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(71) Applicant *(for all designated States except US)*: **EXXONMOBIL UPSTREAM RESEARCH COMPANY** [US/US]; CORP-URC-E2.4A.296, P.O. Box 2189, Houston, TX 77252-2189 (US).

(72) Inventor; and
(71) Applicant *(for US only)*: **YOUNAN, Adel, H.** [US/US]; 5009 Bellevue Falls Ln, Sugar Land, TX 77479 (US).

(74) Agents: **HOLTHUS, Lisa, K.** et al.; Exxonmobil Upstream Research Company, CORP-URC-E2.4A.296, P.O. Box 2189, Houston, TX 77252-2189 (US).

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(54) Title: PROTECTING A STATIONARY VESSEL FROM ENCROACHING ICE

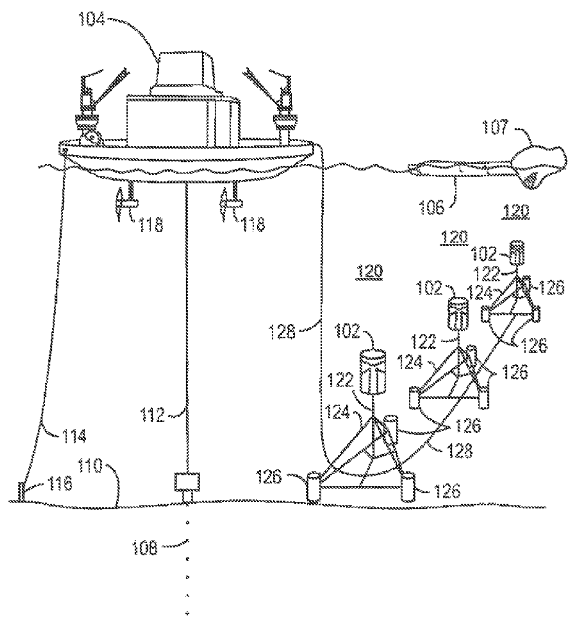

FIG. 1

(57) Abstract: Techniques are provided for protecting a stationary vessel from encroaching ice. In an example, a system has a subsea mount disposed on a seafloor and a thruster disposed on the subsea mount under a water surface. The thruster is configured to destabilize a water column under the encroaching ice.

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

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PROTECTING A STATIONARY VESSEL FROM ENCROACHING ICE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the priority benefit of U.S. Provisional Patent Application 62/087,504, filed 4 December 2014, entitled PROTECTING A STATIONARY VESSEL FROM ENCROACHING ICE, the entirety of which is incorporated by reference herein.

FIELD

[0002] The present techniques are directed to protecting stationary vessels from sea ice. More specifically, the present techniques are for breaking sea ice drifting towards a stationary vessel.

BACKGROUND

[0003] This section is intended to introduce various aspects of the art, which may be associated with exemplary embodiments of the present techniques. This discussion is believed to assist in providing a framework to facilitate a better understanding of particular aspects of the present techniques. Accordingly, it should be understood that this section should be read in this light, and not necessarily as admissions of prior art.

[0004] Arctic drilling attention has recently transcended shallow waters, e.g., less than about 100 meters (m), into deep waters, e.g., greater than about 100 meters. This, however, multiplies the challenges as arctic and deep-water frontiers are now merged. The challenges generally result from problems in stationkeeping, which is the ability of a vessel to hold a position over a subsea location, such as a well.

[0005] Station keeping is often important to prevent stress on drilling risers and lines that run from a vessel to the seafloor. Station keeping can be performed passively, such as by mooring lines, dynamically using propulsion systems, or a combination of the two. In arctic environments, station keeping can be challenged by sea ice floes. While fixed platforms are in direct contact with the seafloor and can withstand forces up to tens of thousands of tonnes, floating platforms are anchored to the seafloor via mooring systems with the capacity to withstand forces in the range of 1,000-2,000 tonnes.

[0006] While subsea developments may become a viable concept for arctic deep-water development, some operations still need to be conducted at the surface, such as drilling a subsea well or loading crude from subsea storage, among others. With conventional technology, these surface operations would have to rely on open water season. However, in many arctic locations, an open water season can be limited, highly variable, or, in some years, non-existent. Accordingly, systems to protect platforms and other vessels from drifting ice may be useful. Extending the open water season will depend on ice breakers, which may be limited in number and costly to operate.

SUMMARY

[0007] An exemplary embodiment provides a system for protecting a stationary vessel from encroaching ice. The system includes a subsea mount disposed on a seafloor and a thruster disposed on the subsea mount under a water surface. The thruster is configured to destabilize a water column under the encroaching ice.

