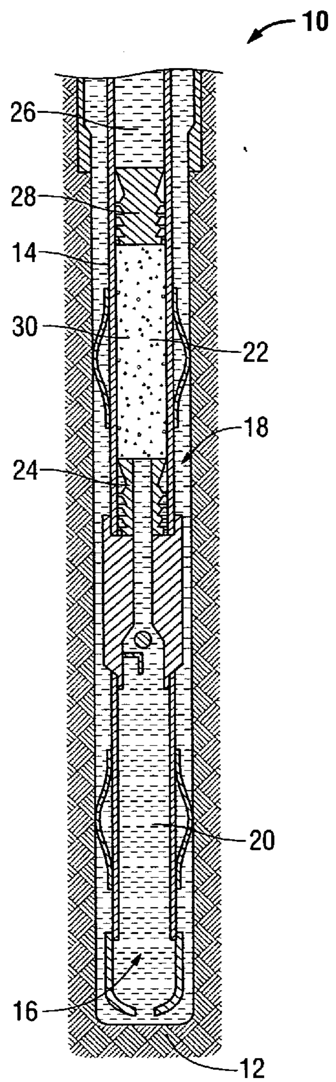
E21B 47/001	(2012.01)
E21B 47/117	(2012.01)
E21B 47/113	(2012.01)
E21B 33/13	(2006.01)
E21B 47/11	(2012.01)

(52) **U.S. Cl.**

USPC **166/337**; 166/336

(57) **ABSTRACT**

Methods and systems for detecting subsea cement returns, leaks in subsea cement, leaks in blowout preventer operating systems or other equipment or conduits, or the presence of sweep or spacer media subsea or at the surface, include mixing an indicator, such as sodium fluorescein, with a quantity of cement or other medium, the indicator being insulated from contact with the subsea environment. The medium and indicator can be provided into a subsea wellbore, and upon contact of a portion of the medium with the subsea environment, the indicator can become detectable. Exposing the subsea environment proximate to the wellbore to a detector, such as an ultraviolet light source, enables detection of the indicator, and thereby, detection of the medium, which can indicate a cement return or leak of operating fluids in a subsea blowout preventer system.



