



(51) International Patent Classification:

G01M 3/04 (2006.01) G01M 3/38 (2006.01)

(21) International Application Number:

PCT/US2016/031808

(22) International Filing Date:

11 May 2016 (11.05.2016)

(25) Filing Language:

English

(26) Publication Language:

English

(71) Applicant: HALLIBURTON ENERGY SERVICES, INC. [US/US]; 3000 N. Sam Houston Parkway E., Houston, TX 77032-3219 (US).

(72) Inventors: JASSKELAINEN, Mikko; 4011 Bell Hollow Lane, Katy, TX 77494 (US). PARK, Brian, V.; 1514 Robins Forest, Spring, TX 77379 (US).

(74) Agent: PEACOCK, Gregg, A. et al.; Gilliam IP PLLC, 7200 N. Mopac, Suite 440, Austin, TX 78731 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR,

HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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

Declarations under Rule 4.17:

— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))

Published:

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

(54) Title: LEAK DETECTION SYSTEM FOR INTERMITTENT USE PIPELINES

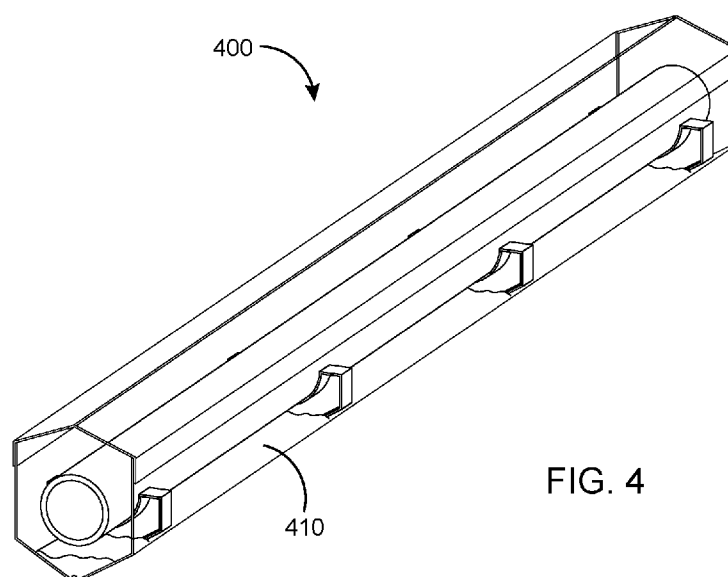


FIG. 4

(57) Abstract: A system is described for reliably detecting leaks in a distributed manner in intermittent use pipelines by making use of thermal or acoustic events triggered by the leak. The system can work in pressurized or unpressurized pipelines and in high flow or no flow conditions.



Title

Leak Detection System for Intermittent Use Pipelines

5 Background

The purpose of the invention is to enable leak detection in pipelines where the pipeline is intermittently used, i.e. extended periods of inactivity with low or no pressure in an environment where the pipeline fluid may approach the environmental ambient temperature. The pipeline may contain hydrocarbons, or for example be a buried hydrochloric acid pipeline intermittently used for down-hole well stimulation. Hydrochloric acid is often used to stimulate carbonate reservoirs by dissolving the carbonate formation, and the ground where the pipeline is buried may also be carbonate, which may be a concern if the hydrochloric pipeline leaks. The great challenge with any non-pressurized and intermittently used pipeline is the ability to detect a leak at any time.

Conventional leak detection systems utilize single point field instrumentation (e.g. for flow, pressure, fluid temperature) to monitor internal pipeline parameters, and these pipeline parameters are subsequently used for inferring a leak.

The issue with each of these types of sensors is: (a) when there is no flow, then the flow sensors used to measure normal flows will not be able to detect the low flows of a leak; (b) when there is no pressure then pressure sensors cannot detect a pressure change due to a leak; and (c) with a buried pipeline and no flow the pipeline contents will approach environmental temperatures so temperature sensors will not detect a leak.

Similarly, distributed fiber optic sensors like Distributed Temperature Sensing (DTS) or Distributed Acoustic Sensing (DAS) systems rely on
5 deviations from a base line. But DTS systems – rely on the leaked fluid having a different temperature than the location where the optical fiber distributed sensing cable is located. This may not be the case with a buried pipeline where the fluid may approach the environmental temperature over time when the pipeline isn't in use. In the case of DAS
10 systems– they rely on acoustic noise generated when the pipeline is pressurized and the sound generated when the fluid escapes the high pressure inside the pipeline. But this may not be case when the pipeline is inactive and not pressurized.

