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US

(71) Applicant (for US only): **SHELL OIL COMPANY**
[US/US]; One Shell Plaza, P.O. Box 2463, Houston, Texas
77252-2463 (US).

(71) Applicant (for all designated States except US): **SHELL
INTERNATIONALE RESEARCH MAATSCHAPPIJ
B.V.** [NL/NL]; Carel van Bylandtlaan 30, NL-2596 The
Hague (NL).

(72) Inventors: **STROUD, Justin**; 9 Foley Drive, Farmingham,
Massachusetts 01701 (US). **BULL, Hannuman**; 609

County St #1, New Bedford, Massachusetts 02740 (US).
FEHRMANN, Gary; 18723 Peralta Hill Lane, Tomball,
Texas 77377 (US).

(74) Agent: **HITCHCOCK, Thomas S.**; Shell Oil Company,
One Shell Plaza, P.O. Box 2463, Houston, Texas 77252-
2463 (US).

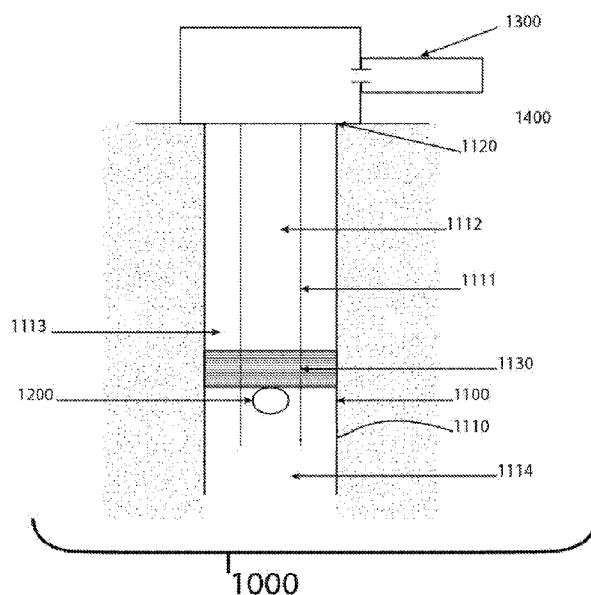
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[Continued on next page]

(54) Title: LEAK DETECTION SYSTEM FOR WELL ABANDONMENT

Figure 1



(57) Abstract: A leak detection system comprising: a well
comprising a wellbore and a wellhead; a trace gas emitter
disposed within the wellbore; and a trace gas detector at the
wellhead and associated methods.



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LEAK DETECTION SYSTEM FOR WELL ABANDONMENT

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/169,009, filed June 1, 2015, which is incorporated herein by reference.

BACKGROUND

[0002] The present disclosure relates generally to leak detection systems for well abandonment. More specifically, in certain embodiments, the present disclosure relates to leak detection systems for well abandonment comprising one or more trace gas emitters and associated methods.

[0003] Once wells used for the production of oil and gas reach the end of their economic or useful lives they must be properly abandoned. Typically wells are abandoned using a sealing material. One of the most common sealing materials for well plugging is Portland Cement. In sealing operations, the Portland Cement may form a cement plug that prevents formation fluid and pressure from moving up or down the wellbore from one permeable formation to another or to the surface or sea floor. The cement plug thereby isolates zones of a formation from one another in order to prevent pressure and fluid flow between them, which may prevent contamination of nearby fresh water supplies.

[0004] Conventionally, cement plugs are placed in the well by means of pumping a mixture of cement and water down the center of a work string and out of its open end or by cutting or perforating existing pipe to establish a circulation path for placement. The cement plug is then allowed to set. For a cement plug to properly function, it must set with sufficient strength and have good adhesion to the borehole or casing wall. If a cement plug is not properly set, oil or gas may leak into the environment.

[0005] Once cement plugs are placed in the well, operators periodically will monitor the well for hydrocarbon leaks and pressure accumulation. In order to test the well, operators may apply a topside hydrostatic pressure to the plug to assess any apparent top to bottom leak paths. If an issue, such as sustained casing pressure (SCP), persists after the abandonment, the operators often must blindly intervene in the well under the assumption that the SCP is due to a failed plug. Conventional verification methods only address partial failure modes and the intervention plans often use several costly assumptions as to where the source of the leak is located.

[0006] Currently, operators lack the ability to non-invasively assess plug integrity

soon after the setting process is complete. This may prevent the operator from being assured that they can move on in the abandonment process steps such as cutting casing below the mud line. The lack of this ability can lead to costly re-abandonment efforts long after the well was initially abandoned.

[0007] It is desirable to develop a method that allows operators to non-invasively and confidently verify their plugs/barriers and to diagnose and triage problematic abandonments soon after the plug sets.

SUMMARY

[0008] The present disclosure relates generally to leak detection systems for well abandonment. More specifically, in certain embodiments, the present disclosure relates to leak detection systems for well abandonment comprising one or more trace gas emitters and associated methods.

[0009] In one embodiment, the present disclosure provides a leak detection system comprising: a well comprising a wellbore and a wellhead; a trace gas emitter disposed within the wellbore; and a trace gas detector at the wellhead.

[0010] In another embodiment, the present disclosure provides a method of abandoning a well comprising: providing a well comprising a wellbore and a wellhead and placing a trace gas emitter and a barrier in the wellbore.