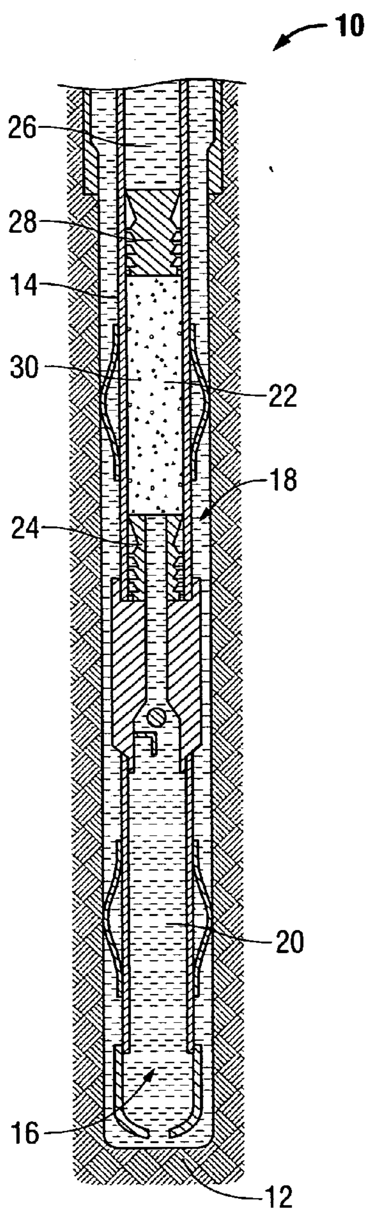


FIG. 1A

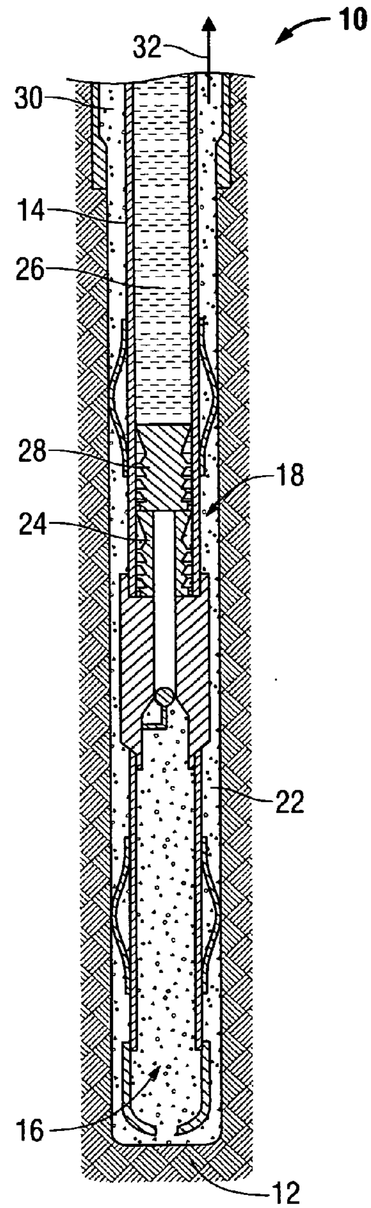


FIG. 1B

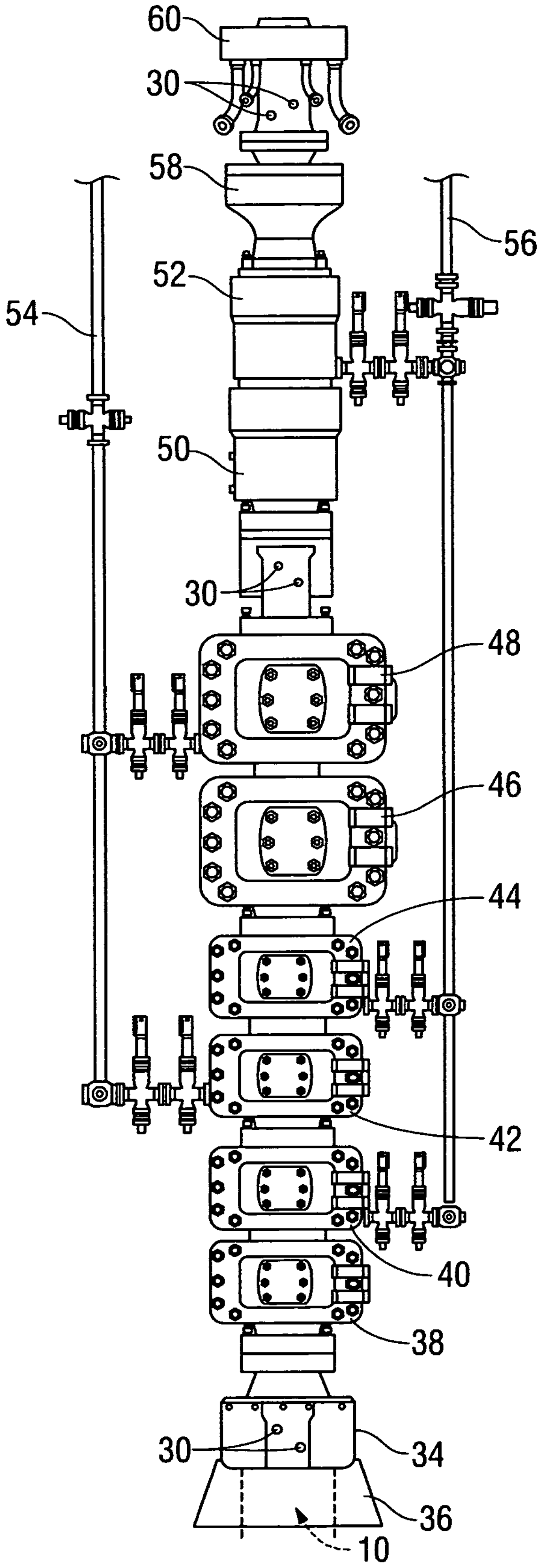


FIG. 2

SYSTEMS AND METHODS FOR DETECTING LEAKS IN SUBSEA CEMENT AND WELLBORE EQUIPMENT

FIELD

[0001] Embodiments usable within the scope of the present disclosure relate, generally, to methods and systems for detecting leaks and/or substances used in association with a subsea wellbore, and more specifically, to methods and systems for detecting cement returns, sweeps, spacers, leaks in cement and/or equipment, and/or other similar substances or features through detection of indicator chemicals in a subsea environment or at the surface of a subsea well.

BACKGROUND

[0002] After drilling and casing a subsea well, it is necessary to cement the well to secure the casing string in place. Typically, cementing a well includes pumping quantities of cement into the well to displace the drilling fluid within, interspersed with quantities of a spacing medium, the cement and spacing medium being separated by plugs or similar members. The objective of a cementing operation is to provide a sufficient quantity of cement into a well such that the annulus surrounding the casing is filled with liquid cement, while the interior of the casing is swept substantially free of cement by the plugs and/or spacing medium. The cement is then allowed to cure, securing the casing in place, to allow for subsequent completion and production operations to be performed.

[0003] Errors in the cementing process, especially in a subsea environment, can be catastrophic, allowing hydrocarbons and/or wellbore fluids to escape into the environment, and/or causing extensive damage to equipment, as well as the possibility of death or injury to personnel. Often, the presence of a leak in cured cement, or the presence of a liquid cement return on the subsea floor, must be determined visually, such as through use of a remotely operated vehicle equipped with a light source and/or camera. Due to the fact that the subsea environment is entirely dark beyond a certain depth, additionally or alternatively, the presence of sweeping and/or spacing media can be visually verified at the surface of a well. Similarly, leaks in operating equipment, such as operating systems of blowout preventers and/or other portions of a subsea wellbore or conduit, must be detected visually, in the subsea environment, such as through detection of visible fluid and/or moving water.