[0008] Another exemplary embodiment provides a method for protecting a sea surface location from encroaching ice. The method includes detecting encroaching ice and activating a seafloor mounted thruster, wherein the thruster destabilizes the water column below the ice.

[0009] Another exemplary embodiment provides a method for producing hydrocarbons. The method includes positioning a vessel at a location on a sea surface. A thruster attached to a mount on a seafloor is positioned proximate to the location. Hydrocarbons are produced from a well using the vessel. Ice that is encroaching on the vessel is detected. The thruster is activated to destabilize the water column below the ice.

DESCRIPTION OF THE DRAWINGS

[0010] The advantages of the present techniques are better understood by referring to the following detailed description and the attached drawings, in which:

[0011] **Fig. 1** is a schematic diagram of the use of anchored thrusters to protect a stationary vessel from encroaching ice floes;

[0012] **Fig. 2** is a schematic diagram showing thrusters breaking an encroaching ice floe;

[0013] **Fig. 3** is a schematic diagram of a single thruster destabilizing a water column under an encroaching ice sheet;

[0014] **Fig. 4** is a drawing of a single thruster that may be used for breaking up an encroaching ice floe;

[0015] **Fig. 5** is a schematic diagram of a drilling location showing the placement of sensors and thrusters that may be used to protect a vessel;

[0016] **Fig. 6** is a process flow diagram of a method for producing hydrocarbons while using thrusters to break up ice floes before they reach a drilling location; and

[0017] **Fig. 7** is a process flow diagram of a method for using thrusters to break up ice floes before they reach a surface location.

DETAILED DESCRIPTION

[0018] In the following detailed description section, specific embodiments of the present techniques are described. However, to the extent that the following description is specific to a particular embodiment or a particular use of the present techniques, this is intended to be for exemplary purposes only and simply provides a description of the exemplary embodiments. Accordingly, the techniques are not limited to the specific embodiments described below, but rather, include all alternatives, modifications, and equivalents falling within the true spirit and scope of the appended claims.

[0019] As discussed above, protecting a vessel or vessels at a sea surface location from encroaching ice may be problematic, especially in deep water operations. Accordingly, embodiments described herein provide protection from ice encroachment for a location at the surface. Thrusters are mounted to locations along the seafloor and used to destabilize the water column under ice floes. Destabilizing the water column may break up the ice floes into fragments that do not apply as much pressure to a vessel. In some embodiments, the thruster may be used to steer larger ice fragments, such as ice ridges or icebergs, away from the vessel.

[0020] The thrusters may be mounted in arcs upstream of the vessel, e.g., in the general direction of encroaching ice floes, to break up or divert ice floes before they reach the vessel. In some embodiments, the subsea mount includes rails (or tracks) mounted to the seafloor. The thrusters may be mounted along the rails, allowing the thrusters to be repositioned to be more effective. For example, the rails may be mounted to mooring pilings, such as suction pilings, used to moor the ship in place. Combinations of these techniques can be used to make multiple layers of protection. For example, fixed thrusters may be mounted in an arc upstream of the vessel, while a rail may be mounted proximate to the fixed thrusters, allowing additional thrusters to be moved into place as needed. Similarly, multiple rails with mounted thrusters can be nested around a location to protect vessels by allowing multiple thrusters on each of the rails to be moved into place as needed.

[0021] The thrusters can be controlled and powered from the vessel being protected or may have a separate power system, control system, or both. In some embodiments, the thrusters may have sensors to detect objects, such as sea life, vessels, ice floes, and the like. The detection of the objects may be used to adjust the depth of the thruster in the water column, to power the thruster down, or both, to avoid collisions and damage.

[0022] **Fig. 1** is a schematic diagram of the use of anchored thrusters **102** to protect a stationary vessel **104** from encroaching ice floes **106**. The vessel **104** may be a drillship, used to drill a well **108** to a reservoir located below the seafloor **110**. However, as discussed herein, any number of other vessels may be protected using the current techniques, including tankers, service vessels, floating storage, offloading, and production (FSOP) vessels, and the like. If the vessel **104** is in deep water, for example, greater than about 100 meters in depth, it may not be in direct contact with the seafloor **110**. In this example, station keeping is important to protect equipment and piping that extends between the vessel **104** and the seafloor **110**, such as a drilling riser **112**.