[0011] In another embodiment, the present disclosure provides a method of detecting a leak comprising: providing a leak detection system comprising a well comprising a wellbore and a wellhead, a trace gas emitter disposed within the wellbore, and trace gas detector at the wellhead and allowing the trace gas emitter to generate a volume of gas.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] A more complete and thorough understanding of the present embodiments and advantages thereof may be acquired by referring to the following description taken in conjunction with the accompanying drawings.

[0013] Figure 1 is an illustration of a leak detection system in accordance with certain embodiments of the present disclosure.

[0014] Figure 2 is an illustration of a leak detection system in accordance with certain embodiments of the present disclosure.

[0015] The features and advantages of the present disclosure will be readily

apparent to those skilled in the art. While numerous changes may be made by those skilled in the art, such changes are within the spirit of the disclosure.

DETAILED DESCRIPTION

[0016] The description that follows includes exemplary apparatuses, methods, techniques, and/or instruction sequences that embody techniques of the inventive subject matter. However, it is understood that the described embodiments may be practiced without these specific details.

[0017] The present disclosure relates generally to leak detection systems for well abandonment. More specifically, in certain embodiments the present disclosure relates to leak detection systems for well abandonment comprising one or more trace gas emitters and associated methods.

[0018] In certain embodiments, the present disclosure describes methods and systems that enable an operator to non-invasively verify the integrity of a seal and/or barrier within a wellbore. In certain embodiments, the use of one or more trace gas emitters within the wellbore and a trace gas detector at the wellhead may permit an operator to verify the proper abandonment of a well.

[0019] There may be several advantages to the methods and systems described herein. In certain embodiments, the use of the methods and systems described herein permit operators to non-invasively assess the integrity of a plug soon after the curing process is complete. In certain embodiments, this ability allows operators to determine if a plug has properly set before they complete the abandonment process. In certain embodiments, this ability allows for operators to ensure that plugs have properly set thus avoiding having to re-abandon a well after a leak has been detected. In certain embodiments, the use of the methods and systems described herein permit operators to identify specifically which barrier is leaking in wellbore systems comprising multiple barriers.

[0020] In certain embodiments, the present disclosure describes a leak detection system. Referring now to Figure 1, Figure 1 illustrates leak detection system 1000. In certain embodiments, leak detection system 1000 may comprise well 1100, trace gas emitter 1200, and a trace gas detector 1300.

[0021] In certain embodiments, well 1100 may comprise any conventional oil and/or gas producing well. In certain embodiments, well 1100 may comprise a land well, a fixed leg well, a tension leg platform well, or a subsea well. In certain embodiments, well 1100 may be an abandoned well. In other embodiments, well 1100 may be a producing

well.

[0022] In certain embodiments, well 1100 may comprise wellbore 1110, well head 1120, and barrier 1130.

[0023] In certain embodiments, wellbore 1110 may comprise any conventional type of wellbore. In certain embodiments, wellbore 1110 may penetrate subterranean formation 1400. In certain embodiments, wellbore 1110 may be a lined wellbore. In other embodiments, well bore 1110 may be an open-hole wellbore.

[0024] In certain embodiments, wellbore 1110 may comprise tubular 1111. In certain embodiments, tubular 1111 may be a casing or a production liner. In certain embodiments, tubular 1111 may define a cavity 1112. In certain embodiments, wellbore 1110 and tubular 1111 may define an annulus 1113. In certain embodiments, a portion of wellbore 1110 may not comprise tubular 1111. In such embodiments, the portion of wellbore 1110 not comprising tubular 1111 may define a cavity 1114. In certain embodiments, wellbore 1110 may comprise any number of tubulars 1111.

[0025] In certain embodiments, well head 1120 may comprise any conventional wellhead. In certain embodiments, wellhead 1120 may comprise a subsea wellhead or a land wellhead.

[0026] In certain embodiments, barrier 1130 may comprise any barrier. In certain embodiments, barrier 1130 may comprise a cement plug, a mechanical plug, a foam plug, a resin plug, or any other type plug. In certain embodiments, wellbore 1100 may comprise any number of barriers 1130.

[0027] In certain embodiments, as illustrated in Figure 1, barrier 1130 may be disposed within wellbore 1110 within cavity 1112 and annulus 1113. In other embodiments, not necessarily shown in Figure 1, one or more barriers 1130 may be disposed within wellbore 1110 within cavity 1112, annulus 1113, and/or cavity 1114, and any combination thereof. In certain embodiments, barrier 1130 may be capable of providing a seal across cavity 1112 and annulus 1113. In other embodiments, barrier 1130 may be capable of providing a seal across any annulus and/or cavity in which it is disposed or any combination of annuli and/or cavities in which it is disposed.

[0028] In certain embodiments, trace gas emitter 1200 may comprise any apparatus that is capable of generating a volume of gas within a wellbore. In certain embodiments, the volume of gas may be proportional to the diameter of wellbore 1110 and/or tubular 1111. In certain embodiments, the volume of gas may be an amount sufficient to generate

a bubble which is capable of contacting an entire bottom surface of barrier 1130. In certain embodiments, the volume of gas volume may be an amount in the range of from 0.1 cubic feet to 10 cubic feet at the wellbore conditions where gas emitter 1200 and/or barrier 1130 are located. In certain embodiments, the volume of gas volume may be an amount in the range of from 0.2 cubic feet to 3.5 cubic feet at the wellbore conditions where gas emitter 1200 and/or barrier 1130 are located. In certain embodiments, the volume of gas volume may be an amount in the range of from 0.5 cubic feet to 2 cubic feet at the wellbore conditions where gas emitter 1200 and/or barrier 1130 are located.