[0004] To facilitate detection of cement, sweeping/spacing media, and/or leaks in cement, equipment, and/or conduits, various dyes can be used to provide color to cement, or other wellbore fluids. However, such dyes often become rapidly diluted and difficult to visualize, especially in a subsea environment, where attempts to visualize the dye are subject to moving water and limited light. Further such dyes also become diluted and/or ineffective after prolonged exposure to and/or movement of wellbore fluid and/or seawater that contacts the dye and/or the medium within which the dye has been added.

[0005] A need exists for systems and methods usable to detect cement returns and/or leaks in a subsea environment, and/or a sweeping or spacing medium associated with a subsea well, that enables efficient, reliable detection.

[0006] A further need exists for systems and methods usable within a subsea environment to detect cement returns and/or leaks associated with a subsea wellbore, blow out preventer operation systems, and/or other similar wellbore equipment and/or conduits.

[0007] A need also exists for systems and methods for detecting cement returns, leaks, and/or wellbore media that remain inactive and/or unexpended until a detectable anomaly and/or event occurs.

[0008] Embodiments usable within the scope of the present disclosure meet these needs.

SUMMARY

[0009] Embodiments usable within the scope of the present disclosure relate to methods for detecting leaks in subsea cement and/or cement returns in a subsea environment in which an indicator is mixed with a quantity of lead cement, the indicator being in an inactive state and insulated from contact with water, providing the quantity of cement and the indicator into a subsea wellbore. When a portion of the lead cement contacts the subsea environment proximate to the subsea wellbore, the indicator is activated to an active state. The subsea environment proximate to the subsea wellbore can be exposed to a detector adapted to detect the indicator, thereby detecting the lead cement. Cement provided into the wellbore subsequent to the lead cement can thereby be allowed to cure.