15 There are consequences to not detecting a leak. In the case of hydrochloric acid pipeline leaks during the inactive time may leak without means to detect the event. And the acid may then dissolve the carbonate foundation on which the pipeline rests, and other structures may also be impacted by a large acid leak.

20

There is a need for a better system that can detect small leaks during normal operation and also leaks during periods between well stimulation and pipeline usage if fluid is left in the pipeline.

25

Brief Description of the Drawings

Figure 1 Figure 1 illustrates prior art deployment of optical fiber for
5 pipeline leak detection.

Figure 2 illustrates an enhanced deployment method where
environmental effects may be reduced.

10 Figure 3 illustrates a side view of the deployment of Figure 2.

Figure 4 illustrates a system that could achieve the desired objective.

Figure 5 illustrates an alternate embodiment in which a pipeline may be
15 placed in a trough inside a buried trench.

Detailed Description

In the following detailed description, reference is made to accompanying
5 drawings that illustrate embodiments of the present disclosure. These
embodiments are described in sufficient detail to enable a person of
ordinary skill in the art to practice the disclosure without undue
experimentation. It should be understood, however, that the
embodiments and examples described herein are given by way of
10 illustration only, and not by way of limitation. Various substitutions,
modifications, additions, and rearrangements may be made without
departing from the spirit of the present disclosure. Therefore, the
description that follows is not to be taken in a limited sense, and the
scope of the present disclosure will be defined only by the final claims.

15 The invention use materials deployed in the fluid leak path and the
materials are selected such that exothermic reactions occur when the
fluid contacts the material. The optical fiber distributed sensing cable is
placed inside a trough to control leaked fluids towards the material and
20 sensing cable such that the exothermic event is detected when the fluid
contacts the material.

Figure 1, shown generally as **100**, illustrates prior art deployment of
optical fiber for pipeline leak detection. The optical fiber cable **140** is
25 buried below the pipeline **120** such that there is a thermal gradient
between the pipeline **120** and the location where the sensing fiber optic
is located. A leak **130** will cause fluid **150** of a one temperature to seep
into the ground and eventually reach the optical fiber distributed sensing
cable in an environment with a different temperature. This is detected by
30 the fiber optic sensing system. The underlying assumption here is that
there is a difference in temperature between the optical fiber distributed
sensing cable **140** and the pipeline product, and that sufficient amount of

pipeline product reaches the sensing cable to generate a decent size thermal event. This may not always be true due to soil variations, seasonal temperature changes, rain and other environmental effects.

5 Figure 2, shown generally as **200**, shows an enhanced deployment method where environmental effects may be reduced. A pipeline **210** is
trenched and a glass fiber reinforced plastic (GRP) trough **250** is located
in the trench (trench not shown). Baffles **240** located along the trough
support the pipeline and control the spacing between the pipeline **210**
10 and optical fiber distributed sensing cable **230**, and also provide a barrier
for fluid migration in case of a leak. A lid **220** may be attached on top of
the trough to provide an environment where rain and other
environmental effects are reduced and thereby generate a more stable
environment for the sensing system. The space inside the trough may
15 be filled with gravel or other suitable materials to support the weight of
the pipeline **210** when filled while providing a good migration path for fluid
from a pipeline leak down to the optical fiber distributed sensing cable
230. The V-shaped bottom of the trough **250** will focus leaked fluids
towards the optical fiber distributed sensing cable.

20

Figure 3, shown generally as **300**, illustrates a side view of the
arrangement of Figure 2. Pipeline **210**, containing pipeline product **320**
rests on the structure of the baffles **240**. The optical fiber cable **230** is
located at the lowest part of the arrangement and any leaked pipeline
25 product **340** from leak **330** naturally collects there surrounding the
detecting fiber cable **230**.

The arrangement in Figures 2 & 3 will enhance the ability to detect a
pipeline leak, but there may still be conditions where the thermal
30 differences between the pipeline product and the optical fiber distributed
sensing cable is very small. So what is needed is a system that can
detect very small leaks.

One example of such a system could be a pipeline used for acid transportation. Hydrocarbon wells drilled in carbonate reservoirs are commonly stimulated by acid injection of e.g. hydrochloric acid where the acid dissolves the carbonate and increase the flow area to contact a larger reservoir volume. The surface infrastructure may be located on carbonate rock and a leak would have a serious negative impact on the foundation of the infrastructure. It is therefore desirable to have a leak detection system that can monitor leaks irrespective of environmental conditions.

