(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
4 October 2012 (04.10.2012)

WIPO | PCT

(10) International Publication Number
WO 2012/134640 A2

(51) International Patent Classification:
F16L 1/16 (2006.01) *B25J 1/06* (2006.01)
F16L 1/26 (2006.01)

(21) International Application Number:
PCT/US2012/024468

(22) International Filing Date:
9 February 2012 (09.02.2012)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
13/075,964 30 March 2011 (30.03.2011) US

(71) Applicant *(for all designated States except US)*: **CHEVRON U.S.A. INC.** [US/US]; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **LISO, Stephen** [US/US]; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US). **HARDING, Eric** [US/US]; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US). **O'DONNELL, Thomas** [US/US]; 6001 Bollinger Canyon Road, San Ramon, California 94583 (US).

(74) Agents: **DIDOMENICIS, Karen R.** et al.; Chevron Corporation, Law Department, Post Office Box 6006, San Ramon, California 94583-0806 (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, 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, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, 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.

[Continued on next page]

(54) Title: SYSTEMS AND METHODS FOR REPOSITIONING AND REPAIRING A SECTION OF SUBSEA PIPE LOCATED ON A SEABED

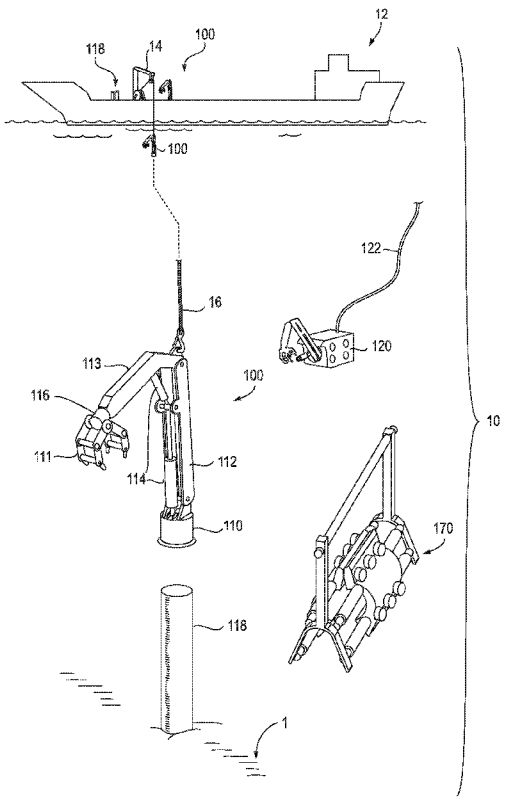

FIG. 1

(57) Abstract: Methods and systems are provided for repositioning and/or repairing a section of pipe within a pipeline or other equipment located on a seabed. System components are delivered by a surface vessel to the vicinity of the section of pipe or other equipment. Piles are partially driven into the seabed adjacent the section of pipe or other equipment such that each of the piles has an exposed pile top above the seabed. Pile tops are employed to support load-bearing manipulator assemblies each having a hydraulically controlled manipulator arm having a grapple capable of grasping and repositioning a section of pipe or other equipment. The manipulator assemblies are operated to reposition the pipe or other equipment in one embodiment, and to hold the pipe so that a repair clamp can be installed.

WO 2012/134640 A2

(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, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, 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, 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))*

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

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

SYSTEMS AND METHODS FOR REPOSITIONING AND REPAIRING A SECTION OF SUBSEA PIPE LOCATED ON A SEABED

BACKGROUND

The invention relates to systems and methods for repositioning and repairing a section of subsea pipe located on a seabed, such as pipe used in an oil and gas transportation pipeline.

Known methods for repairing subsea oil and gas transportation pipelines located on soft and sloping seabed conditions require specialized pipeline repair equipment and procedures, and/or terrain modifications to improve the stability. Currently used methods for pipe repair on slopes of 5 to 10° with respect to the horizontal generally require minor terrain modifications. Pipe repair on slopes of greater than 10° generally require some equipment modifications. For instance, load handling equipment used for such repairs must be stabilized with a stable anchoring system such as a large cumbersome mud mat system, such as, for example, the system disclosed in U.S. Patent No. 6,290,431. Such systems cannot be stabilized for use in sloping terrain without additional anchoring, making them impractical on sloping or uneven terrain. On steep slopes of greater than 15°, mud mat systems have been found to be unstable.