[0023] The station keeping can be performed using mooring lines **114**, for example, coupled to a piling **116** embedded in the seafloor **110**. The piling **116** may be driven into the seafloor or may be a suction piling. Suction pilings are pulled into the soft surface of the seafloor by placing an open bottom of the piling in contact with the seafloor and then pumping water out of a chamber located at the top of the piling. In some embodiments, station keeping can be performed by azimuthing thrusters **118** on the vessel **104**. Combinations of these techniques may also be used, for example, using a mooring line **114** to generally hold the vessel **104** in place while the azimuthing thrusters **118** hold tension on the mooring line **118** and keep the vessel **104** from lateral motions.

[0024] Encroaching ice floes **106**, or ice ridges **107**, may approach the vessel **104** and interfere with the station keeping, for example, by forcing the vessel **104** to disconnect the drilling riser **112** from the well **108**, pull it up, and move out of the way. The use of the thrusters **102** in a water column **120** can mitigate problems with the ice floes **106**. The thrusters **102** may be disposed on the subsea mount by attaching the thrusters **102** to the mount using tethers **122**. The subsea mount may include a frame and one or more pilings. The frame, called a template **124**, may be attached to pilings **126** set into the seafloor **110**. The pilings **126** may be driven into the seafloor **110** or may be suction pilings. In other embodiments, the thruster may be attached to a piling **116** used for mooring the stationary vessel **104**. For example, mooring lines for a drilling vessel **104** may be attached to a series of suction pilings located around the vessel. Each of the suction pilings may also be used as attachment points for anchoring thrusters **102**. As discussed herein, the pilings **116** may also be used as anchor points for rails that are used as attachment points for anchoring the thrusters **102**. This would allow the thrusters to be moved to positions that are between encroaching ice floes **106** and the stationary vessel **104**.

[0025] A power and control cable **128** may be attached from the vessel **104** to each tether **122** to provide power to the thruster **102** attached to that tether **122**. In some embodiments, a subsea generator may be used to provide power for a thruster **102**. Further, power may be provided to the thrusters **102** from an on-shore generating station, depending on the location of the field relative to the shore, e.g., within about 50 miles of the shore or less.

[0026] The thrusters **102** can be made from any number of marine propulsion units, such as tunnel thrusters available from Rolls-Royce PLC of London, England, and Thrustmaster of Houston, Texas, USA, among others. The selection of the sizes for the thrusters **102** may depend on the location of the vessel **104** and the likely type of sea ice to be encountered, such as first year, second year, etc. In some embodiments, the thrusters **102** may be about 180 kilowatts (kW) to about 1 megawatt (MW) in power generation, while in other areas, the thrusters **102** may be about 3 to about 8 MW.

[0027] As the thrusters **102** may take water in at the top and eject it from the bottom, the tether **122** will remain in tension. Further, the tether **122** may be coiled to allow the thruster **102** to move vertically in a water column **120** without the tether **122** developing slack. A thruster **102** may change its vertical position along a water column by adjusting its buoyancy. This allows the thrusters **102** to be useful for various water depths and avoid various sea ice keel depths.

[0028] In some embodiments, a thruster **102** may be configured to allow a reversal of flow, e.g., from the bottom of the thruster **102** and out the top. This may allow the thruster **102** to deflect ice floes **106** or ice ridges **107** away from the vessel **104** when they are too large to break up. In this case, the thruster **102** would not be mounted to the template **124** by a flexible tether **122**, but would, instead, be disposed on the subsea mount by attaching the thruster with a bar or other rigid part. The bar may be hinged at the bottom to allow the thruster **102** to be lowered in a water column **120**, for example, to avoid a collision.

[0029] **Fig. 2** is a schematic diagram showing thrusters **102** breaking an encroaching ice floe **202**. Like numbered items are as described with respect to **Fig. 1**. In this example, the thrusters **102** are configured to pull water in through the top **204** and eject the water from the bottom **206**, as indicated by arrows. Removing water from underneath the ice floe **202** can cause it to collapse under its own weight, as indicated by the cracks **208** forming in the ice floe **202**. The fragments **210** formed by the collapse may be too small to cause problems with the station keeping of the vessel.

[0030] The tethers **122** may be used to set the vertical depth **212** at which the thrusters **102** sit under the ocean surface **214**. The depth **212** may be selected by a combination of factors, including the expected size of the ice floes **202**, the clearance needed for vessels operating in the area, and the size of the thrusters **102**. In various embodiments, the thrusters **102** may be set to be about 5 meters to about 30 meters below the surface.

[0031] **Fig. 3** is a schematic diagram of a single thruster **102** destabilizing a water column **300** under an encroaching ice sheet **302**. Like numbered items are as described with respect to **Figs. 1** and **2**. As described herein, the thruster **102** may take inlet water **304** in through the top **204** and eject outlet water **306** through the bottom **206**. The flow may lower the pressure in the water column **300** under the ice sheet **302**, resulting in a loss of support for the ice sheet **302**. The ice sheet **302** may then form fractures **308** and, as the ice sheet moves over the unstable water column **300**, the fractures **308** may be propagated through the ice sheet **302**, breaking it into smaller fragments.

