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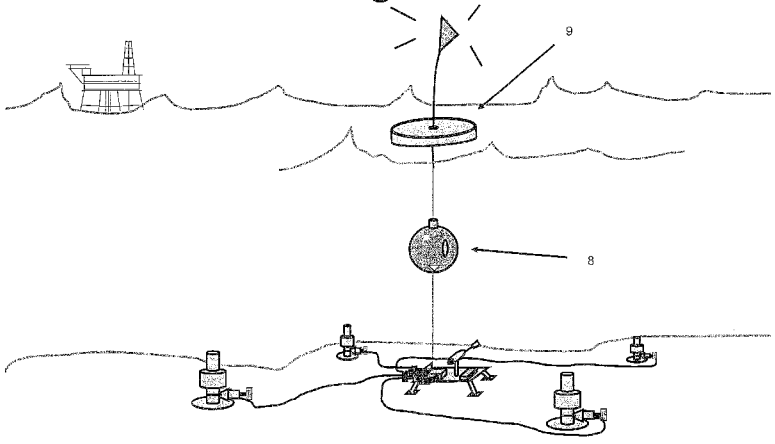
(54) **Title**: LEAK DETECTION AND EARLY WARNING SYSTEM FOR CAPPED OR ABANDONED SUBSEA WELLHEADS

Fig. 4



(57) **Abstract**: A method and apparatus for acoustic detection of potential and actual leaks in pipelines, particularly in subsea valves and wellheads in the oil and gas industry via broadband acoustic emissions sensors, and a means for communicating the existence, location and severity of said leaks via an electronic signal processor to above-sea monitoring facilities via cellular or other means in a quick and efficient manner.

PATENT APPLICATION

SPECIFICATION

Title of the Invention

Title: Leak Detection and Early Warning System for Capped or Abandoned Subsea Wellheads

Inventors: Stanley Hale, Kennesaw, Georgia

US Patent References Cited (*=closest prior art)

US 6,668,619
US 3,859,845
US 4,301,006
US 3,903,729
US 4,445,863
US 5,101,774*
US 5,201,212

Background of the Invention

Field of the Invention

This invention is an advancement in the field of subsea wellhead leak detection, and, more particularly, to an improved method and apparatus for detection of potential and actual leaks in subsea wellheads and pipelines with acoustic emission devices and a means for communicating the existence, location and severity of said leaks to surface monitoring facilities in a quick and efficient manner.

Description of Related Art

In all subsea wellheads where hydrocarbon products such as crude oil or natural gas are extracted, the potential for leaks is a substantial issue with regard to environmental protection and governmental regulation. Leakage from temporarily abandoned wellheads that have not been produced and are still at high pressure are of particular concern because facilities and personnel necessary to detect the presence of a leak are not typically left in the area of the temporarily abandoned or capped wellhead and detection of leakage by conventional means is less likely. The typical approaches used by offshore operators to detect hydrocarbon leaks from subsea wellheads includes aerial observation where leaks are eventually detected as a sheen on the surface of the water, periodic flybys with underwater remotely operated vehicles (ROVs) that scan the wellhead area with various types of sensors such as active acoustics (sonar) or infrared video, monitoring devices that detect acoustic noise in the water caused by a leak and sensors in the water near the wellhead that detect changes in the chemical makeup of the seawater. Leaks from abandoned wellheads are a major concern and could cause

significant detrimental effects on the environment and subject the owners and operators of the wellheads to regulatory penalties. Of particular concern are abandoned wellheads in deep water fields where the leaked hydrocarbon product may not surface within many miles of the leaking wellhead and use of remote monitoring tools, aerial reconnaissance or periodic ROV flyby cannot occur on a regular and frequent basis. In these cases subsea wellheads can leak for many days and even weeks before detection and then an additional period of time is required before the precise location can be detected and repaired.