Figure 4 shown generally as 400, illustrates a system that will achieve the desired objective. Figure 4 shows the system in Figures 2 & 3 with the addition of a material **410** located at the bottom of the trough. In the case of an acid pipeline the material can be calcium carbonate as it is well known that it will cause a strong exothermic reaction when in contact with the hydrochloric acid. The rise in temperature will depend on the actual concentration of the acid and the material, in this case calcium carbonate even though other similar chemicals obviously fall within the scope of the invention. This will generate an event that will deviate from the thermal base line regardless of environmental conditions, whether there is flow or not, pressure or not, and can easily be detected with a DTS monitoring system. The reaction between the acid and calcium carbonate will bubble and also generate noise when the bubbling of the chemical reaction occurs, and this can be detected with a DAS system. The optical fiber distributed sensing cable may be coated in a material that is acid resistant, e.g. Teflon. Other materials well known to generate exothermic reactions with hydrochloric acid include e.g. lithium, potassium, calcium, sodium, magnesium, aluminum, zinc, iron and lead. Suitable materials may be selected based on applications and desired thermal response as e.g. zinc may generate a thermal event of around 8-10C whereas magnesium may generate a vigorous thermal event of up

to 60C. It may however not be desirable to have materials like lithium and magnesium in some applications due to the material properties.

5 Water may also be used in the trough because hydrochloric acid gives off heat when it is added to water. The limitation is that water may evaporate or leak off in time, so a solid material like calcium carbonate has the advantage of being permanent.

10 Similarly, thermal and acoustic signatures can be generated with other material combinations. The materials may be designed for other pipeline products to for example release acoustic energy when wetted. Thus a custom product with stored acoustic or mechanical energy may be housed in a material that will dissolve when in contact with, for example, hydrocarbons, and the released energy may be detected with a
15 Distributed Acoustic Sensing (DAS) system.

As an alternative to fluid or granular reactive materials the granular material could be supplied as a gel or bricks to facilitate keeping the reactive material in place for pipelines with steep slopes.

20

The reactive material can also be made available in other ways. In an alternative embodiment it can be supplied encapsulated within a sensing cable. Sensing cables may have various encapsulations and/or fillers, and it is common for these encapsulations to be extruded onto the
25 sensing cables or fillers may be added to the cable construction. The encapsulation material may be melted during the process and it may possible to mix materials with exothermic reaction into the extrusion process, or various filler materials can be manufactured to include exothermic materials.

30

It is also common to add tape on top of sensing cables or in cable layers and this is another possible embodiments where layers of tape are used

and where one layer may include materials with exothermic properties. The encapsulation may then act as an exothermic barrier around the sensing cable, or the outer layer of a sensing cable may dissolve when exposed to the pipeline fluid to expose layer/fillers/tape
5 with exothermic materials.

Making use of the encapsulation approach described above an alternate embodiment could be employed in which no trough is needed and no baffles, similar to that shown in Figure 1. The sensing cable with
10 encapsulated reactive material could be deployed directly below the pipeline and gravity would drive any liquid leaks to seep down and active the reactive material within the sensing cable. As with the other approaches described the distributed sensing could be either DTS or DAS systems.

15 In an alternate embodiment as shown generally as **500** in Figure 5 the concept can be applied by use of retaining walls **510** around a trench dug into any soil **515** with a simple trough **520** inside the retaining walls and carrying a pipeline **530** for delivering a pipeline product **550**. Optical
20 fiber sensing cables **535** can be placed under the pipeline and a material **540** that is reactive to product **550** is poured into the trough so that it covers the optical fiber sensing cables. The material might be liquid or a granular solid. Once in place a trench lid **560** could be placed in place to protect the pipeline in place and to offer convenient access to the
25 pipeline for maintenance purposes.

Value Added

Earlier attempts rely on the thermal difference between the pipeline
30 product and the environment where the optical fiber distributed sensing cable is located, and this condition may not be satisfied thus resulting in a leak detection system that cannot detect leaks under certain

environmental conditions. The invention generates a thermal event triggered by a leak regardless of environmental conditions.