[0032] The water ejected from the bottom **206** of the thruster **102** may be flowed through a grate or other structure to divert the flow out to the side. This may be useful for decreasing scouring of the ocean bottom below the thruster **102**, which could lead to loss of integrity of the supporting piles **126**.

[0033] Although the thrusters **102** may cause ice sheets **302** and ice floes **202** to break up, they may also be useful against larger ice structures, such as ice ridges. For example, the flow from the thrusters **102** may be used to change a path of an ice ridge, diverting it away from vessels. This may be caused by the swirling motion and indentation that would form in the surface above the thruster **102**, e.g., a whirlpool. The control system may be used to determine how to use the thrusters **102** to divert the larger ice structures.

[0034] **Fig. 4** is a drawing of a single thruster **102** that may be used for breaking up an encroaching ice floe. Like numbered items are as described with respect to **Figs. 1-3**. As described herein, the thruster **102** is coupled to a tether **122**, which may also provide power and control. The inlet water **304** is pulled in the open top **204** by thruster blade **402** that is turned by a motor **404**. The motor **404** may be an electric motor or may be a hydraulic engine, for example, powered by a sea water flow from a pump on a vessel. The outlet water **306** is ejected through the bottom **206** of the thruster **102**. As described herein, a grate **406** may be used to divert the flow of the outlet water **306** away from direct impact with the seafloor, lowering the chance of scouring around the mounting piles or rail.

[0035] The thruster **102** may have buoyancy compartments **408**, which may be used to increase or decrease the depth of the thruster **102**. The buoyancy compartments **408** may be, for example, hollow vessels that can be partially or completely filled with air from a compressor on the vessel. The buoyancy compartments **408** may not be effective at adjusting the depth when the thruster **102** is operating, as the thrust generated may tend to push the thruster **102** closer to the surface of the water. However, the buoyancy compartments **408** may be useful for lowering the thruster **102** to avoid an impact with an object while the thruster **102** is powered down. Such objects may be detected or identified by any number of means, such as by a sensor **410** mounted to the thruster **102**. When an approaching object, such as a ship or a marine mammal, among others, is detected, the thruster **102** may be instructed to shut down, lower its depth in the water, or both.

[0036] The thruster **102** may be mounted to the tether **122** by a framework **412** extending from the tether **122** to the outside shell **414**. In addition to the open top **204** and bottom **206**, the outside shell **414** may also have other openings **416** that may be used to provide differential thrust if desired. One or more of the side openings **416** may be configured to move the thruster **102** to the side, for example, angled to the side. The amount of thrust provided by these openings **416** may be controlled by louvers **418** that may be opened or closed by a control signal sent to an operator **420** from the vessel.

[0037] **Fig. 5** is a schematic diagram of a drilling location **500** showing the placement of sensors **502** and thrusters **102** that may be used to protect a vessel **104**. Like numbered items are as described with respect to **Fig. 1**. In this example, two sets of thrusters **102** protect the vessel **104**. The first set is mounted to a rail **504** to allow the thrusters **102** to be repositioned as needed, as indicated by an arrow **506**. A second set of thrusters **102** is positioned inside the rail **504**, for example, in an ice drift direction from the vessel **102**. The rail **504** may also decrease the total number of thrusters **102** needed by allowing the thrusters **102** to be moved back and forth across the front of the encroaching ice.

[0038] In this example, an ice sheet **510** is moving in a down drift direction **512** towards the vessel **104**. Further, ice ridges **514** may be embedded within the ice sheet **510**. Three zones can be defined around the vessel **104** to respond to the ice encroachment. In an outer zone defined by a first ring **516**, incoming ice, such as the ice sheet **510** and ice ridges **514**, are detected and tracked to determine the actions that may need to be taken. The outer zone may have a radius of about 10 to 40 kilometers (km) or greater.