[0010] For example, one usable indicator can include sodium fluorescein, and/or another similar fluorescein ($C20H12O5$) salt. In an inactive state, sodium fluorescein is a red powder, generally detectable only through visual observation, which can be readily mixed with liquid cement, an oil-based or synthetic mud-based spacer or sweeping solution, or the like, without becoming activated (e.g., by dissasociating into constituent ions). Upon contact with free water, sodium fluorescein becomes activated (e.g., the compound disassociates into sodium and fluorescein ions). The free fluorescein ions will fluoresce a bright green color when exposed to ultraviolet light, enabling a very small quantity of sodium fluorescein to be easily detected once activated.

[0011] As such, sodium fluorescein, another fluorescein salt, or a similar indicator compound, chemical, and/or substance can be mixed with a quantity of cement and provided into a subsea wellbore. When the cement cures, the inactive sodium fluorescein remains embedded in the cement, insulated from contact with the subsea environment. However, in the event that the cement develops a crack or leak, exposure to water will activate the sodium fluorescein, enabling the crack or leak to be easily detected. Similarly, if a cement return occurs at the subsea floor, the sodium fluorescein will be exposed to the water in the subsea environment, enabling the cement return to be easily detected.

[0012] Specifically, an ultraviolet light source can be transported to the subsea floor. For example, in an embodiment, a remotely operated vehicle can be equipped with an ultraviolet light source, and maneuvered proximate to the subsea wellbore to expose the environment proximate to the wellbore to ultraviolet light. Responsive to the presence of ultraviolet light, the activated/dissolved sodium fluorescein will fluoresce (e.g., a bright green), such that even a trace quantity can be readily visualized in a subsea environment, allowing leaks and/or cement returns, independent of sizes, to be quickly and efficiently detected.

[0013] As such, embodiments usable within the scope of the present disclosure also relate to systems for detecting leaks in subsea cement and/or cement returns that include a quantity of cement disposed in association with a subsea wellbore, and an indicator (e.g., sodium fluorescein) within the quantity of cement in an inactive state that is insulated from contact with water. If/when a leak in the cement and/or a cement return in the subsea environment exposes the indicator to water, the indicator is activated (e.g., releasing fluorescein ions), such that a detector adapted for detecting the activated indicator (e.g., an ultraviolet light source) can be used to detect the presence of the indicator, and thereby the leak and/or cement return, as described above.

[0014] Other embodiments usable within the scope of the present disclosure can include methods for detecting a non-aqueous substance associated with a subsea wellbore, such as a liquid cement return on the subsea floor, fluid from within a blowout preventer operating system that contacts water due to a leak, a sweep and/or spacer medium (e.g., a water-based mud and/or oil/synthetic-based medium), and/or other similar non-aqueous substances used in association with a subsea wellbore.

[0015] Specifically, the non-aqueous substance is mixed with an indicator (e.g., sodium fluorescein) in such a manner that the indicator is insulated from contact with water (e.g., from the subsea environment), such that a leak in any component, conduit, and/or piece of equipment used in association with the subsea wellbore, a cement return, or the presence of the spacer or sweep medium at the surface, will cause the indicator to contact water and become activated. A detector (e.g., an ultraviolet light source) can then be used to detect the indicator, and thereby detect the non-aqueous medium. To detect quantities of the non-aqueous medium in the subsea environment proximate to the wellbore, a remotely operated vehicle can be provided with an ultraviolet light source or similar detector, while to detect quantities of the non-aqueous medium at the surface (e.g., a spacer or sweep medium), a small amount of water can be added to the non-aqueous medium as it appears on the surface to ensure activation of the indicator, then a handheld or similar portable ultraviolet light source or other type of detector can be used to detect the activated indicator.