[0029] In certain embodiments, the type of gas in the volume of gas may be any inert gas that is capable of being detected by a trace gas detector 1300. Examples of inert gases that are capable of being detected by trace gas detector 1300 include helium, neon, argon, krypton, xenon, radon, halogens, or hydrogen. In certain embodiments, the inert gas may any inert gas that is not naturally present in a measurable quantity in the well.

[0030] In certain embodiments, trace gas emitter 1200 may be a canister filled with the volume of the gas. In certain embodiments, the canister may have a release mechanism. In certain embodiments, the release mechanism may comprise a cylinder valve with a fused release mechanism. In certain embodiments, the release mechanism may be a time-release mechanism. In certain embodiments, the time-release mechanism may permit the canister to release the volume of the gas after a particular amount of time. In certain embodiments, the particular amount of time may be an amount in the range of from 1 day to 28 days. In certain embodiments, the particular amount of time may be an amount in the range of from 5 days to 28 days. In certain embodiments, the particular amount of time may be an amount in the range of from 10 days to 28 days. In certain embodiments, the particular amount of time may be an amount in the range of from 20 days to 28 days. In certain embodiments, the particular amount of time may be an amount of time after it would take a barrier to properly set. In other embodiments, the release mechanism may be a remotely activated release mechanism.

[0031] In certain embodiments, trace gas emitter 1200 may comprise two chemicals that are capable of reacting downhole to generate the volume of gas may be generated by allowing two chemical to react downhole. In certain embodiments, the two chemicals may be any chemicals that are capable of reacting together to produce a noble gas, a halogen, or hydrogen. In certain embodiments, trace gas emitter 1200 may be designed so that the two chemicals react after a particular amount of time. In certain

embodiments, the particular amount of time may be an amount in the range of from 1 day to 28 days. In certain embodiments, the particular amount of time may be an amount in the range of from 5 days to 28 days. In certain embodiments, the particular amount of time may be an amount in the range of from 10 days to 28 days. In certain embodiments, the particular amount of time may be an amount in the range of from 20 days to 28 days. In certain embodiments, the particular amount of time may be an amount of time after it would take a barrier to properly set.

[0032] In certain embodiments, trace gas emitter 1200 may be disposed within wellbore 1110 below barrier 1130. In certain embodiments, trace gas emitter 1200 may be mechanically connected to barrier 1130 or magnetically connected to barrier 1130. In certain embodiments, trace gas emitter 1200 may be mechanically connected to tubular 1111 or magnetically connected to tubular 1111. In certain embodiments, trace gas emitter 1200 may be not connected to barrier 1130 or tubular 1111. In certain embodiments, trace gas emitter 1200 may be capable of generating the volume of gas below barrier 1130. In certain embodiments, the volume of gas generated by trace gas emitter 1200 may disperse across the entire surface area of the bottom of barrier 1130.

[0033] In certain embodiments, for example when barrier 1130 is an effective barrier, barrier 1130 may prevent any of the volume of gas from migrating around and/or through barrier 1130. In such embodiments, no portion of the volume of gas generated by trace gas emitter 1200 may migrate through and/or around barrier 1130 and flow up wellbore 1110 through cavity 1112 and/or annulus 1113.

[0034] In other embodiments, for example when barrier 1130 is not an effective barrier, all or a portion of the volume of gas generated by trace gas emitter 1200 may migrate around and/or through barrier 1130 and travel up the annuli and/or cavities in which barrier 1130 is disposed.

[0035] In certain embodiments, leak detection system 1000 may comprise any number of trace gas emitters 1200.

[0036] In certain embodiments, trace gas detector 1300 may comprise any apparatus capable of detecting the presence of the gas released by trace gas emitter 1200. In certain embodiments, trace gas detector 1300 may comprise any conventional device capable of detecting the presence of any of the following gases: helium, neon, argon, krypton, xenon, radon, halogens, and hydrogen.

[0037] In certain embodiments, trace gas detector 1300 may be located at wellhead

1120. In certain embodiments, trace gas detector 1300 may comprise a part of wellhead 1120. In certain embodiments, trace gas detector 1300 may be connected to wellhead 1120 via a hose (not illustrated in Figure 1). In certain embodiments, trace gas detector 1300 may be capable of withdrawing a gas sample from the well head either directly or by a sample container for analysis.

[0038] In certain embodiments, trace gas detector 1300 may be capable of detecting any portion of the volume of gas generated by trace gas emitter 1200 that has migrated around and/or through barrier 1130. In certain embodiments, leak detection system 1000 may comprise any number of trace gas detectors 1300. In certain embodiments, trace gas detector 1300 may be capable of detecting more than one type of gas. In certain embodiments, for example when leak detection system 1000 comprises multiple trace gas detectors 1300, each trace gas detector 1300 may be capable of detecting a different gas than the other trace gas detectors 1300.

[0039] In certain embodiments, the present disclosure describes a leak detection system comprising two trace gas emitters. Referring now to Figure 2, Figure 2 illustrates leak detection system 2000. In certain embodiments, leak detection system 2000 may comprise well 2100, upper trace gas emitter 2201, lower trace gas emitter 2202, and trace gas detector 2300.