[0039] A middle zone can be defined by a second ring **518**, for example, at a radius of about 2 to 10 km. Sensors **502**, such as sonar sensors, may be placed along the second line **518** to determine the approach of ice. Encroaching ice may also be detected by other means, such as satellite imagery, optical sensing, or manual sighting. The middle zone may be used as a management zone to deal with the ice. For example, thrusters **102** mounted along the rail **504** may be moved circumferentially into position to break up the ice sheet **510** into fragments **520** as it crosses the thrusters **102**. The second set of thrusters **102**, mounted inside of the rail **504**, may be used to further break up the ice sheet **510** or to divert at least some of the ice ridges **514**. The second set of thrusters **102** may also be mounted on a rail to make this operation more efficient. An icebreaker **522** may be used to divert ice ridges **514** that are too large to be diverted by the thrusters **102**. The use of the thrusters **102** to break up the majority of the ice sheet **510** may allow the ice breaker **522** to function more efficiently, allowing fewer ice breakers, or even just a single ice breaker **522**, to protect the vessel **104** from most encroaching ice.

[0040] An inner zone can be defined by a third ring **524**. The third ring **524** may be located at about 1 to 2 km from the vessel **104** and may be placed at a distance that gives the vessel **104** sufficient time to secure and detach a drilling riser from a well, or other subsea connections, in order to move away from encroaching ice.

[0041] **Fig. 6** is a process flow diagram of a method **600** for producing hydrocarbons while using thrusters to break up ice before reaching an operational location, such as a drilling location. The method **600** begins at block **602** by positioning a vessel at a location on the sea surface. At block **604**, a thruster attached to a mount is positioned on the seafloor. At block **606,** while hydrocarbons are being produced using the vessel, ice encroaching on the vessel is detected. At block **608**, the thruster is activated to destabilize the water column below the ice.

[0042] **Fig. 7** is a process flow diagram of a method **700** for using thrusters to break up ice before reaching a surface location. The method **700** begins at block **702** by detecting ice that is encroaching on the surface location. At block **704** a thruster attached to a mount on the seafloor is activated to destabilize the water column below the ice.

[0043] While the present techniques may be susceptible to various modifications and alternative forms, the embodiments discussed above have been shown only by way of example. However, it should again be understood that the techniques are not intended to be limited to the particular embodiments disclosed herein. Indeed, the present techniques include all alternatives, modifications, and equivalents falling within the true spirit and scope of the appended claims.

CLAIMS

What is claimed is:

1. A system for protecting a stationary vessel from encroaching ice, comprising:

a subsea mount disposed on a seafloor; and

a thruster disposed on the subsea mount under a water surface, wherein the thruster is configured to destabilize a water column under the encroaching ice.

2. The system of claim 1, comprising a cable from the stationary vessel to the subsea mount, wherein the cable carries power, control signals, or both to the thruster.

3. The system of any of claim 1 or claim 2, comprising a sonar sensor configured to detect encroaching ice.

4. The system of claim 1 or any of claims 2 to 3, wherein the subsea mount comprises a template and one or more pilings.

5. The system of claim 4, wherein the one or more piles comprise a suction pile set into the seafloor.

6. The system of claim 1 or any of claims 2 to 5, wherein the subsea mount comprises a rail to allow the position of the thruster to be changed.

7. The system of claim 1 or any of claims 2 to 6, wherein the thruster pulls water in through the top of the thruster and ejects the water downwards towards the seafloor.

8. The system of claim 1 or any of claims 2 to 7, wherein the thruster pulls water in through the bottom of the thruster and ejects water upwards towards the water surface.

9. The system of claim 1 or any of claims 2 to 8, wherein the thruster comprises one or more side openings configured to move the thruster to the side.

10. The system of claim 1 or any of claims 2 to 7 or 9, wherein the thruster comprises a bottom grate to redirect the water outward from the thruster.

11. The system of claim 1 or any of claims 2 to 7 or 9 to 10, wherein the thruster has one or more buoyancy compartments for adjusting the vertical depth of the thruster.

12. The system of claim 1 or any of claims 2 to 11, comprising a sensor on the thruster configured to detect the approach of an object and instruct the thruster to shut down, lower its depth in the water, or both.

13. The system of claim 1 or any of claims 2 to 12, wherein a plurality of subsea mounts are configured to form multiple rails in arcs.

14. The system of claim 1 or any of claims 2 to 7 or 9 to 13, wherein the thruster is disposed on the subsea mount using a tether which is coiled to allow vertical mobility from the mount.

15. The system of claim 1 or any of claims 2 to 14, comprising a subsea generator to provide power for the thruster.

16. A method for protecting a sea surface location from encroaching ice, comprising:

detecting encroaching ice; and

activating a seafloor mounted thruster, wherein the thruster destabilizes the water column below the ice.

17. The method of claim 16, comprising lowering the thruster to avoid impact with an object.

18. The method of claim 16 or claim 17, comprising moving thrusters to positions calculated to intersect the encroaching ice.

19. The method of claim 16 or either of claims 17 or 18, comprising powering the thrusters from a vessel at the sea surface location.