[0016] Embodiments usable within the scope of the present disclosure thereby enable cement returns, sweeping and/or spacing/displacement media, and/or leaks in cement, blowout preventer operating systems, and/or other subsea well equipment or conduits, to be efficiently and reliably detected, in a subsea environment or at the surface, through use of indicators that remain inactive and/or unexpended until a detectable anomaly and/or event occurs.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] In the detailed description of various embodiments usable within the scope of the present disclosure, presented below, reference is made to the accompanying drawings, in which:

[0018] FIG. **1**A depicts an embodiment of a wellbore during a first portion of a cementing operation.

[0019] FIG. **1**B depicts the wellbore of FIG. **1**A during a second portion of the cementing operation.

[0020] FIG. **2** depicts an embodiment of a blowout preventer system usable with embodiments of the present invention.

[0021] One or more embodiments are described below with reference to the listed Figures.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0022] Before describing selected embodiments of the present disclosure in detail, it is to be understood that the present invention is not limited to the particular embodiments described herein. The disclosure and description herein is illustrative and explanatory of one or more presently preferred embodiments and variations thereof, and it will be appreciated by those skilled in the art that various changes in the design, organization, means of operation, structures and location, methodology, and use of mechanical equivalents may be made without departing from the spirit of the invention.

[0023] As well, it should be understood that the drawings are intended to illustrate and plainly disclose presently preferred embodiments to one of skill in the art, but are not intended to be manufacturing level drawings or renditions of final products and may include simplified conceptual views to facilitate understanding or explanation. As well, the relative size and arrangement of the components may differ from that shown and still operate within the spirit of the invention.

[0024] Moreover, it will be understood that various directions such as "upper", "lower", "bottom", "top", "left", "right", and so forth are made only with respect to explanation in conjunction with the drawings, and that components may be oriented differently, for instance, during transportation and manufacturing as well as operation. Because many varying and different embodiments may be made within the scope of the concept(s) herein taught, and because many modifications may be made in the embodiments described herein, it is to be understood that the details herein are to be interpreted as illustrative and non-limiting.

[0025] Referring now to FIG. **1**A, a lower portion of a subsea wellbore (**10**) is depicted, the wellbore generally consisting of a drilled channel, conduit, shaft, bore, etc., extending vertically through a formation (**12**). It should be noted that while FIG. **1**A depicts a vertical wellbore drilled in a subsea environment, embodiments usable within the scope of the present disclosure can be used with any type of land-based or subsea wellbore, including deviated, directional, and/or horizontal wellbores, multilaterals, or any other type of wellbore known in the art, independent of the purpose of the wellbore (e.g., production of hydrocarbons, water, deposition of waste, storage of hydrocarbons, etc.).

[0026] A tubular string (**14**) (e.g., a landing string) is shown positioned in the wellbore (**10**). The depicted tubular string (**14**) includes one or more segments of a tubular conduit (e.g., casing), terminating at a float collar and a guide shoe, and one or more centralizers for positioning and/or stabilizing the string (**14**) in the wellbore (**10**). The specific components of a landing string are well known in the art, and it should be understood that embodiments usable within the scope of the present disclosure can be used in connection with any type of tubular string or other wellbore conduit or equipment, as well as in uncased and/or open-hole regions, independent of the type and/or arrangement of tubular elements or equipment within the wellbore.

[0027] The tubular string (**14**) includes an axial bore (**16**) extending therethrough for communicating cement and/or other fluids/substances. Positioning the tubular string (**14**) within the wellbore (**10**) defines an annulus (**18**) between the exterior of the tubular string (**14**) and the formation (**12**). As described above, the typical objective of a cementing operation is to provide liquid cement into the wellbore (**10**) through the axial bore (**16**) of the string (**14**), then displace the cement into the annulus (**18**), e.g., using one or more plugs and a spacing medium, where the cement is allowed to cure to secure the tubular string (**14**) in a desired position.