[0040] In certain embodiments, well 2100 may comprise any combination of features discussed above with respect to well 1100. In certain embodiments, well 2100 may comprise wellbore 2110, well head 2120, upper barrier 2131, and lower barrier 2132.

[0041] In certain embodiments, wellbore 2110 may comprise any combination of features discussed above with respect to wellbore 1110. In certain embodiments, wellbore 2110 may penetrate subterranean formation 2400.

[0042] In certain embodiments, wellbore 2110 may comprise a first tubular 2111 and/or a second tubular 2112. In certain embodiments, first tubular 2111 and/or second tubular 2112 may comprise any combination of features discussed above with respect to tubular 1111. In certain embodiments, first tubular 2111 and second tubular 2112 may be different types of tubulars. In certain embodiments, as shown in Figure 2, first tubular 2111 may be an intermediate casing and second tubular 2112 may be an inner casing.

[0043] In certain embodiments, first tubular 2111 may define a cavity 2113. In certain embodiments, wellbore 2110 and first tubular 2111 may define an annulus 2114. In certain embodiments, a portion of wellbore 2110 may not be lined with first tubular 2111.

In such embodiments, the portion of wellbore 2110 not lined with first tubular 2111 and second tubular 2112 may define an annulus 2115. In certain embodiments, first tubular 2111 and second tubular 2112 may define an annulus 2116. In certain embodiments, second tubular 2112 may define a cavity 2117.

[0044] In certain embodiments, well head 2120 may comprise any combination of features discussed above with respect to wellhead 1120.

[0045] In certain embodiments, upper barrier 2131 and/or lower barrier 2132 may comprise any combination of features discussed above with respect to barrier 1130. In certain embodiments, upper barrier 2131 and lower barrier 2132 may be the same type of barrier. In other embodiments, upper barrier 2131 and lower barrier 2132 may comprise different types of barriers.

[0046] In certain embodiments, as illustrated in Figure 2, upper barrier 2131 may be disposed within wellbore 2110 within cavity 2113 and lower barrier 2132 may be disposed within wellbore 2110 within cavity 2117. In other embodiments, not necessarily illustrated in Figure 2, upper barrier 2131 may be disposed within wellbore 2110 within cavity 2113, annulus 2114, annulus 2115, annulus 2116, cavity 2117, or any combination thereof and/or lower barrier 2132 may be disposed within wellbore 2110 within cavity 2113, cavity 2117, annulus 2114, annulus 2115, annulus 2116, or any combination thereof. In certain embodiments, each of barrier 2131 and barrier 2132 may be capable of providing a seal across the annuli or cavities in which they are disposed.

[0047] In certain embodiments, upper trace gas emitter 2201 and lower trace gas emitter 2202 may comprise any combination of features discussed above with respect to trace gas emitter 1200. In certain embodiments, the gas in the volume of gas that upper trace gas emitter 2201 is capable of generating may be a different gas than the gas in the volume of gas that lower trace gas emitter 2202 is capable of generating. In certain embodiments, upper trace gas emitter 2201 and lower trace gas emitter 2202 may be the same type of trace gas emitter. In other embodiments, upper trace gas emitter 2201 and lower trace gas emitter 2202 may be different types of trace gas emitters.

[0048] In certain embodiments, upper trace gas emitter 2201 may be disposed within wellbore 2110 below upper barrier 2131. In certain embodiments, upper trace gas emitter 2201 may be mechanically connected to upper barrier 2131 or magnetically connected to upper barrier 2131. In certain embodiments, upper trace gas emitter 2201 may be mechanically connected to tubular 2111 or magnetically connected to tubular 2111.

In certain embodiments, upper trace gas emitter 2201 may be not connected to upper barrier 2131 or tubular 2111. In certain embodiments, upper trace gas emitter 2201 may be capable of generating the volume of gas below upper barrier 2131. In certain embodiments, the volume of gas generated by upper trace gas emitter 2201 may disperse across the entire surface area of the bottom of upper barrier 2131.

[0049] In certain embodiments, for example when upper barrier 2131 is an effective barrier, upper barrier 2131 may prevent any of the volume of gas from migrating around and/or through barrier 2131 and up through tubular 2111 to the surface. In such embodiments, no portion of the volume of gas generated by upper trace gas emitter 2201 may migrate through and/or around upper barrier 2131 and flow up wellbore 2110 through cavity 2113 to the surface.

[0050] In other embodiments, for example when upper barrier 2131 is not an effective barrier, all or a portion of the volume of gas generated by upper trace gas emitter 2201 may migrate around and/or through upper barrier 2131 and flow up through wellbore 2110 through cavity 2113 to the surface.

[0051] In certain embodiments, lower trace gas emitter 2202 may be disposed within wellbore 2110 below lower barrier 2132. In certain embodiments, lower trace gas emitter 2202 may be mechanically connected to lower barrier 2132 or magnetically connected to lower barrier 2132. In certain embodiments, lower trace gas emitter 2202 may be mechanically connected to tubular 2112 or magnetically connected to tubular 2112. In certain embodiments, lower trace gas emitter 2202 may be not connected to lower barrier 2132 or tubular 2112. In certain embodiments, lower trace gas emitter 2202 may be capable of generating the volume of gas below lower barrier 2132. In certain embodiments, the volume of gas generated by lower trace gas emitter 2202 may disperse across the entire surface area of the bottom of lower barrier 2132.