It would be desirable to have systems and methods to accommodate subsea pipeline repairs on seabed conditions ranging from very soft and powdery soil to moderate clay and on topography ranging from relatively flat to inclines and declines of up to about 30° with respect to the horizontal.

SUMMARY

In a first embodiment, a method is provided for repositioning a section of subsea pipe located on a seabed, the method including the following steps:

a. partially driving at least two manipulator support piles into the seabed adjacent a section of pipe to be repositioned such that each of the piles has an exposed pile top above the seabed;
b. installing on each pile a manipulator assembly having a base for receiving the pile top, a hydraulically controlled manipulator arm including a proximal arm pivotally connected to the base, a distal arm pivotally connected to the proximal

arm, a swivel joint connected to the distal arm and a grapple connected to the swivel joint capable of grasping and repositioning a section of pipe;

c. grasping and repositioning the section of pipe with the hydraulically controlled manipulator arm; and

d. releasing the section of pipe from the hydraulically controlled manipulator arm.

In a second embodiment, a method is provided for repairing a pinhole leak in a subsea pipe located on a seabed, the method including the following steps:

a. partially driving at least two manipulator support piles into the seabed adjacent a section of pipe having a pinhole leak therein such that each of the piles has an exposed pile top above the seabed;

b. installing on each pile a manipulator assembly having a base for receiving the pile top, a hydraulically controlled manipulator arm including a proximal arm pivotally connected to the base, a distal arm pivotally connected to the proximal arm, a swivel joint connected to the distal arm and a grapple connected to the swivel joint capable of grasping and repositioning a section of pipe;

c. grasping and lifting the section of pipe with the hydraulically controlled manipulator arm;

d. installing a repair clamp onto the pipe to repair the pinhole leak;

e. lowering to the seabed the section of pipe with the hydraulically controlled manipulator arm; and

f. releasing the section of pipe from the hydraulically controlled manipulator arm.

In a third embodiment, a system is provided for repositioning and/or repairing subsea pipe located on a seabed, the system including:

a. a plurality of piles capable of being partially driven into a seabed adjacent a section of pipe thereby providing a plurality of exposed pile tops above the seabed;

b. a plurality of manipulator assemblies, each manipulator assembly having a base for receiving the pile top, a hydraulically controlled manipulator arm including a proximal arm pivotally connected to the base, a distal arm pivotally connected to the proximal arm, a swivel joint connected to the distal arm and a grapple

connected to the swivel joint capable of grasping and repositioning a section of pipe; and

c. a control means for controlling the manipulator arms.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates the equipment components to be used in a pipe repair system according to an embodiment of the present invention.

Figure 2 illustrates the repositioning and/or repairing of a section of pipe according to embodiments of the present invention.

DETAILED DESCRIPTION

The methods and systems described herein are useful for repositioning and/or repairing a section of subsea pipe or other subsea equipment located on, near or beneath a seabed, for convenience, simply referred to herein as "on a seabed." Such subsea pipe, also referred to interchangeably as "pipe," is employed as part of a greater pipeline for transporting liquid and/or gas. For instance, the pipeline can be used for transporting hydrocarbon products such as oil, water or gas between offshore production facilities or between a platform and a shore facility. Typically, such pipe is made from steel or suitable alloy and has a diameter between about 2 in (5 cm) and about 50 in (127 cm). The methods and systems disclosed herein have particular advantages when the pipe is located on an area of seabed having a slope up to about 30° with respect to the horizontal.

In addition to repositioning and/or repairing a section of subsea pipe, the systems and methods disclosed herein can also be used to reposition and/or repair other pieces of subsea equipment having dimensions susceptible to manipulation by the presently disclosed systems as would be apparent to one skilled in the art.

In the embodiments disclosed herein, a system is provided which utilizes certain equipment components to reposition and/or repair a section of subsea pipe or other subsea equipment. Figure 1 illustrates the equipment components utilized by the system.

Surface vessel 12 delivers the system components to the vicinity of the location of the needed repositioning and/or repair at the surface of the ocean. The vessel 12 is equipped with a crane/winch 14 for lifting and lowering equipment via deployment rigging 16. The steps of

the methods of the embodiments disclosed herein are carried out in conjunction with the surface vessel as described hereinafter.