While the potential for such leaks is relatively low, the remoteness and isolation of the wellheads pose a challenge with regard to monitoring methods and communication of the presence or potential for leaks to surface monitoring stations. The use of acoustic emission monitoring is desirable due to the sensitivity of certain acoustic emission devices and signal processing methods to the high frequency noise caused by leakage of hydrocarbon products on the pressurized side of the capped wellhead to the lower pressure area on the other side of closed valves or the environment. Based on similar deployments of acoustic emission techniques to detect leaks through valves and process equipment on the surface such as on the platform or in a shore-based process plant environment, acoustic emission is known to provides an effective method to detect and provide early warning of leaks through valves and to the environment. These similar deployments rely on transmission of the leakage noise through the hydrocarbon media or through the air to the sensor where the noise is detected and processed using a variety of signal processing means. Similar approaches have been employed with limited success for the purpose of detecting leaks to the environment from capped and abandoned subsea wellheads. However, given the lack of infrastructure in the immediate vicinity of the

wellheads, there is a need for additional electronic and signal processing systems required to communicate the leakage data to a surface monitoring station such that offshore operators can manage and maintain remote subsea equipment and protect the environment. It is also an object of this invention to employ acoustic emission sensors and signal processing that are different from previously applied art. The acoustic emission sensors employed herein are sensitive to much higher frequency ranges than those previously employed and instead of detecting the leakage noise as it travels through the hydrocarbon media or the surrounding seawater, the present invention detects the pressure wave caused by the leak that travels in the steel structure of the wellhead and surrounding steel structure.

Acoustic emission sensors of the type described above are normally referred to as broadband acoustic emission sensors. In order to employ the commercial versions of these sensors in the high pressure subsea environment they must be manufactured into a robust sensor housing such that the acoustic coupling between the steel structure of the wellhead equipment and the sensing element of the sensor is maintained. Appropriately packaged sensors that are ROV deployable with long term battery life, that are structurally designed for deep sea operations are a desirable improvement in the industry. By coupling ROV deployable acoustic emission sensors with the capability of transmitting information regarding potential and actual leaks to the surface represents an improved method for leak detection in the industry.

There are a wide range of acoustic emission devices and signal processing approaches used in industry, but the signal processing techniques and method of

application were designed for specific applications of AE and not customized for leak detection in this manner. Previous devices in the industry include:

U.S. Pat. No. 3,760,280 to Covington, which discloses a method and apparatus for delaying an electrical signal. The electrical signal to be delayed is converted into a frequency modulated signal which is coupled to a digital memory device that operates in response to a control signal. The rate of the control signal and the capacity of the memory device determine the delay of the FM signal. The delayed FM signal is then demodulated back to its original format.

U.S. Pat. No. 3,903,729 to Covington, discloses a method and apparatus for detecting a break or other occurrence in a pipeline containing gas under pressure. This patent discloses detecting the adiabatic pressure wave generated in the gas by the break and propagated through the gas at the speed of sound. The location of the break is determined by the change of pressure with respect to time of the leading wedge of adiabatic pressure wave. Spaced pressure-electrical transducers are utilized to detect the compression waves. Electronic circuitry is utilized to delay a selected one of the transduced electrical signals for a selective time interval to substantially eliminate the portion of the signal responsive to compressional wave traveling in the direction opposite the preselected direction.

U.S. Pat. No. 4,455,863 to Huebler, et al., discloses the sonic detection of gas leaks in underground pipes. The patent detects sound waives created by leaking gas using a sound transducer attached to an elongated probe inserted into the ground for a substantial portion of its length. The elongated probe and transducer combination has an

effective mechanical resonant frequency equal to or below the electrical resonant frequency of the sound transducer. The passive sonic detection apparatus and process of this invention provides improved sensitivity for detection of sounds created by leaking gas and thereby more accurate pinpointing of the gas leak in an underground pipeline.

U.S. Pat. No. 5,101,774 to Marziale, et al, discloses an acoustic leak detection system. The system is monitored for leaks by an acoustic leak detection system responsive to atmospherically carried sound transmissions. Energy level amplitudes of respective analog electrical signals generated sequence multiplicity of microphones are converted in a rapid time sequence to a first electric pulse signal sequence represented of a corresponding digital values.

U.S. Pat. No. 5,201,212 to Williams, discloses a method and apparatus for testing underground fluid containing lines for leaks. The apparatus includes a differential pressure transducer mounted to a reservoir for indicating volumetric change in the reservoir, a temperature transducer mounted in the reservoir for monitoring temperature fluctuation in the reservoir, a gauge pressure transducer mounted in the reservoir, and a remote temperature sensor and data acquisition and processing system. Readings are taken and pressure and temperature fluctuations in the line are tested at 30 second intervals. Thereafter, the system calculates the leak rate during each 5 minute interval of the test, as well as a cumulative leak rate.