[0052] In certain embodiments, for example when lower barrier 2132 is an effective barrier, lower barrier 2132 may prevent any of the volume of gas from migrating around and/or through lower barrier 2132 and up the wellbore 2110 through tubular. In such embodiments, no portion of the volume of gas generated by lower trace gas emitter 2202 may migrate through and/or around lower barrier 2132 and flow up wellbore 2110 through cavity 2117.

[0053] In other embodiments, for example when lower barrier 2132 is not an effective barrier, all or a portion of the volume of gas generated by lower trace gas emitter

2202 may migrate around and/or through lower barrier 2132 and flow up through wellbore 2110 through cavity 2117.

[0054] In other embodiments, for example when lower barrier 2132 and upper barrier 2131 are both not effective barriers, all or a portion of the volume of gas generated by lower trace gas emitter 2202 may migrate around and/or through lower barrier 2132 and upper barrier 2131 and flow up through wellbore 2110 through cavity 2113.

[0055] In certain embodiments, trace gas detector 2300 may comprise any combination of features discussed above with respect to trace gas detector 1300. In certain embodiments, trace gas detector 2300 may comprise a trace gas detector capable of detecting the presence of a gas released by upper trace gas emitter 2201 and the presence of a gas released by lower trace gas emitter 2202. In other embodiments, trace gas detector 2300 may comprise a first trace gas detector and a second trace gas detector, wherein the first trace gas detector is capable of detecting the presence of a gas released by upper trace gas emitter 2201 and the second trace gas detector is capable of detecting the presence of a gas released by lower trace gas emitter 2202.

[0056] In another embodiment, the present disclosure provides a method of abandoning a well comprising: providing a well comprising a wellbore and a wellhead and placing a trace gas emitter and a barrier in the wellbore.

[0057] In certain embodiments, the well may comprise any combination of features discussed above with respect to well 1100 and/or well 2100.

[0058] In certain embodiments, the wellbore may comprise any combination of features discussed above with respect to wellbore 1110 and/or wellbore 2110.

[0059] In certain embodiments, the wellbore may comprise a tubular. In certain embodiments, the tubular may comprise any combination of features discussed above with respect to tubular 1111. In certain embodiments, the tubular may define a first cavity. In certain embodiments, the first cavity may comprise any combination of features discussed above with respect to cavity 1112. In certain embodiments, the wellbore and the tubular may define an annulus. In certain embodiments, the annulus may comprise any combination of features discussed above with respect to annulus 1113. In certain embodiments, the wellbore may define a second cavity. In certain embodiments, the second cavity may comprise any combination of features discussed above with respect to cavity 1114.

[0060] In other embodiments, the wellbore may comprise a first tubular and a

second tubular. In certain embodiments, the first tubular may comprise any combination of features discussed above with respect to first tubular 2111. In certain embodiments, the second tubular may comprise any combination of features discussed about with respect to second tubular 2112. In certain embodiments, the first tubular may define a first cavity. In certain embodiments, the first cavity may comprise any combination of features discussed above with respect to cavity 2113. In certain embodiments, the wellbore and the first tubular may define a first annulus. In certain embodiments, the first annulus may comprise any combination of features discussed above with respect to annulus 2114. In certain embodiments, the wellbore and the second tubular may define a second annulus. In certain embodiments, the second annulus may comprise any combination of features discussed above with respect to annulus 2115. In certain embodiments, the first tubular and the second tubular may define a third annulus. In certain embodiments, the third annulus may comprise any combination of features discussed above with respect to annulus 2116. In certain embodiments, the second tubular may define a second cavity. In certain embodiments, the second cavity may comprise any combination of features discussed above with respect to cavity 2117.

[0061] In certain embodiments, the wellhead may comprise any combination of features discussed above with respect to wellhead 1120 and/or wellhead 2120.

[0062] In certain embodiments, placing the trace gas emitter and the barrier in the wellbore may comprise placing a single trace gas emitter below a single barrier in the wellbore. In certain embodiments, the trace gas emitter may comprise any combination of features discussed above with respect to trace gas emitter 1200. In certain embodiments, the barrier may comprise any combination of features discussed above with respect to barrier 1130. In certain embodiments, the trace gas emitter may be placed in the wellbore before the barrier. In other embodiments, the trace gas emitter may be placed in the wellbore simultaneously with the placement of the barrier. In certain embodiments, the method may further comprise allowing the barrier to set.