[0028] For example, FIG. **1**A depicts the lower portion of the tubular string (**14**) containing drilling fluid (**20**), within both the lower section of the bore (**16**) and throughout the annulus (**18**). Above the drilling fluid (**20**) within the bore (**16**), a cement slurry (**22**) is shown, which is pumped downward through the string (**14**) just above a bottom plug (**24**). Above the cement slurry (**22**), a displacement fluid (**26**) is shown, which is pumped downward through the string (**14**) just above a top plug (**28**).

[0029] As the cement slurry (**22**) is pumped through the tubular string (**14**), the bottom plug (**24**) displaces the drilling fluid (**20**) until the bottom plug (**24**) is seated in the tubular string (**14**) (e.g., on a float collar). The cement slurry (**22**) is then pumped through a bore in the bottom plug (**24**), where it exits the lower end of the tubular string (**14**), then travels upward in the annulus (**18**). FIG. **1**B depicts the cement slurry (**22**) occupying the lower portion of the tubular string (**14**) beneath the bottom plug (**24**), and occupying the annulus (**18**).

[0030] To remove undesired cement from the operative portions of the tubular string (**14**), the displacement fluid (**26**) can be pumped into the bore (**16**), such that the top plug (**28**) displaces the cement slurry (**22**) through the bore in the bottom plug (**24**), out from the upper portions of the tubular string (**14**). Continued pumping of the displacement fluid (**26**) further displaces the cement slurry (**22**) into the annulus (**18**). Once the cement within the annulus (**18**) cures, the tubular string (**14**) is secured, and subsequent operations (e.g., perforating, stimulation, production, etc.) can be performed.

[0031] For illustrative purposes, FIGS. **1**A and **1**B depict quantities of an indicator compound (**30**) (e.g., particles and/or groups of particles of sodium fluorescein or a similar indicator) mixed with and substantially encased in the cement slurry (**22**), such that the indicator compound (**30**) is insulated from water and the adjacent subsea environment. It should be understood that the specific depiction and placement of exemplary quantities of indicator compound (**30**) is merely a conceptual diagram, and that any quantity of indicator can be substantially mixed throughout any portion of the cement, or in an embodiment, mixed with the displacement fluid (**26**), as described previously.

[0032] When a liquid cement return, diagrammatically illustrated by the arrow (**32**), contacts the subsea floor, the indicator compound (**30**) is exposed to the subsea environment and becomes activated, such that use of an ultraviolet light source or similar detector can determine the presence of the cement return by detecting the indicator compound. Similarly, leaks in cured cement containing the indicator compound (**30**), and/or the presence of displacing fluid at the surface that contains the indicator compound, can also be detected through use of a detector.

[0033] Referring now to FIG. **2**, an embodiment of a blowout preventer system is shown in association with a subsea wellbore (**10**), the depicted blowout preventer including a bottom connector (**34**) with a guide funnel (**36**) attached thereto, the bottom connector (**34**) being engaged with the upper portion (e.g., a conduit) of the wellbore (**10**). The blowout preventer system is shown having a set of SST rams (**38**) proximate to the bottom connector (**34**) (e.g., near the top of the wellhead), and three sets of rams (e.g., lower (**40**), middle (**42**), and upper (**44**) rams) above the SST rams (**38**). The rams can engage the top of the wellhead via any manner of wellhead connector and/or fasteners (e.g., studs, locking dogs, etc.) known in the art. Two sets of shear rams—a set of casing shear rams (**46**) and a set of blind shear rams (**48**)—are shown above the upper rams (**44**). Above the shear rams, (**46**, **48**), a lower annular packer (**50**) and an upper annular packer (**52**) are shown. A choke line (**54**) is usable to gain access to the wellbore below one or more sets of closed rams and/or annular packers, as known in the art, while a kill line (**56**) is similarly usable to gain access to and/or below one or more sets of rams and/or packers. Each of the lines (**54**, **56**) can include any number and/or type of valves engaged between the lines (**54**, **56**) and respective sets of rams, as well as any number and/or type of bleed valves. At the top of the depicted blowout preventer system, a flex joint (**58**) and a riser flange (**60**) for engaging a subsea riser are shown. It should be understood that the depicted number, type, and configuration of rams, packers, lines, and connectors is merely exemplary, and that embodiments usable within the scope of the present disclosure can be used with any type of blowout preventer system. Further, it should be understood that the typical components found in a blowout preventer system are known in the art and that the depicted blowout preventer system may include numerous components not depicted, such as collets, hydraulic stabs, pressure transducers, regulators, motors, and various valves, piping, and/or other conduits, each of which can be operated by hydraulic fluid and/or a similar medium, and each of which could be potentially subject to leaks.