None of the previous efforts of others, taken either alone or in combination, teach or suggest all of the elements of the present invention, nor the advantages and benefits of the present invention.

Brief Summary of the Invention

This invention represents advancement in the area of leak detection in subsea wellheads, subsea production equipment and pipelines. The invention comprises a method and apparatus for acoustic detection of potential and actual leaks in subsea production equipment and pipelines, particularly in subsea valves and wellheads in the oil and gas industry, and a means for communicating the existence, location and severity of said leaks to surface monitoring facilities in a quick and efficient manner.

The acoustic emissions sensor is comprised of a broadband acoustic emission sensor that operates in the frequency band above 60 KHz up to 1 MHz. The acoustic emission sensor is acoustically coupled to the wellhead, wellhead valve or pipe such that high frequency vibrations traveling in the pipe wall are detected by the sensor. The sensor can use the natural coupling afforded by seawater or a silicon pad of appropriate acoustic properties may be used to achieve the desired coupling. The acoustic emission sensor is connected to a electronic signal processing such the sensor output can be appropriately captured, processed and transmitted to a surface monitoring facility.

The subsea sensor and signal processing can communicate with the surface over wires provided they are available. However, subsea wellheads that are not actively producing do not usually have any type of nearby infrastructure on the seafloor that is capable of communicating data to nearby surface facilities or vessels. In many cases the closest surface facilities are many miles away from the wellhead. Data collected by the acoustic emissions sensor can also be electronically conveyed to a nearby underwater power and communications skid containing a wireless subsea modem and SCADA (supervisory control and data acquisition) communications module, whereby any data

gathered is communicated to a communications antenna buoy and subsequently relayed via cellular communications or satellite to a surface data acquisition system.

All components of the power and communications skid shall be modular and serviceable by an ROV. Additionally, the power and communications skid shall contain a rechargeable battery pack which may be charged by an ocean current battery charger which utilizes the kinetic energy of ocean movement to create an electrical charge.

An alternate embodiment of the present invention would include the sensors, electronic signal processing and software required to launch a balloon or other floating device that can transmit the data from a leaking wellhead once released to the surface.

Description of the Drawings

FIG. 1 is a detailed view of the broadband acoustic sensor (1) and its electrical components (2) having been affixed to a pipe of a wellhead by ROV with a flexible pad (3) of the broadband acoustic sensor (1) being in contact with the pipe.

FIG. 2 shows a representation of the ROV (6) placing the broadband acoustic sensor (1) in contact with a pipe, said broadband acoustic sensor (1) affixing to the pipe via locking pins (5).

FIG. 3 is an overview of the entire subsea apparatus including the broadband acoustic sensor (1) as connected to the communications module (7), said communications module (7) further being comprised of a wireless means of communication (7a), and ocean current battery charge (7b) and a rechargeable battery pack (7c).

FIG. 4 shows a representation of communication of data to above sea monitoring stations via stabilization by a buoy (8) with the data being transmitted beyond the local area via a communications antenna (9)

Reference Numbers in Drawings

1 Broadband Acoustic Sensor
2 Electrical Components
3 Flexible Pad
4 Apparatus as installed by ROV
5 Locking Pins
6 ROV Handle
7 Communications Module
  7a Wireless Means of Communication
  7b Ocean Current Battery Charger
  7c Rechargeable Battery Pack
8 Buoy
9 Communications Antenna

Claims

I claim,

1 A method and apparatus for detecting hydrocarbon leaks from subsea wellhead equipment consisting of :

broadband acoustic emission sensors

said broadband acoustic emission sensors being capable of detecting high frequency acoustic waves that are created by leaks in the wellhead equipment and that travel in the steel surface of the wellhead equipment away from the leak source location to the sensor and communicating the existence of leaks via average signal level,

an electronic signal processor

said electronic signal processer being capable of capturing the average signal level of the broadband acoustic emission sensor output and generating and transmitting data regarding leaks,

software

said software being capable of capturing data transmitted by the electronic signal processor, calculating the size of the leak based on the ASL level and generating a leakage alarm,

firmware

said firmware being capable of communicating the leakage alarm generated by the software to a surface monitoring facility such that responsible oil company personnel can tend to the leak in a timely manner.