[0063] In other embodiments, placing the trace gas emitter and the barrier in the wellbore may comprise placing a first trace gas emitter below a first barrier in the wellbore and placing a second trace gas emitter below a second barrier in the wellbore. In certain embodiments, the first trace gas emitter may comprise any combination of features discussed above with respect to trace gas emitter 1200, upper trace gas emitter 2101, and/or lower trace gas emitter 2202. In certain embodiments, the barrier may comprise any

combination of features discussed above with respect to barrier 1130, upper barrier 2131, and/or lower barrier 2132. In certain embodiments, the second trace gas emitter may comprise any combination of features discussed above with respect to trace gas emitter 1200, upper trace gas emitter 2101, and/or lower trace gas emitter 2202. In certain embodiments, the second barrier may comprise any combination of features discussed above with respect to barrier 1130, upper barrier 2131, and/or lower barrier 2132. In certain embodiments, the first trace gas emitter may be placed in the wellbore before the first barrier. In other embodiments, the first trace gas emitter may be placed in the wellbore simultaneously with the placement of the first barrier. In certain embodiments, the second trace gas emitter may be placed in the wellbore before the second barrier. In other embodiments, the second trace gas emitter may be placed in the wellbore simultaneously with the placement of the second barrier. In certain embodiments, the method may further comprise allowing the first barrier and/or the second barrier to set. In certain embodiments, the first barrier and/or the first trace gas emitter may be placed into the wellbore before or after the second barrier sets. In other embodiments, the second barrier and/or the second trace gas emitter may be placed into the wellbore before or after the first barrier sets.

[0064] In certain embodiments, the method may further comprise installing one or more trace gas detectors at the wellhead. In certain embodiments, the one or more trace gas detectors may comprise any combination of features discussed above with respect to trace gas detector 1300 and/or trace gas detector 2300.

[0065] In another embodiment, the present disclosure provides a method of detecting a leak comprising: providing a leak detection system comprising a well comprising a wellbore and a wellhead, a trace gas emitter disposed within the wellbore, and a trace gas detector at the wellhead and allowing the trace gas emitter to generate a volume of gas.

[0066] In certain embodiments, the leak detection system may comprise any combination of features discussed above with respect to leak detection system 1000 and/or leak detection system 2000.

[0067] In certain embodiments, the leak detection system may comprise a single trace gas emitter and a single barrier. In certain embodiments, the trace gas emitter may comprise any combination of features discussed above with respect to trace gas emitter 1200. In certain embodiments, the barrier may comprise any combination of features

discussed above with respect to barrier 1130. In such embodiments, allowing the trace gas emitter to generate a volume of gas may comprise allowing the volume of gas generated by the trace gas emitter to form a bubble that contacts an entire surface of the barrier. In certain embodiments, for example when the barrier is an effective barrier, the barrier will prevent the volume of gas from passing around and/or through the barrier. In other embodiments, for example when the barrier is not an effective barrier, the barrier may allow the volume of gas to pass through and/or around the barrier. In such embodiments, the method may further comprise allowing a portion of the volume of gas to rise to the wellhead.

[0068] In certain embodiments, the leak detection system may comprise a first trace gas emitter and a first barrier and a second trace gas emitter and a second barrier. In certain embodiments, the first trace gas emitter may comprise any combination of features discussed above with respect to upper trace gas emitter 2201 and the second trace gas emitter may comprise any combination of features discussed above with respect to lower trace gas emitter 2202. In certain embodiments, the first barrier may comprise any combination of features discussed above with respect to upper barrier 2131 and the second barrier may comprise any combination of features discussed above with respect to lower barrier 2131. In such embodiments, allowing the trace gas emitter to generate a volume of gas may comprise allowing both the first trace gas emitter and the second trace gas emitter to generate a volume of gas. In certain embodiments, the gas in the volume of gas generated by the first trace gas emitter may be a different gas than the gas in the volume of gas generated by the second trace gas emitter.

[0069] In certain embodiments, allowing the first trace gas emitter to generate a volume of gas may comprise allowing the volume of gas generated by the first trace gas emitter to form a bubble that contacts an entire surface of the first barrier. In certain embodiments, for example when the first barrier is an effective barrier, the first barrier will prevent the volume of gas from passing around and/or through the first barrier. In other embodiments, for example when the first barrier is not an effective barrier, the first barrier may allow the volume of gas to pass through and/or around the first barrier. In such embodiments, the method may further comprise allowing a portion of the volume of gas generated by the first gas emitter to rise to the wellhead.

[0070] In certain embodiments, allowing the second trace gas emitter to generate a volume of gas may comprise allowing the volume of gas generated by the second trace gas

emitter to form a bubble that contacts an entire surface of the second barrier. In certain embodiments, for example when the second barrier is an effective barrier, the second barrier will prevent the volume of gas from passing around and/or through the second barrier. In other embodiments, for example when the second barrier is not an effective barrier, the second barrier may allow the volume of gas to pass through and/or around the second barrier. In such embodiments, the method may further comprise allowing a portion of the volume of gas generated by the second gas emitter to rise to the wellhead.

[0071] In certain embodiments, the method may further comprise measuring a gas sample from the wellhead. In certain embodiments, the gas sample may be measured with the trace gas detector. In certain embodiments, the gas sample may be measured to detect the presence of gas generated by single gas emitter. In other embodiments, the gas sample may be measured to detect the presence of gas generated by the first gas emitter and/or the second gas emitter.

[0072] While the embodiments are described with reference to various implementations and exploitations, it will be understood that these embodiments are illustrative and that the scope of the inventive subject matter is not limited to them. Many variations, modifications, additions and improvements are possible.

[0073] Plural instances may be provided for components, operations and/or structures described herein as a single instance. In general, structures and functionality presented as separate components in the exemplary configurations may be implemented as a combined structure or component. Similarly, structures and functionality presented as a single component may be implemented as separate components. These and other variations, modifications, additions, and improvements may fall within the scope of the inventive subject matter.