Although certain embodiments and their advantages have been
5 described herein in detail, it should be understood that various changes, substitutions and alterations could be made without departing from the coverage as defined by the appended claims. Moreover, the potential applications of the disclosed techniques is not intended to be limited to the particular embodiments of the processes, machines, manufactures,
10 means, methods and steps described herein. As a person of ordinary skill in the art will readily appreciate from this disclosure, other processes, machines, manufactures, means, methods, or steps, presently existing or later to be developed that perform substantially the same function or achieve substantially the same result as the
15 corresponding embodiments described herein may be utilized. Accordingly, the appended claims are intended to include within their scope such processes, machines, manufactures, means, methods or steps.

Claims

1. A system for detecting pipeline leaks for intermittent use pipelines
5 comprising:
 - a. a pipeline carrying a pipeline product that might be of intermittent use;
 - b. a trough in which the pipeline rests;
 - c. at least one optical fiber distributed sensing cable running
10 through the trough and located below the pipeline;
 - d. separated baffles located along the trough supporting the pipeline and controlling a spacing between the pipeline and the optical fiber distributed sensing cable;
 - e. a reactive material in the bottom of the trough; and in
15 contact with the at least one optical fiber distributed sensing cable;
 - f. wherein the reactive material is selected that will react with the pipeline product if it comes in contact with it, creating a thermal or acoustic event.
- 20 2. The system for detecting pipeline leaks for intermittent use pipelines of claim 1 wherein the optical fiber distributed sensing cable is part of a distributed temperature sensing (DTS) system and can detect any thermal events along the pipeline.
3. The system for detecting pipeline leaks for intermittent use
25 pipelines of claim 1 wherein the optical fiber distributed sensing cable is part of a distributed acoustic sensing (DAS) system and can detect any acoustic events along the pipeline.
4. The system for detecting pipeline leaks for intermittent use pipelines of claim 1 wherein the pipeline product is a hydrochloric
30 acid.
5. The system for detecting pipeline leaks for intermittent use pipelines of claim 4 wherein the reactive material at the bottom of

the trough is calcium carbonate that may react with the hydrochloric acid, releasing thermal energy that can be measured by a DTS system.

- 5 6. The system for detecting pipeline leaks for intermittent use pipelines of claim 1 wherein the trough in which the pipeline rests comprises a V-shaped bottom.
7. The system for detecting pipeline leaks for intermittent use pipelines of claim 1 wherein the reactive material is in granular form.
- 10 8. The system for detecting pipeline leaks for intermittent use pipelines of claim 1 wherein the pipeline material is a hydrocarbon.
9. The system for detecting pipeline leaks for intermittent use pipelines of claim 8 wherein the reactive material is a material that
15 may dissolve in hydrocarbons, releasing acoustic energy that can be measured by a DAS system.
10. The system for detecting pipeline leaks for intermittent use pipelines of claim 1 wherein the reactive material is supplied as a gel or in small brick form that will stay in place in sloped pipeline
20 deployments.
11. The system for detecting pipeline leaks for intermittent use pipelines of claim 1 wherein the reactive material in the bottom of the trough is supplied encapsulated within a sensing cable running through the trough and located below the pipeline.
- 25 12. A system for detecting pipeline leaks for intermittent use pipelines comprising:
 - a. a trench dug into soil, with retaining walls surrounding the trench;
 - b. a pipeline carrying a pipeline product that might be of
30 intermittent use;
 - c. a trough located in the trench and in which the pipeline rests;

- d. at least one optical fiber distributed sensing cable running through the trough and located below the pipeline;
 - e. a reactive material in the bottom of the trough and covering the at least one optical fiber distributed sensing cable;
 - 5 f. wherein the reactive material is selected that will react with the pipeline product if it comes in contact with it, creating a thermal or acoustic event;
 - g. a trench lid placed on the retaining walls after the deployment of the trough, pipeline, optical fiber cables, and reactive material.
- 10
13. The system for detecting pipeline leaks for intermittent use pipelines of claim 12 wherein the optical fiber distributed sensing cable is part of a distributed temperature sensing (DTS) system and can detect any thermal events along the pipeline.
- 15
14. The system for detecting pipeline leaks for intermittent use pipelines of claim 12 wherein the optical fiber distributed sensing cable is part of a distributed acoustic sensing (DAS) system and can detect any acoustic events along the pipeline.
15. The system for detecting pipeline leaks for intermittent use pipelines of claim 12 wherein the pipeline product is a hydrochloric acid.
- 20
16. The system for detecting pipeline leaks for intermittent use pipelines of claim 15 wherein the reactive material at the bottom of the trough is calcium carbonate that may react with the hydrochloric acid, releasing thermal energy that can be measured by a DTS system.
- 25
17. The system for detecting pipeline leaks for intermittent use pipelines of claim 12 wherein the trough in which the pipeline rests comprises a V-shaped bottom.
- 30
18. The system for detecting pipeline leaks for intermittent use pipelines of claim 12 wherein the reactive material is in granular form.