2 The method and apparatus for detecting hydrocarbon leaks from subsea wellhead equipment of claim **1** wherein the electronic signal processor can be wired to a surface structure or vessel such that the electronics can be continuously powered and connected to the monitoring station.

3 The method and apparatus for detecting hydrocarbon leaks from subsea wellhead equipment of claim **1** wherein the wellhead location is remote from surface structures or vessels and the broadband acoustic sensors and electronic signal processor must be powered by a local power source such as a battery that may or may not be rechargeable.

4 The method and apparatus of claim **3** wherein the wellhead location is remote from surface structures or vessels and the electronic signal processor must communicate to the monitoring station by wireless means such as by floating buoy and antenna that utilizes the existing cellular telephone infrastructure of the above sea location transmit leakage data to the monitoring facility.

5 The method and apparatus of claim **3** wherein the wellhead location is remote from surface structures or vessels and outside of the range of cellular networks and the information must be communicated to a satellite and then to the monitoring facility.

6 The method and apparatus of claim **3** wherein the wellhead location is remote from surface structures or vessels and the signal processing is performed at the subsea wellhead location and firmware and software in the system automatically calculate leakage level and release a floating ball or balloon that rapidly ascends to the surface where the leakage alarm is transmitted to the nearby cellular network and then to the monitoring station.

7 The method and apparatus of claim **3** wherein the wellhead location is remote from surface structures or vessels and the signal processing is performed at the subsea wellhead location and firmware and software in the system automatically calculate leakage level and release a floating ball or balloon that rapidly ascends to the surface where the leakage alarm is transmitted to a satellite and relayed to the monitoring station.