CLAIMS

1. A leak detection system comprising:
a well comprising a wellbore and a wellhead;
a trace gas emitter disposed within the wellbore; and
a trace gas detector at the wellhead.
2. The leak detection system of claim 1, further comprising a barrier disposed in the wellbore above the trace gas emitter.
3. The leak detection system of claim 1 or 2, wherein the wellbore comprises a tubular defining a cavity and an annulus.
4. The leak detection system of claim 3, wherein the trace gas emitter is disposed within the cavity and/or the annulus.
5. The leak detection system of any one of claim 1-4, wherein trace gas emitter is capable of generating a volume of gas in an amount in the range of from 0.1 cubic feet to 10 cubic feet.
6. The leak detection system of any one of claims 1-5, wherein the trace gas emitter comprises a canister filled with a gas.
7. The leak detection system of any one of claims 1-6, wherein the trace gas emitter has a time-release mechanism.
8. The leak detection system of claim 1, wherein the trace gas emitter comprises an upper trace gas emitter and a lower trace gas emitter.
9. The leak detection system of claim 8, further comprising a first barrier and a second barrier disposed in the wellbore.
10. The leak detection system of claim 8, wherein the first barrier is disposed in the wellbore above the upper trace gas emitter and the second barrier is disposed in the wellbore above the lower trace gas emitter.
11. A method of abandoning a well comprising:
providing a well comprising a wellbore and a wellhead and
placing a trace gas emitter and a barrier in the wellbore.

12. The method of claim 11, wherein the wellbore comprises a tubular.

13. The method of claim 12, wherein the trace gas emitter and the barrier are placed within a cavity defined by the tubular.

14. The method of any one of claims 11-13, wherein the trace gas emitter is placed in the wellbore before the barrier is placed in the wellbore.

15. The method of any one of claims 11-14, wherein the trace gas emitter is connected to the barrier.

16. The method of any one of claims 11-15, wherein placing a trace gas emitter and a barrier in the wellbore comprise placing a first trace gas emitter below a first barrier in the wellbore and placing a second trace gas emitter below a second barrier in the wellbore.

17. The method of any one of claims 11-16, further comprising installing one or more trace gas detectors at the wellhead.

18. A method of detecting a leak comprising:
providing a leak detection system comprising a well comprising a wellbore and a wellhead, a trace gas emitter disposed within the wellbore, and a trace gas detector at the wellhead and
allowing the trace gas emitter to generate a volume of gas.

19. The method of claim 18, wherein the leak detection system comprises the leak detection system of any one of claims 1-10.

20. The method of claim 18 or 19, wherein allowing the trace gas emitter to generate a volume of gas comprise allowing the volume of gas generated by the trace gas emitter to form a bubble that contacts an entire surface of the barrier.