19. The system for detecting pipeline leaks for intermittent use pipelines of claim 12 wherein the pipeline material is a hydrocarbon.
- 5 20. The system for detecting pipeline leaks for intermittent use pipelines of claim 19 wherein the reactive material is a material that may dissolve in hydrocarbons, releasing acoustic energy that can be measured by a DAS system.
- 10 21. The system for detecting pipeline leaks for intermittent use pipelines of claim 12 wherein the reactive material is supplied as a gel or in small brick form that will stay in place in sloped pipeline deployments.
22. The system for detecting pipeline leaks for intermittent use pipelines of claim 12 wherein the reactive material in the bottom of the trough is supplied encapsulated within a sensing cable
- 15 running through the trough and located below the pipeline.
23. A system or detecting pipeline leaks for intermittent use pipelines comprising:
- a. a pipeline carrying a pipeline product that might be of intermittent use;
 - 20 b. at least one optical fiber distributed sensing cable running directly beneath the pipeline;
 - c. a reactive material supplied encapsulated within a sensing cable located below the pipeline;
 - d. wherein the reactive material is selected that will react with
 - 25 the pipeline product if it comes in contact with it, creating a thermal or acoustic event.
24. The system for detecting pipeline leaks for intermittent use pipelines of claim 23 wherein the optical fiber distributed sensing cable is part of a distributed temperature sensing (DTS) system
- 30 and can detect any thermal events along the pipeline.
25. The system for detecting pipeline leaks for intermittent use pipelines of claim 23 wherein the optical fiber distributed

sensing.cable is part of a distributed acoustic sensing (DAS) system and can detect any acoustic events along the pipeline.