[0034] For illustrative purposes, FIG. **2** depicts quantities of an indicator compound (**30**) within various conduits and/or other portions of the blowout preventer system. It should be understood that an indicator compound (e.g., sodium fluorescein or another similar compound) can be present throughout the fluid within the system, including within the opening and closing chambers of rams, annulars, and choke and kill lines, as well as within the valves and/or any other conduits or equipment associated with the depicted system. As such, in an embodiment (e.g., when a non-aqueous medium is used) during normal operations, the indicator compound (**30**) is insulated from contact with water and remains in an inactive state; however, should any portion of the blowout preventer operating system or other conduit, valve, and/or piece of equipment develop a leak, the indicator compound (**30**) can contact free water (e.g., within the subsea environment), thereby becoming activated. Subsequently, leaks can be detected through use of a detector adapted for detecting the activated indicator compound (e.g., an ultraviolet light). In alternate embodiments, the blowout preventer system can include water-based compounds, such as Airfon and/or similar water-based products that include biocides and/or corrosion inhibitors, which can activate the indicator compound (**30**); however, the indicator compound (**30**) remains generally contained within the blowout preventer system and present for detection of future leaks through use of a detector (e.g., ultraviolet light) external to the blowout preventer system.

[0035] While various embodiments usable within the scope of the present disclosure have been described with emphasis, it should be understood that within the scope of the appended claims, the present invention can be practiced other than as specifically described herein.

What is claimed is:

1. A method for detecting leaks in subsea cement or cement returns in a subsea environment, the method comprising the steps of:

mixing an indicator with a quantity of cement, wherein the indicator is in an inactive state and wherein the indicator is insulated from contact with water;

providing the quantity of cement and the indicator into a subsea wellbore;

permitting the quantity of cement to contact the subsea environment proximate to the subsea wellbore thereby activating the indicator to an active state; and

exposing the subsea environment proximate to the subsea wellbore to a detector adapted for detecting the indicator in the active state to detect the indicator and thereby detect the second portion of the cement.

2. The method of claim 1, wherein the indicator comprises sodium fluorescein, another fluorescein salt, or combinations thereof.

3. The method of claim 1, wherein the quantity of cement comprises a cement return and wherein the subsea environment proximate to the subsea wellbore comprises a subsea floor.

4. The method of claim 1, wherein the step of exposing the subsea environment proximate to the subsea wellbore to the detector comprises exposing the subsea environment to an ultraviolet light source.

5. The method of claim 4, wherein the step of exposing the subsea environment to the ultraviolet light source comprises associating the ultraviolet light source with a remotely operated vehicle, maneuvering the remotely operated vehicle to the subsea environment proximate to the subsea wellbore, and exposing the subsea environment proximate to the subsea wellbore to the ultraviolet light source.