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Figure 1

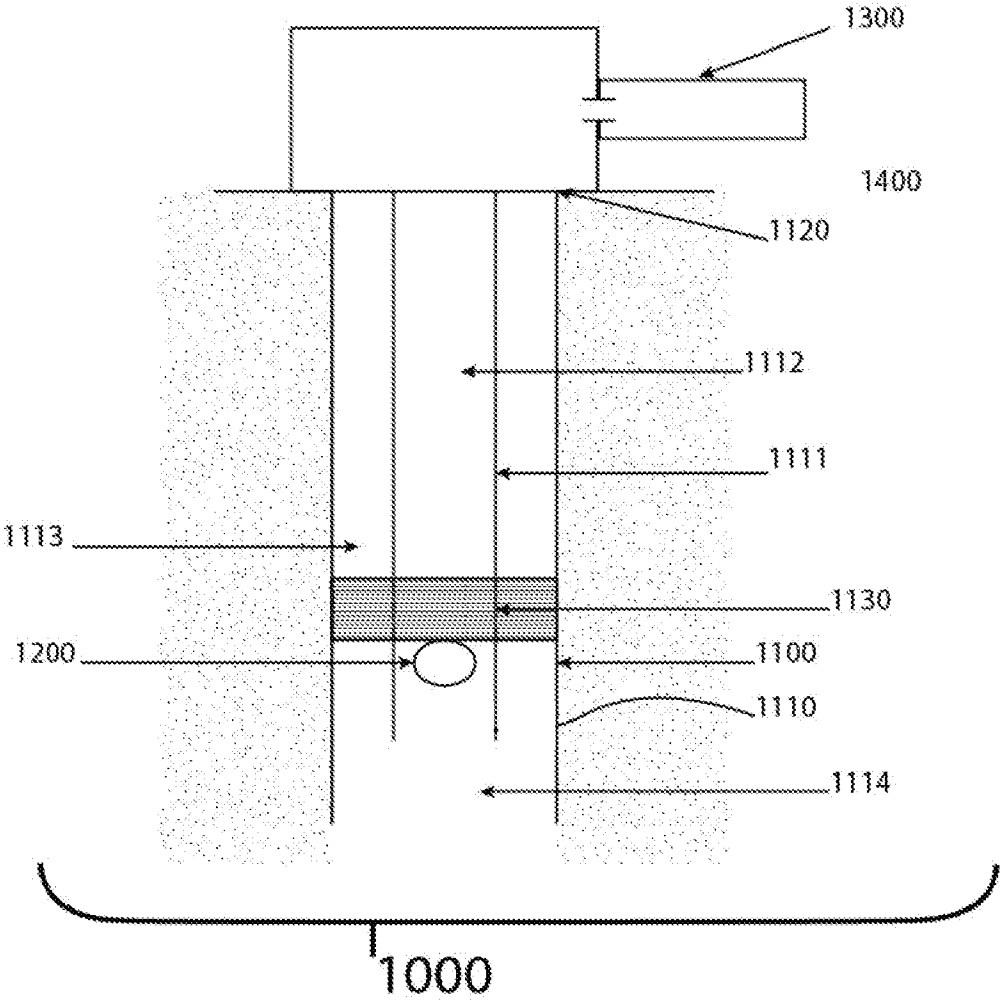
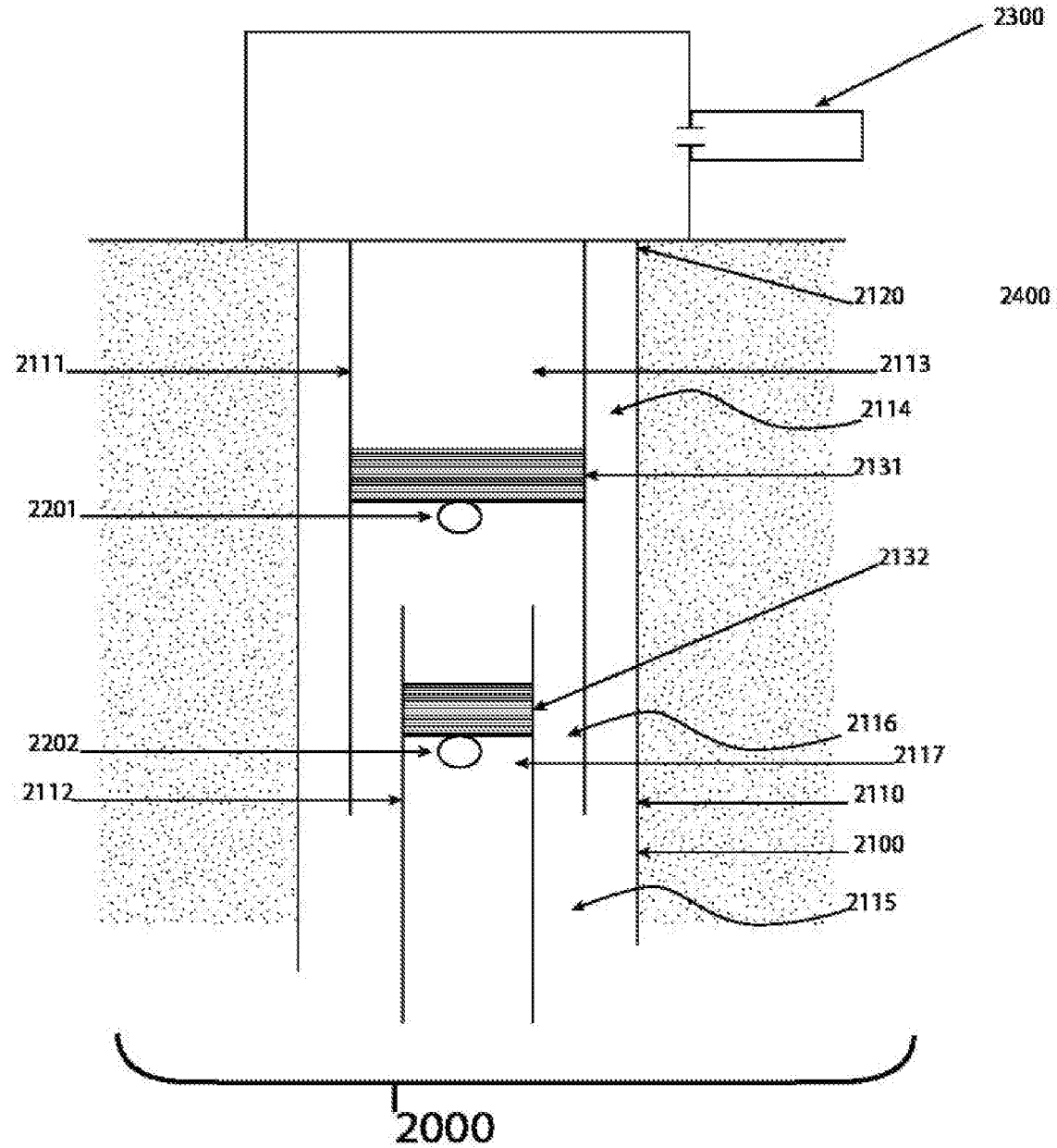


Figure 2



INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/034553

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B47/10
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)
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, TULSA

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2015/134253 A1 (WEATHERFORD LAMB [US]) 14 May 2015 (2015-05-14) paragraphs [0035], [0039], [0107] figure 1	1-10, 18-20
Y	US 5 063 772 A (WELLINGTON SCOTT L [US] ET AL) 12 November 1991 (1991-11-12) abstract	1-10, 18-20
A	US 2013/197810 A1 (HAAS ALLAN KAYSER [US] ET AL) 1 August 2013 (2013-08-01) paragraph [0011]	1-20
A	WO 2013/169255 A1 (BP CORP NORTH AMERICA INC [US]; CROW WALTER PATRICK [US]) 14 November 2013 (2013-11-14) abstract	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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

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"&" document member of the same patent family

Date of the actual completion of the international search

25 August 2016

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Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Schouten, Adri

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2016/034553

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