20. The method of claim 16 or any of claims 17 to 19, wherein destabilizing the

water column below the ice includes pulling water in through the top of the thruster and ejecting the water downwards towards the seafloor.

21. The method of claim 16 or any of claims 17 to 20, wherein destabilizing the water column below the ice includes pulling water in through the bottom of the thruster and ejecting the water upwards towards the water surface.

22. A method for producing hydrocarbons, comprising:

positioning a vessel at a location on a sea surface;

positioning a thruster attached to a mount on a seafloor;

producing hydrocarbons from a well using the vessel;

detecting ice that is encroaching on the vessel; and

activating the thruster to destabilize the water column below the ice.

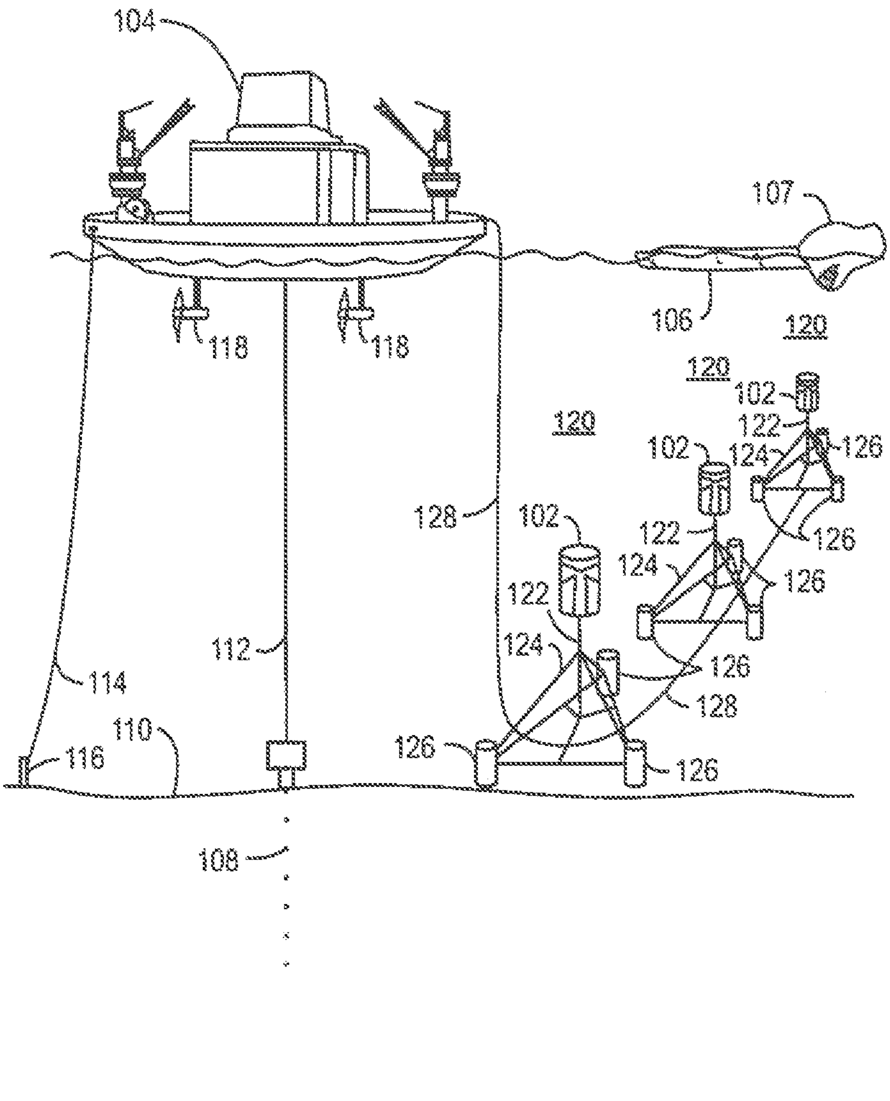
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FIG. 1