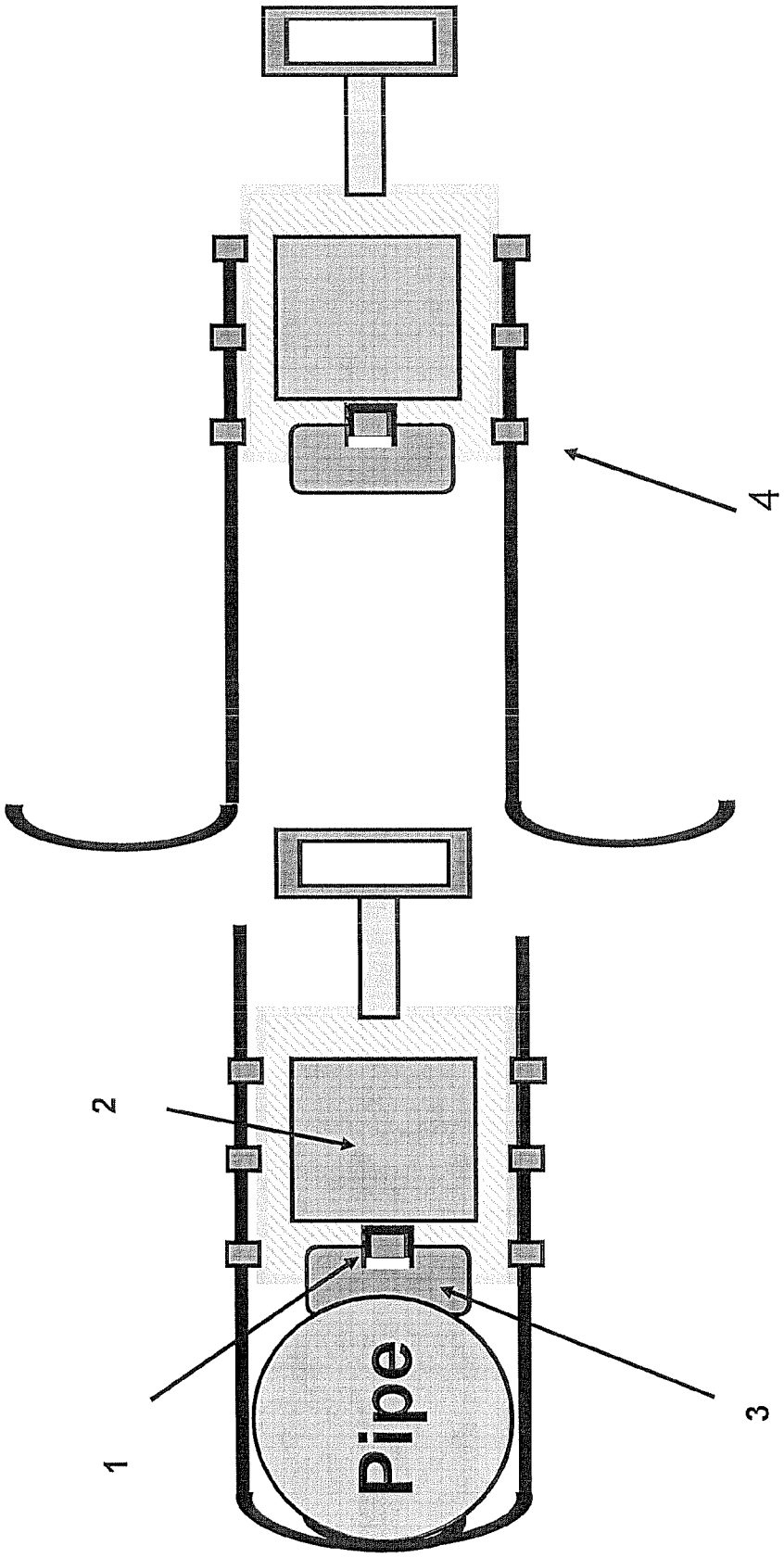


Fig. 1

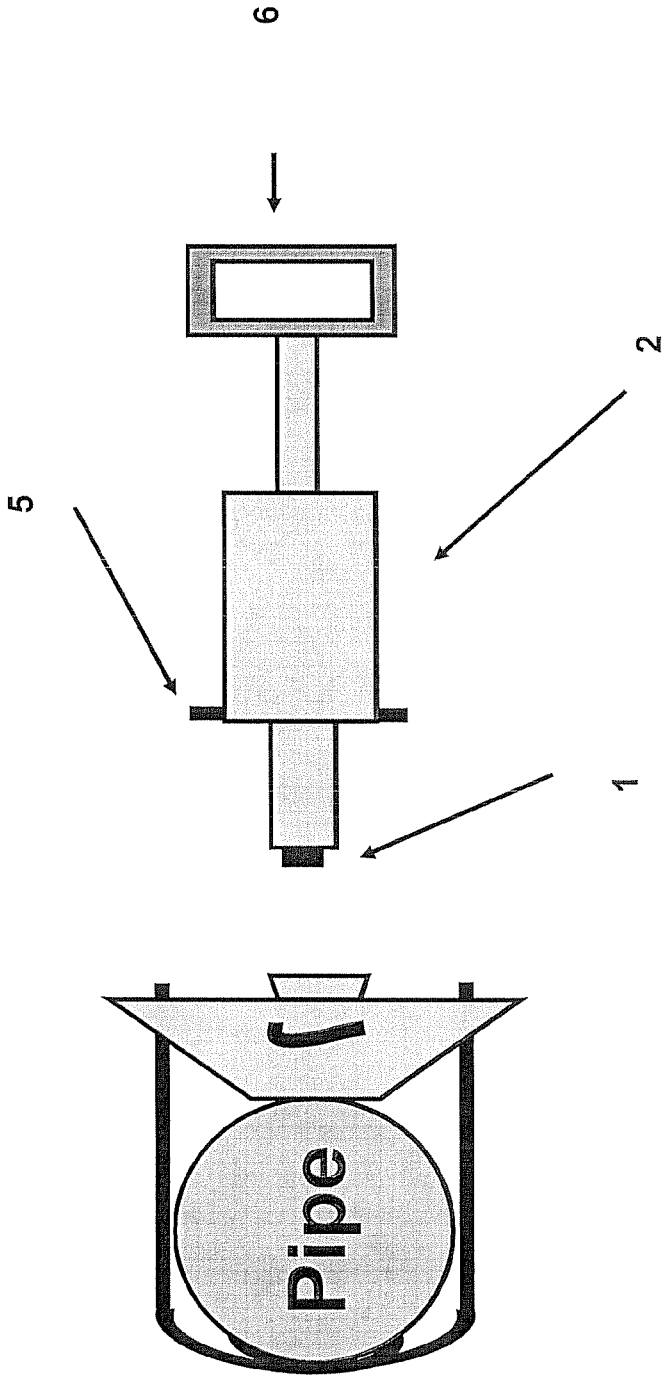


Fig.