Standard remotely operated vehicles (ROV's) 120 including known ROV tooling suites, hydraulic controls and interfaces and pipe preparation tooling can be used with the system components in order to carry out the methods disclosed herein. Throughout this description, system components that are said to be hydraulically controlled can be controlled by standard ROV hydraulic tooling. ROV's are connected to the surface or a control module via tether 122.

Piles 118 are used to anchor load-bearing equipment into the seabed 1. The piles can be suction-type piles. The methods used for driving piles by suction are well known in the art and will not be described in detail. Examples of such piles and their operation are described in U.S. Patent Nos. 4,575,282 and 6,719,496. At least two piles are utilized, although more can be used depending on the objective and magnitude of a given situation.

Manipulator assemblies 100 are used to grasp, lift and hold a section of pipe during the repositioning and/or repairing methods. The number of manipulator assemblies utilized again depends on the specific objective. At least two manipulator assemblies are utilized for repositioning or repairing a pinhole leak. In one embodiment, each manipulator assembly 100 has an azimuthing base 110 and a manipulator arm controllable by hydraulics 114, the manipulator arm including a proximal arm 112 pivotally connected to the base 110 and a distal arm 113 pivotally connected to the proximal arm 112. At the end of the distal arm 113 is a swivel joint 116 and a grapple 111 capable of securely grasping a pipe located on the seabed, and lifting, maneuvering and holding the pipe. The base 110 has up to 360° nominal rotation adapted to receive the top end of a pile. The base is preferably keyed in order to lock the manipulator assembly in place. The base encapsulates the top end of a pile, also referred to herein as a "pile top," and allows the grapple loads to react against the partially driven pile. The manipulator assembly could alternatively be fixed to the pile top by the use of other suitable means, including the use of bolts and the like. The proximal and distal arms of the manipulator arm can extend the grapple up to the full length of the manipulator arm, for instance up to about 20 feet (6 m), even up to about 14 feet (4 m) from the base 110. Each manipulator arm has a hydraulic tool receptacle (not shown) for receiving hydraulic control, for instance from a remotely operated vehicle via a tool for establishing a hydraulic connection commonly referred to as a "hot stab."

In one embodiment, a split sleeve clamp 170 can be used to repair a pinhole leak, local wall thinning or small crack in a pipe. The clamp can be bolted onto a section of pipe, sealed and pressure tested using an ROV. Such clamps are well known in the art for making such repairs on subsea pipeline, and will not be described in detail.

In one embodiment, a method is provided for repositioning a section of pipe or other equipment located on a seabed. The section of pipe to be repositioned can be an integral part of a greater subsea pipeline, also referred to interchangeably as pipe. According to this embodiment, a section of pipe to be repositioned is first identified. With the assistance of an ROV, marker buoys can be placed to identify the location of the pipe section or other equipment to be repositioned. Once the location is identified, the location of the pipe section or other equipment can be marked using marker buoys. At least two piles are then partially driven into the seabed adjacent the section of pipe or other equipment to be repositioned such that each of the piles has an exposed pile top above the seabed. Onto each of the exposed pile tops is then installed a manipulator assembly. Each manipulator assembly can be operated as previously described to grasp the section of pipe or other equipment to be repositioned, lift the pipe from the seabed and adjust the position as desired, and finally return the pipe or other equipment to the seabed in the desired position. Each manipulator assembly then releases the pipe or other equipment, and the manipulator assemblies and piles can be removed from the seabed and returned to the surface vessel.

At least two piles 118 are inserted in the seabed for supporting manipulator assemblies, also referred to herein as "manipulator support piles." The piles are lowered from the surface using rigging 16. The manipulator support piles are partially driven into the seabed 1 adjacent the pipeline 2, preferably with at least one pile on one side and at least one pile on the other side of the section of pipe 2b to be repositioned. By "adjacent" is meant within 10 feet (3 m) of the axis of the pipe. By "partially driven" is meant inserted substantially vertically into the seabed by any known means such that one end of the pile is exposed above the seabed. The exposed pile end is also referred to as a “pile top.”