6. A system for detecting leaks in subsea cement or cement returns in a subsea environment, the system comprising:

a quantity of cement disposed in association with a subsea wellbore;

an indicator within the quantity of the cement, wherein the indicator is in an inactive state, wherein the indicator is insulated from contact with water, and wherein a leak in the quantity of cement, a cement return in the subsea environment, or combinations thereof, exposes the indicator to water, thereby activating the indicator to an active state; and

a detector adapted for detecting the indicator in the active state, thereby detecting the leak, the cement return, or combinations thereof.

7. The system of claim 6, wherein the indicator comprises sodium fluorescein, another fluorescein salt, or combinations thereof.

8. The system of claim 6, wherein the subsea environment comprises a subsea floor proximate to the subsea wellbore.

9. The system of claim 6, wherein the detector comprises an ultraviolet light source.

10. The system of claim 9, further comprising a remotely operated vehicle having the ultraviolet light source associated therewith.

11. A method for detecting a non-aqueous substance associated with a subsea wellbore, the method comprising the steps of:

mixing an indicator with a medium and providing the medium into a subsea wellbore, wherein the indicator is insulated from contact with a subsea environment proximate to the subsea wellbore, and wherein the indicator is thereby insulated from detection,

wherein at least a portion of the medium and the indicator contacts the subsea environment, thereby enabling detection of the indicator; and

exposing said at least a portion of the medium to a detector adapted for detecting the indicator in the active state to detect the indicator and thereby detect the medium.

12. The method of claim 11, wherein the step of mixing the indicator with the medium comprises mixing the indicator with a non-aqueous medium, wherein the indicator is in an inactive state, wherein the indicator is insulated from contact with water, and wherein contact between said at least a portion of the medium and the subsea environment activates the indicator to an active state.

13. The method of claim 11, wherein the step of mixing the indicator with the medium comprises mixing the indicator with liquid cement, wherein at least a portion of the cement contacts the subsea environment as a cement return on a subsea floor, and wherein the step of exposing said at least a portion of the medium to the detector comprises providing the detector proximate to the subsea floor for detecting the cement return by detecting the indicator.

14. The method of claim 11, wherein the step of mixing the indicator with the medium comprises mixing the indicator with fluid within a blowout preventer operating system of a deepwater rig, wherein a leak in the blowout preventer operating system permits at least a portion of the fluid to contact the subsea environment proximate to the blowout preventer operating system, and wherein the step of exposing said at least a portion of the medium to the detector comprises providing the detector proximate to the subsea floor for detecting the leak by detecting the indicator.

15. The method of claim 11, wherein the step of mixing the indicator with the medium comprises mixing the indicator with a sweep, a spacer, or combinations thereof for use during drilling or completion operations, wherein at least a portion of the sweep, the spacer, or combinations thereof contacts the subsea environment, and wherein the step of exposing said at least a portion of the medium to the detector comprises providing the detector at the surface of the subsea wellbore to detect the sweep, the spacer, or combinations thereof by detecting the indicator.

16. The method of claim 11, wherein the indicator comprises sodium fluorescein, another fluorescein salt, or combinations thereof.

17. The method of claim 13, wherein the step of providing the detector proximate to the subsea floor for detecting the cement return comprises associating an ultraviolet light source with a remotely operated vehicle, maneuvering the remotely operated vehicle to the subsea environment proximate to the subsea floor, and exposing the subsea environment proximate to the subsea floor to the ultraviolet light source.

18. The method of claim 14, wherein the step of providing the detector proximate to the subsea floor for detecting the leak comprises associating an ultraviolet light source with a remotely operated vehicle, maneuvering the remotely operated vehicle to the subsea environment proximate to the subsea wellbore, and exposing the subsea environment proximate to the subsea wellbore to the ultraviolet light source.

19. The method of claim 15, wherein the step of providing the detector at the surface of the subsea wellbore to detect the sweep, the spacer, or combinations thereof, comprises pro-

viding a portable ultraviolet source proximate to the surface and exposing the sweep, the spacer, or combinations thereof to the ultraviolet light source.

* * * * *