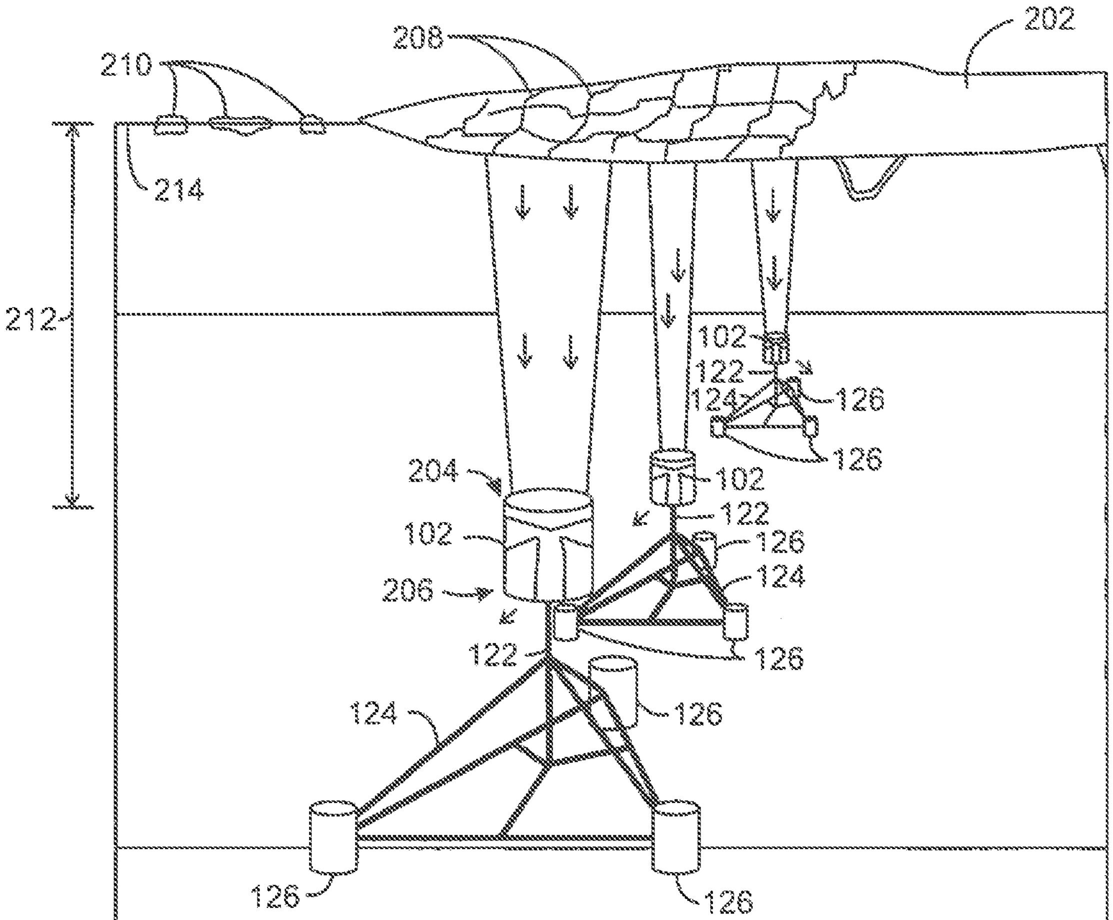

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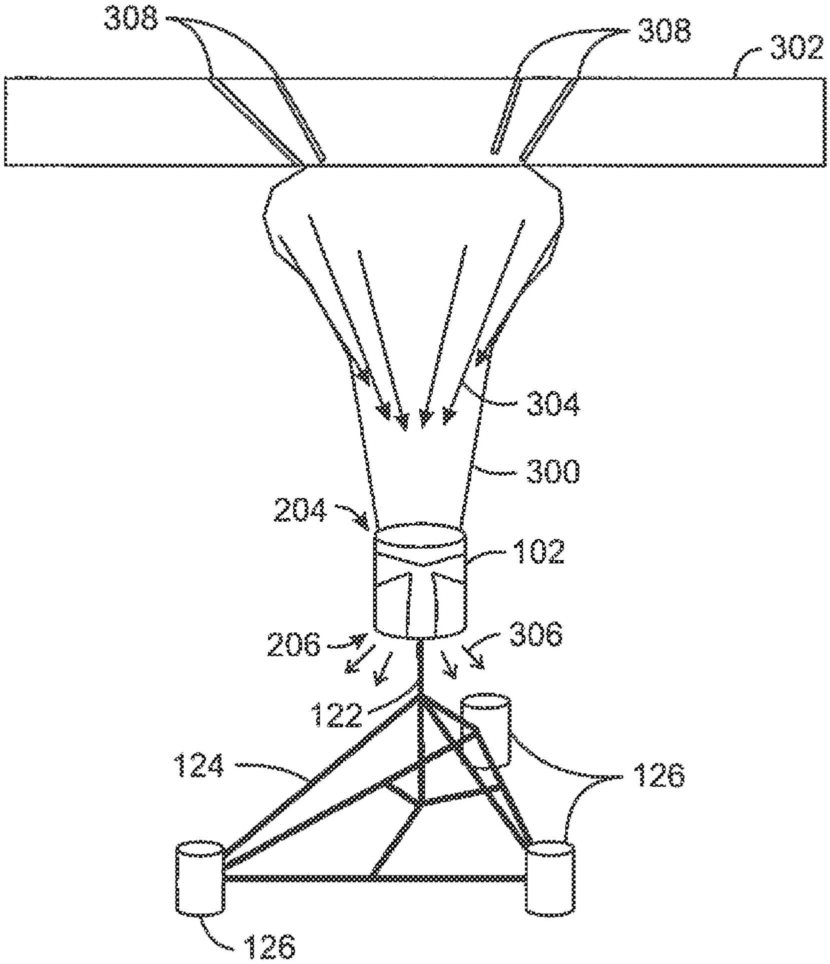
FIG. 2