Once the piles are inserted into the seabed, the manipulator assemblies 100 are lowered into place on the manipulator support piles 118. Once the base of each manipulator assembly has encapsulated the pile, the ROV will then rotate the base into alignment for the orientation key to allow seating of the manipulator assembly onto the pile. This process is repeated for any remaining manipulator assemblies. Each manipulator assembly can be

lowered using rigging cable 16 attached to a hook or loop on the manipulator assembly, which is raised and lowered by the crane/winch 14 aboard surface vessel 12.

Once the manipulator assemblies are installed on the manipulator support piles, the hydraulic controls of the manipulator arms can be engaged by the ROV to securely grasp the pipe or other equipment. At this point, the manipulator arms can be controlled to lift the pipe or other equipment off the seabed into the desired position.

In another embodiment, a method is provided for making a repair such as repairing a pinhole leak in a section of pipe located on a seabed. This may be, for example, a weld fracture in a circumferential weld. Once the area of the leak has been identified, the location of the pipe section to be repaired can be marked using marker buoys. At least two piles are then partially driven into the seabed adjacent the section of pipe to be repaired such that each of the piles has an exposed pile top above the seabed. Onto each of the exposed pile tops is then installed a manipulator assembly. Each manipulator assembly can be operated as previously described to grasp the section of pipe to be repaired and/or lift the pipe from the seabed to a necessary clearance for the repair. At this point, the repair can be made using any suitable repair method, such as, for example the installation of a split sleeve clamp 170 around the circumference of the pipe, shown as installed in Figure 2. The repaired pipe can then be released and/or returned to the seabed. Each manipulator assembly then releases the pipe, and the manipulator assemblies and piles can be removed from the seabed and returned to the surface vessel. The surface vessel will then lower the rigging 16, and the ROV will commence operations to attach the rigging to the manipulator assemblies and piles and recover the equipment to the surface vessel 12. Once recovered to the surface vessel, the piles and manipulator assemblies can be reused repeatedly.

As would be readily apparent to one skilled in the art, the system can optionally be equipped with mechanical lock systems in order to maintain precision load holding while holding equipment in place over prolonged periods of time.

The drawings illustrate particular embodiments of the present invention. It will be appreciated that the apparatus may vary as to configuration and as to details of the parts, and that the methods may vary as to specific steps and sequences, without departing from the basic concepts as disclosed herein.

Although the description above contains many details, these should not be construed as limiting the scope of the invention but as merely providing illustrations of some of the presently preferred embodiments of this invention. Therefore, it will be appreciated that the scope of the present invention fully encompasses other embodiments which may become obvious to those skilled in the art, and that the scope of the present invention is accordingly to be limited by nothing other than the appended claims, in which reference to an element in the singular is not intended to mean "one and only one" unless explicitly so stated, but rather "one or more." All structural, chemical, and functional equivalents to the elements of the above-described preferred embodiment that are known to those of ordinary skill in the art are expressly incorporated herein by reference and are intended to be encompassed by the present claims. Moreover, it is not necessary for a device or method to address each and every problem sought to be solved by the present invention, for it to be encompassed by the present claims.

What is claimed is:

1. A method for repositioning a section of subsea pipe located on a seabed, comprising:
    a. partially driving at least two manipulator support piles into the seabed adjacent a section of pipe to be repositioned such that each of the piles has an exposed pile top above the seabed;
    b. installing on each pile a manipulator assembly having a base for receiving the pile top, a hydraulically controlled manipulator arm including a proximal arm pivotally connected to the base, a distal arm pivotally connected to the proximal arm, a swivel joint connected to the distal arm and a grapple connected to the swivel joint capable of grasping and repositioning a section of pipe;
    c. grasping and repositioning the section of pipe with the hydraulically controlled manipulator arm; and
    d. releasing the section of pipe from the hydraulically controlled manipulator arm.

2. The method of claim 1, further comprising:
    e. removing the manipulator assembly from each pile top; and
    f. removing each pile from the seabed.

3. A method for repairing a pinhole leak in a subsea pipe located on a seabed, comprising:
    a. partially driving at least two manipulator support piles into the seabed adjacent a section of pipe having a pinhole leak therein such that each of the piles has an exposed pile top above the seabed;
    b. installing on each pile a manipulator assembly having a base for receiving the pile top, a hydraulically controlled manipulator arm including a proximal arm pivotally connected to the base, a distal arm pivotally connected to the proximal arm, a swivel joint connected to the distal arm and a grapple connected to the swivel joint capable of grasping and repositioning a section of pipe;

c. grasping and lifting the section of pipe with the hydraulically controlled manipulator arm;

d. installing a repair clamp onto the pipe to repair the pinhole leak;

e. lowering to the seabed the section of pipe with the hydraulically controlled manipulator arm; and

f. releasing the section of pipe from the hydraulically controlled manipulator arm.