Fig. 3

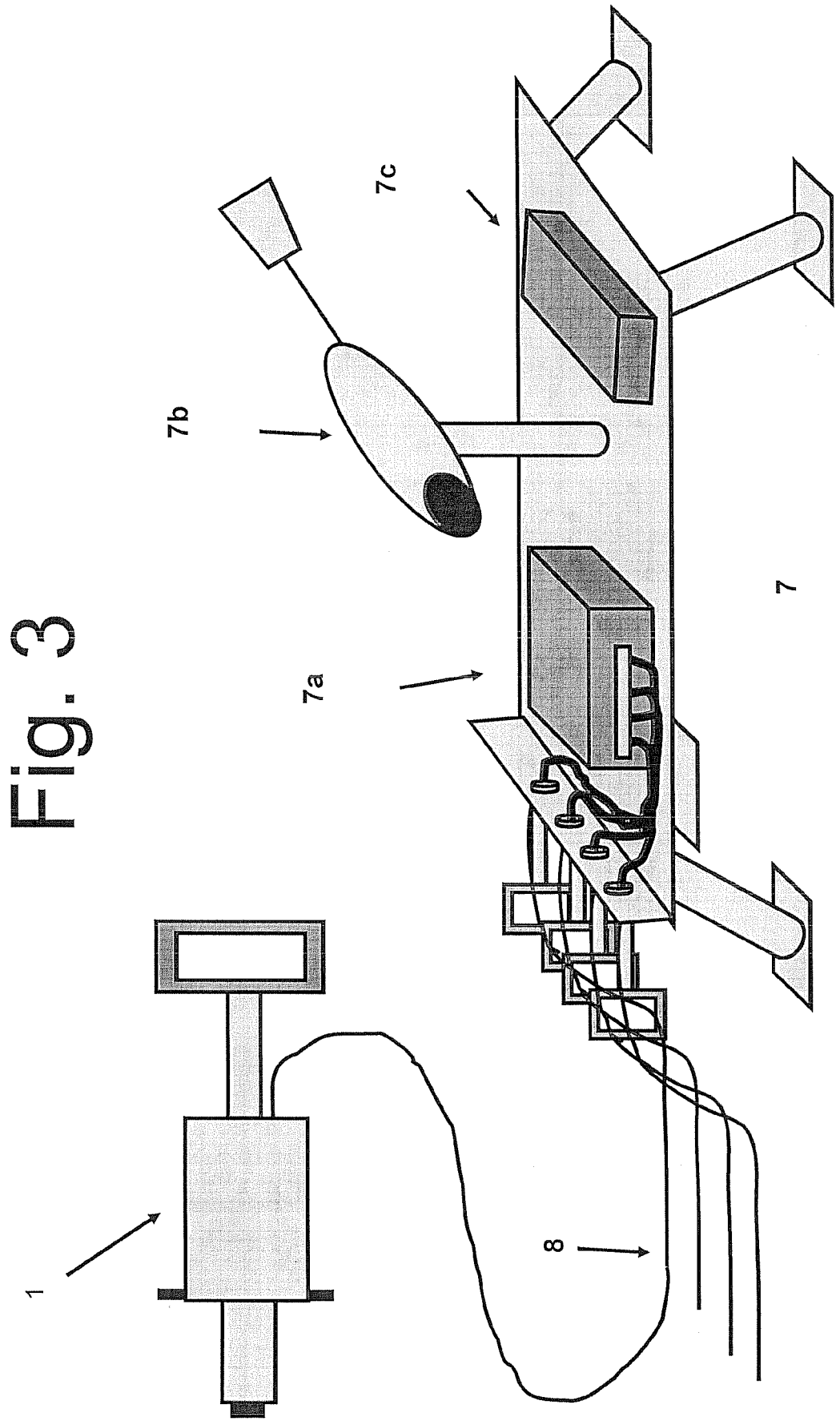
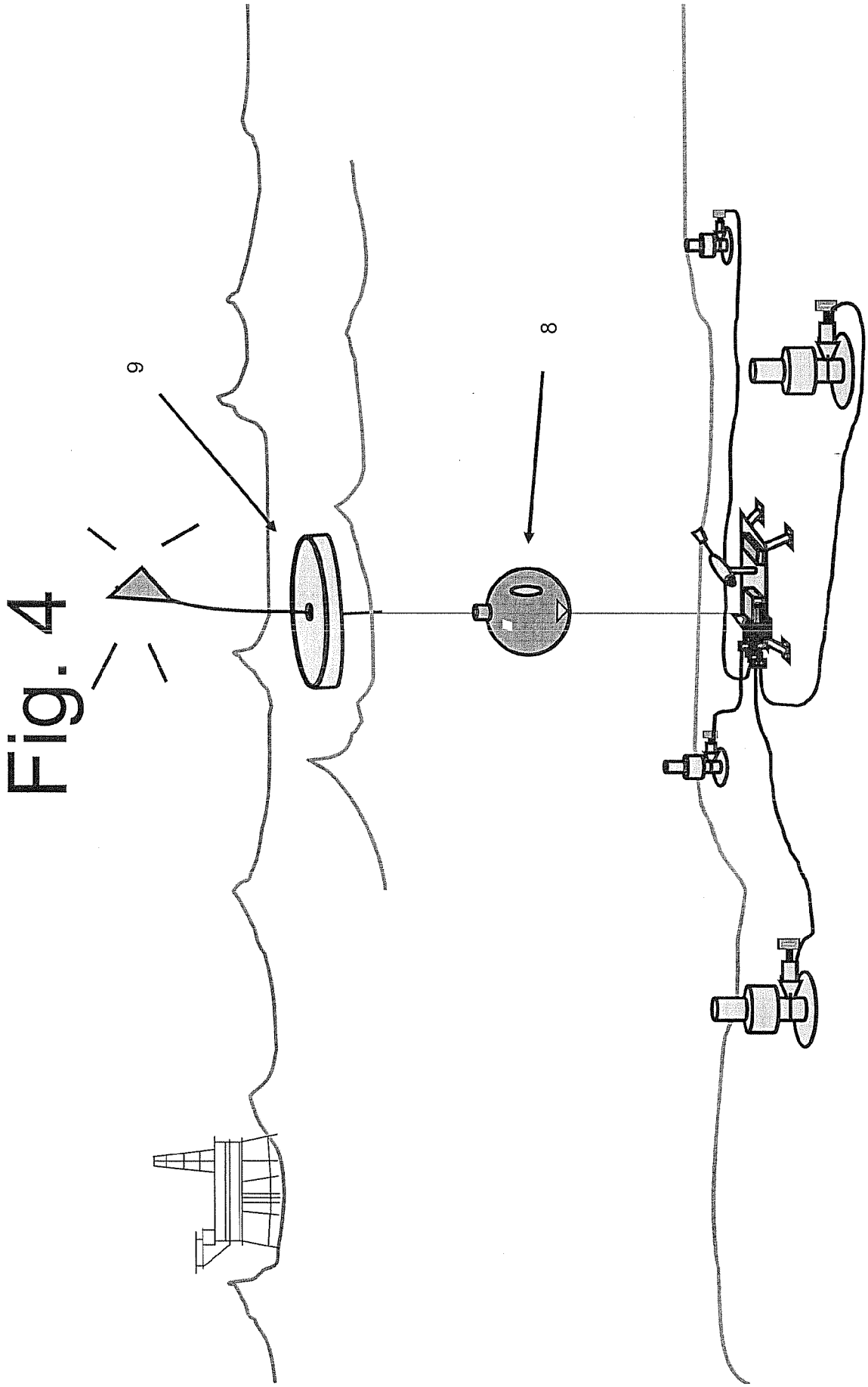


Fig. 4



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/048974

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - E21B 47/10 (2011.01)
USPC - 166/337
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)
IPC(8) - E21B 29/12, 47/10; H04B 11/00, 17/00 (2011.01)
USPC - 166/250.08, 336, 337; 367/13, 86, 131

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)
Patbase, Google Patents, Google Scholar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 6,640,900 B2 (SMITH) 04 November 2003 (04.11.2003) entire document	1-7
Y	US 3,462,240 A (BOSSELAAR et al) 19 August 1969 (19.08.1969) entire document	1-7
Y	US 5,533,383 A (GREENE et al) 09 July 1996 (09.07.1996) entire document	1-7
A	US 7,643,945 B2 (BAKLANOV et al) 05 January 2010 (05.01.2010) col 7, lines 3-15, fig 4A	1-7

☐ Further documents are listed in the continuation of Box C. ☐

* 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
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 November 2011	08 DEC 2011
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774