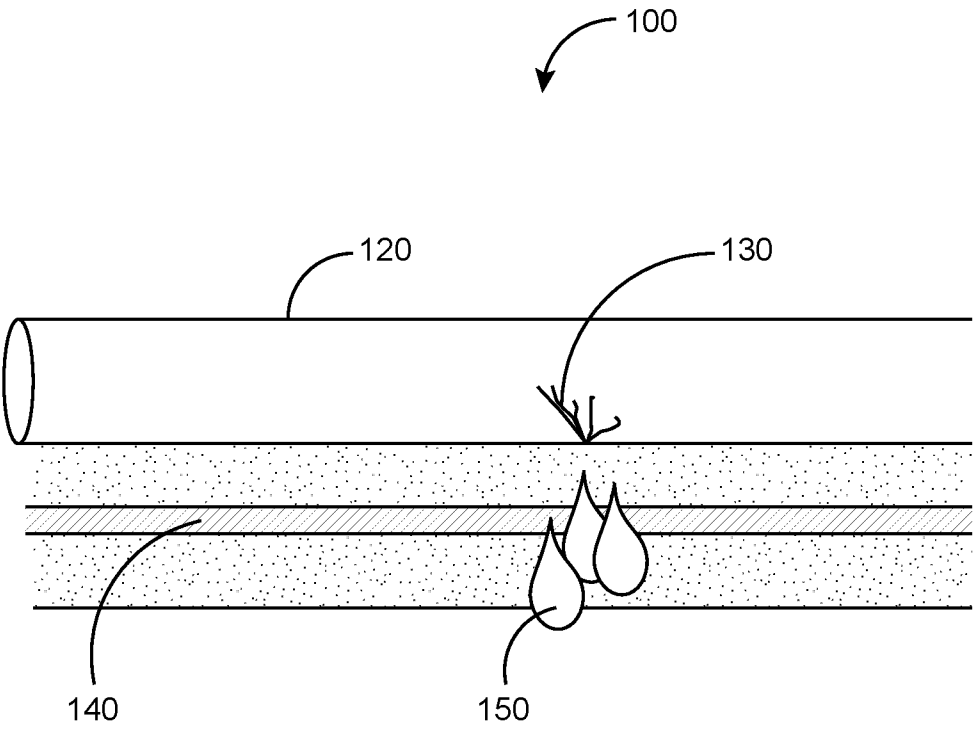


FIG. 1

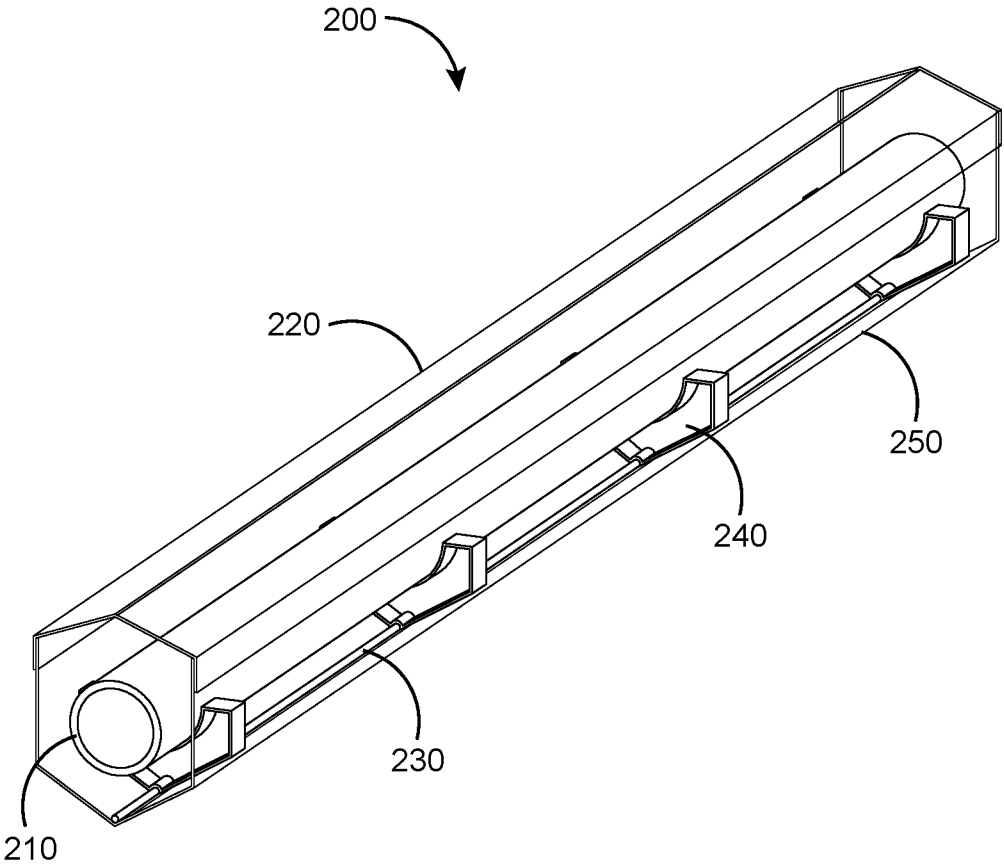


FIG. 2

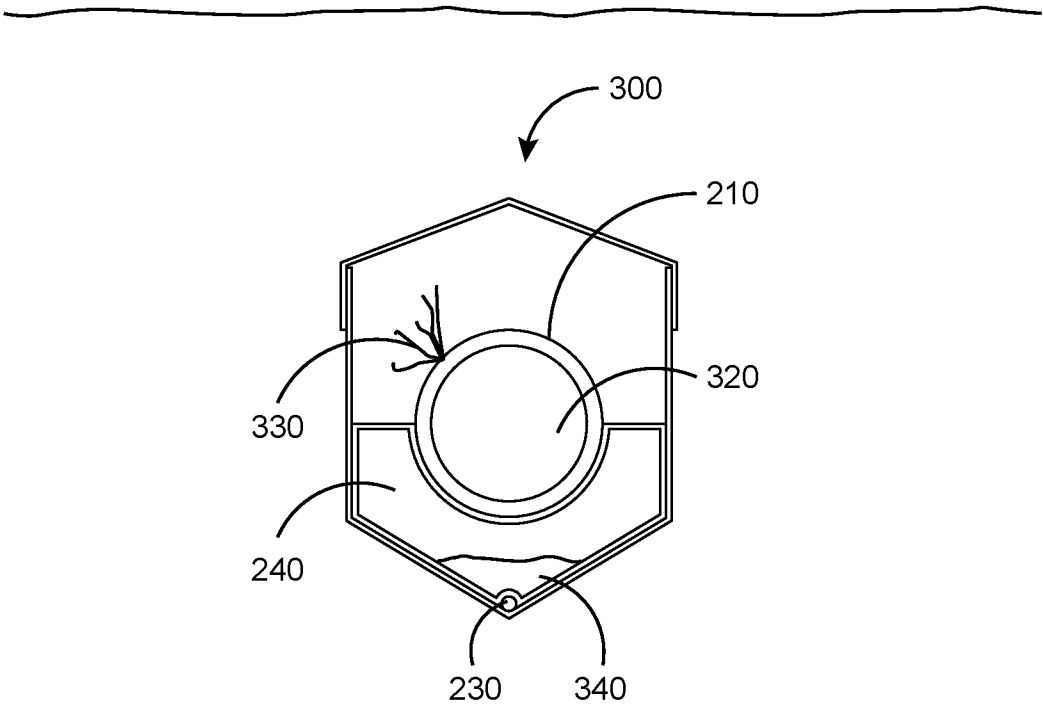


FIG. 3

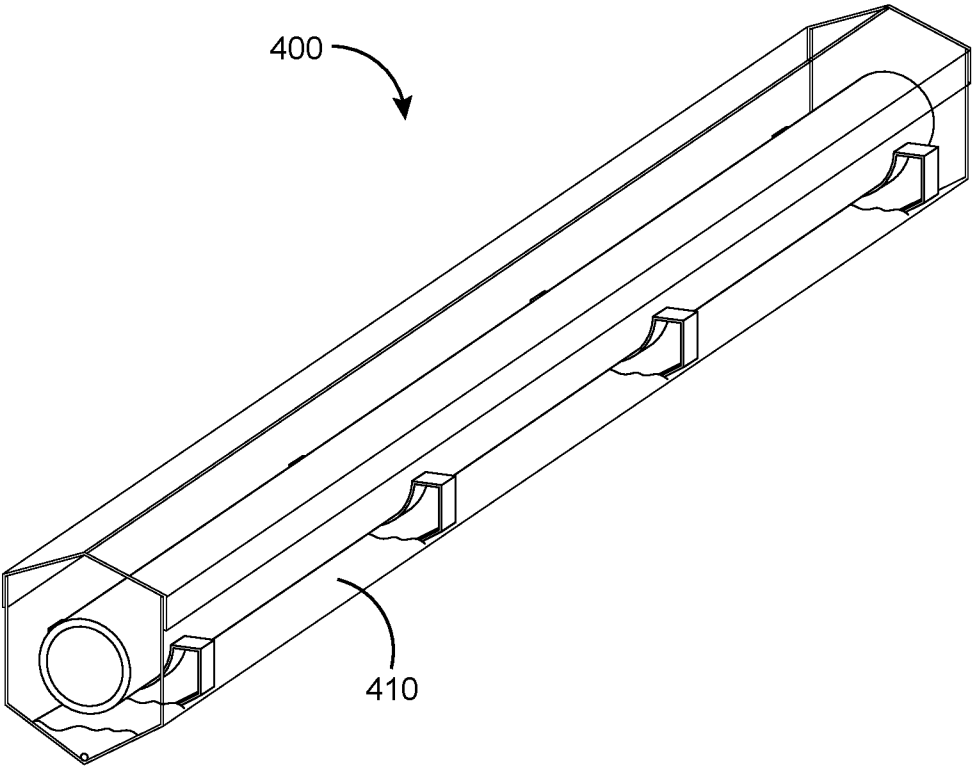


FIG. 4

5/5

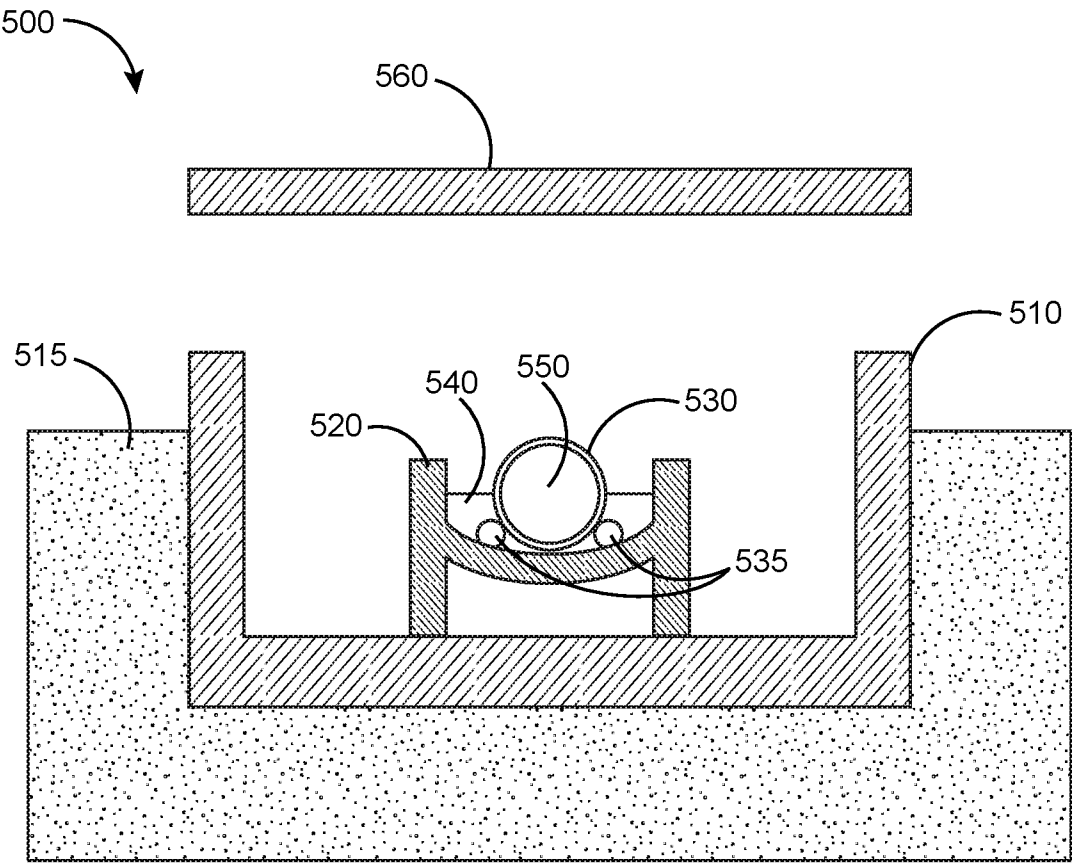


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/031808**A. CLASSIFICATION OF SUBJECT MATTER****G01M 3/04(2006.01)i, G01M 3/38(2006.01)i**

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

B. FIELDS SEARCHEDMinimum documentation searched (classification system followed by classification symbols)
G01M 3/04; G01M 3/08; E03F 3/06; G02B 6/50; G08B 21/00; G01M 3/38; E03F 1/00Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility modelsElectronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: tube, pipe, shell, leak, sensor, detect, optic, fiber, trench, trough, baffle, react**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4673926 A (GORMAN, WALTER T.) 16 June 1987 See column 2, lines 23-48, claims 1, 2, 11, 12, and figures 1, 3.	23-25
Y		1-22
Y	US 2006-0137431 A1 (FERNANDES et al.) 29 June 2006 See paragraphs [0025]-[0027] and figure 6.	1-11
Y	US 2012-0087728 A1 (BROOKS, WILLIAM R.) 12 April 2012 See paragraph [0017] and figure 2.	12-22
A	CN 103926670 A (E-TECH ENERGY TECHNOLOGY DEVELOPMENT CORPORATION) 16 July 2014 See abstract, claims 1-6, and figures 1-3.	1-25
A	JP 04-148836 A (ONO YUTAKA et al.) 21 May 1992 See claims 1, 2, and figures 2, 3.	1-25



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

03 February 2017 (03.02.2017)

Date of mailing of the international search report

03 February 2017 (03.02.2017)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

Facsimile No. +82-42-481-8578

Authorized officer

KIM, Jin Ho

Telephone No. +82-42-481-8699



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/031808

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 4673926 A	16/06/1987	None	
US 2006-0137431 A1	29/06/2006	AT 478329 T BR PI0405388 A CA 2478729 A1 CA 2478729 C CN 1707236 A CN 1707236 B EP 1602910 A1 EP 1602910 B1 ES 2350929 T3 HK 1085790 A1 RU 2004125887 A RU 2365811 C2 US 7155961 B2	15/09/2010 24/01/2006 04/12/2005 08/12/2009 14/12/2005 24/08/2011 07/12/2005 18/08/2010 28/01/2011 20/07/2012 27/02/2006 27/08/2009 02/01/2007
US 2012-0087728 A1	12/04/2012	US 2009-0194473 A1 US 8603332 B2	06/08/2009 10/12/2013
CN 103926670 A	16/07/2014	CN 103926670 B	06/04/2016
JP 04-148836 A	21/05/1992	None	