4. The method of claim 3, further comprising:

g. removing the manipulator assembly from each pile top; and

h. removing each pile from the seabed.

5. A system for repositioning and/or repairing subsea pipe located on a seabed, comprising:

a. a plurality of piles capable of being partially driven into a seabed adjacent a section of pipe thereby providing a plurality of exposed pile tops above the seabed;

b. a plurality of manipulator assemblies, each manipulator assembly having a base for receiving the pile top, a hydraulically controlled manipulator arm including a proximal arm pivotally connected to the base, a distal arm pivotally connected to the proximal arm, a swivel joint connected to the distal arm and a grapple connected to the swivel joint capable of grasping and repositioning a section of pipe; and

c. a control means for controlling the manipulator arms.

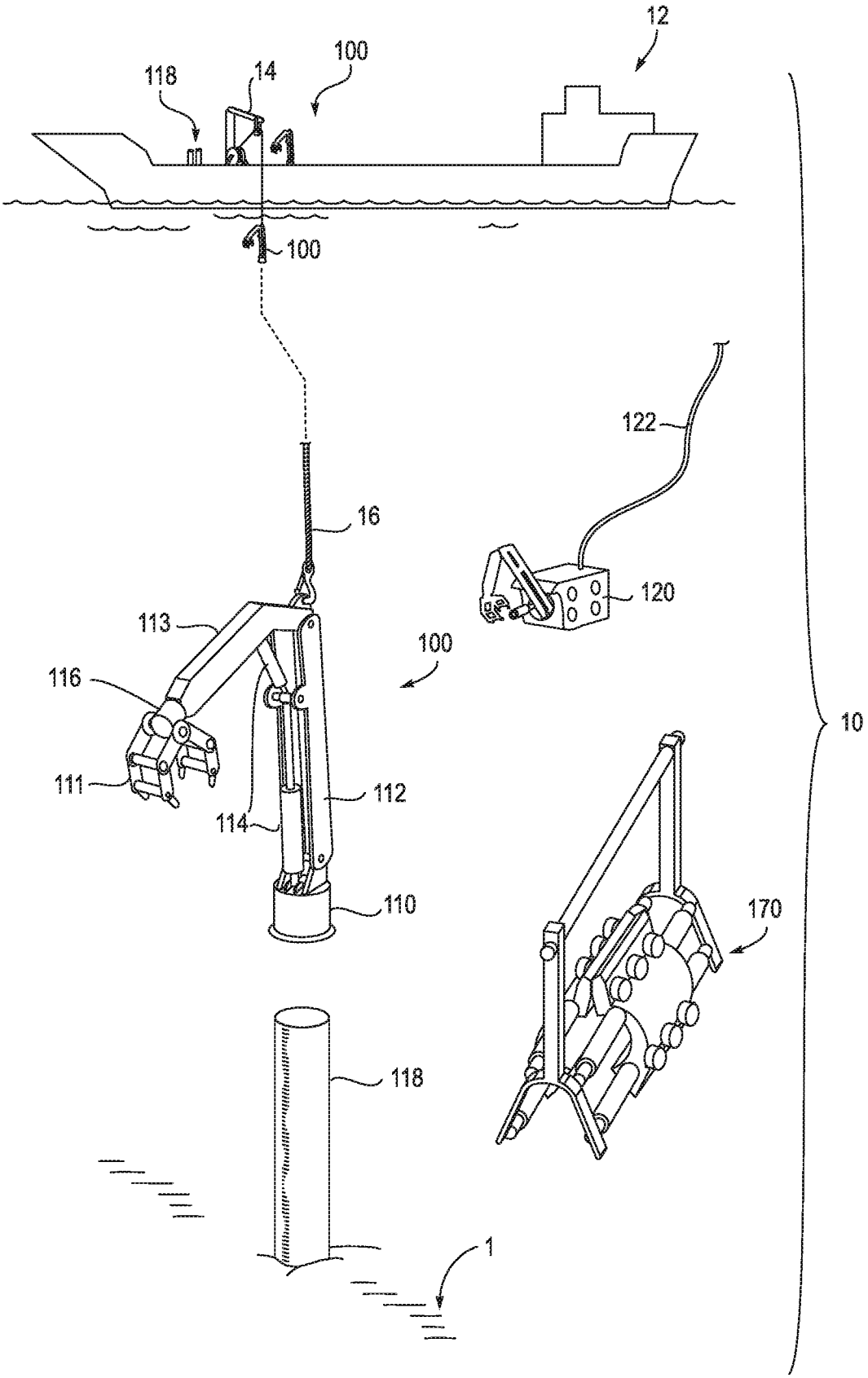
12
100
118
14
100
122
16
120
113
100
116
10
111
112
114
110
170
118
1

FIG. 1

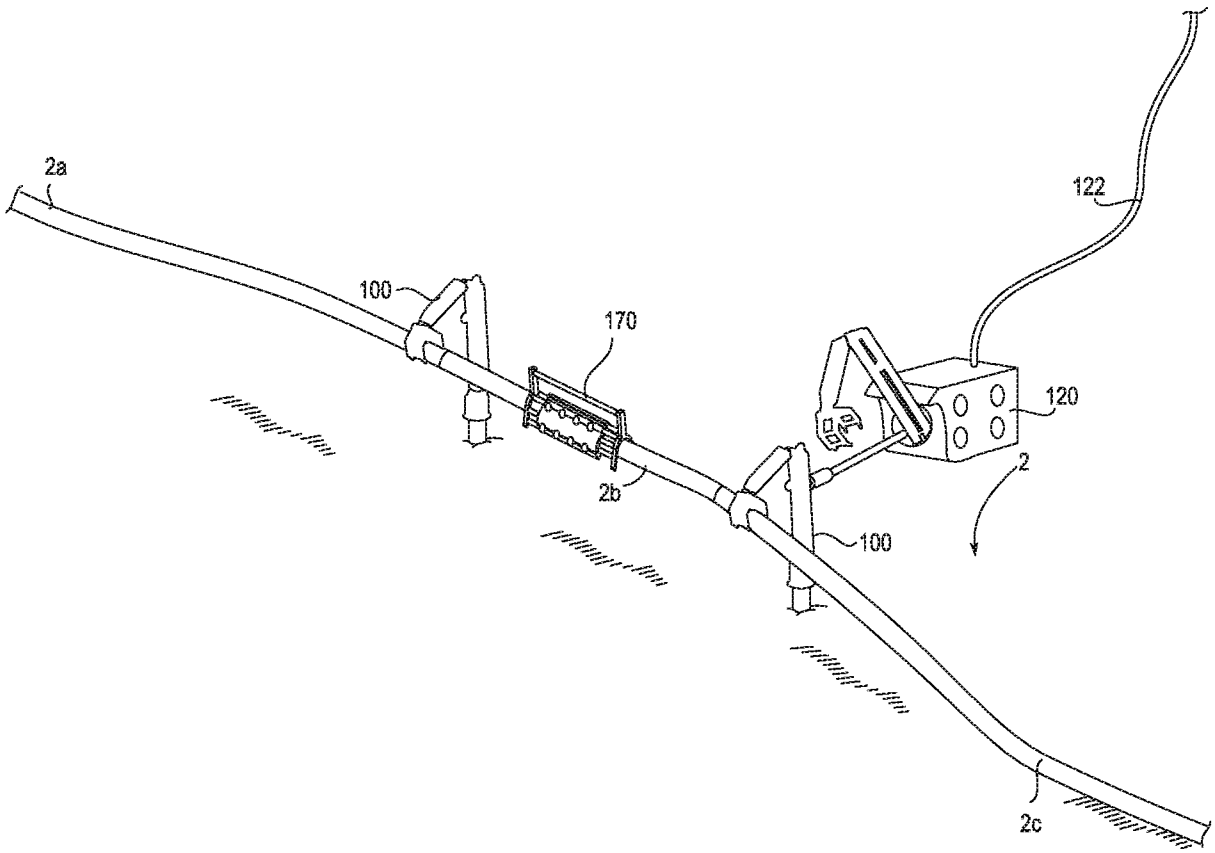

FIG. 2