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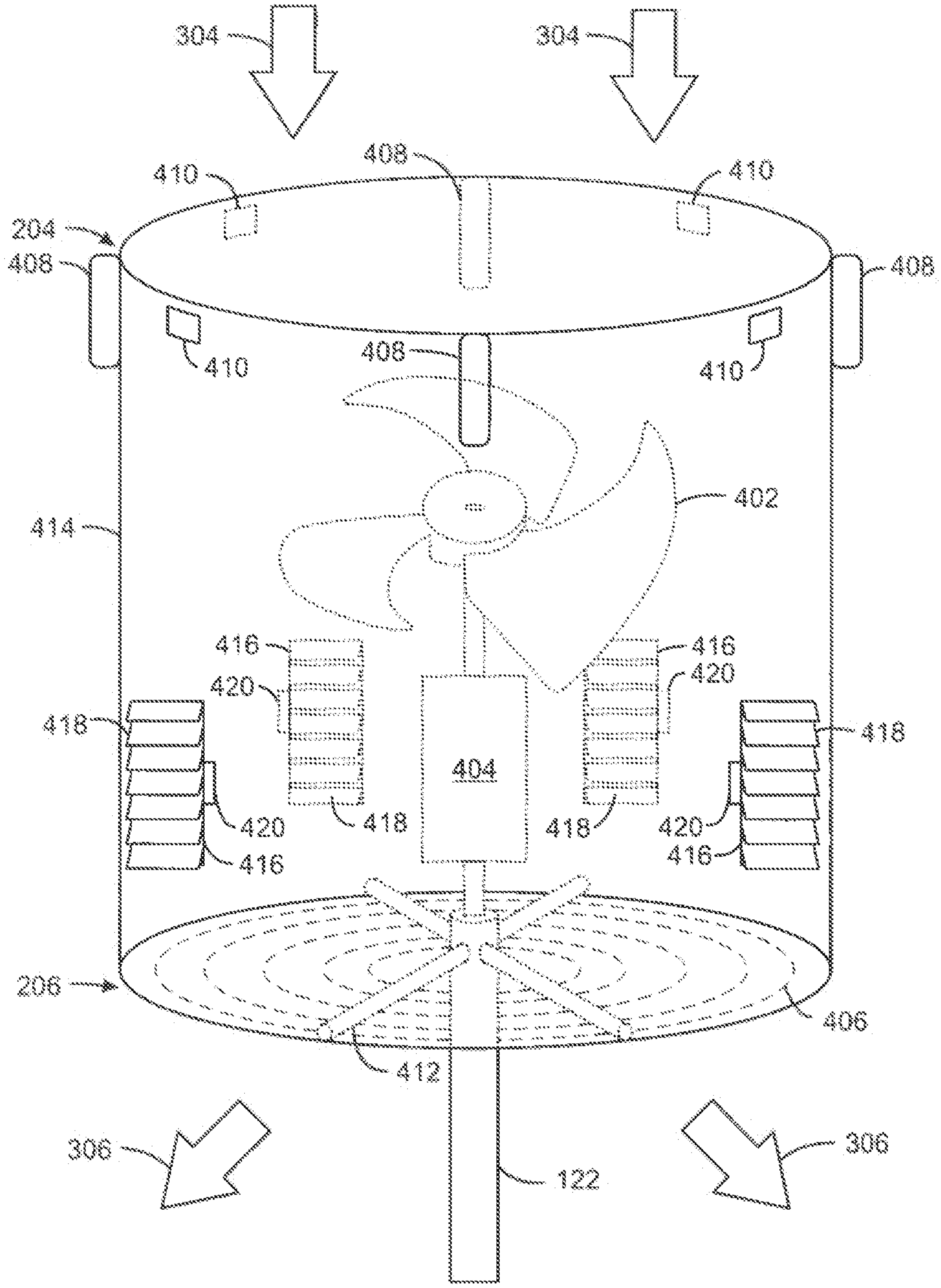
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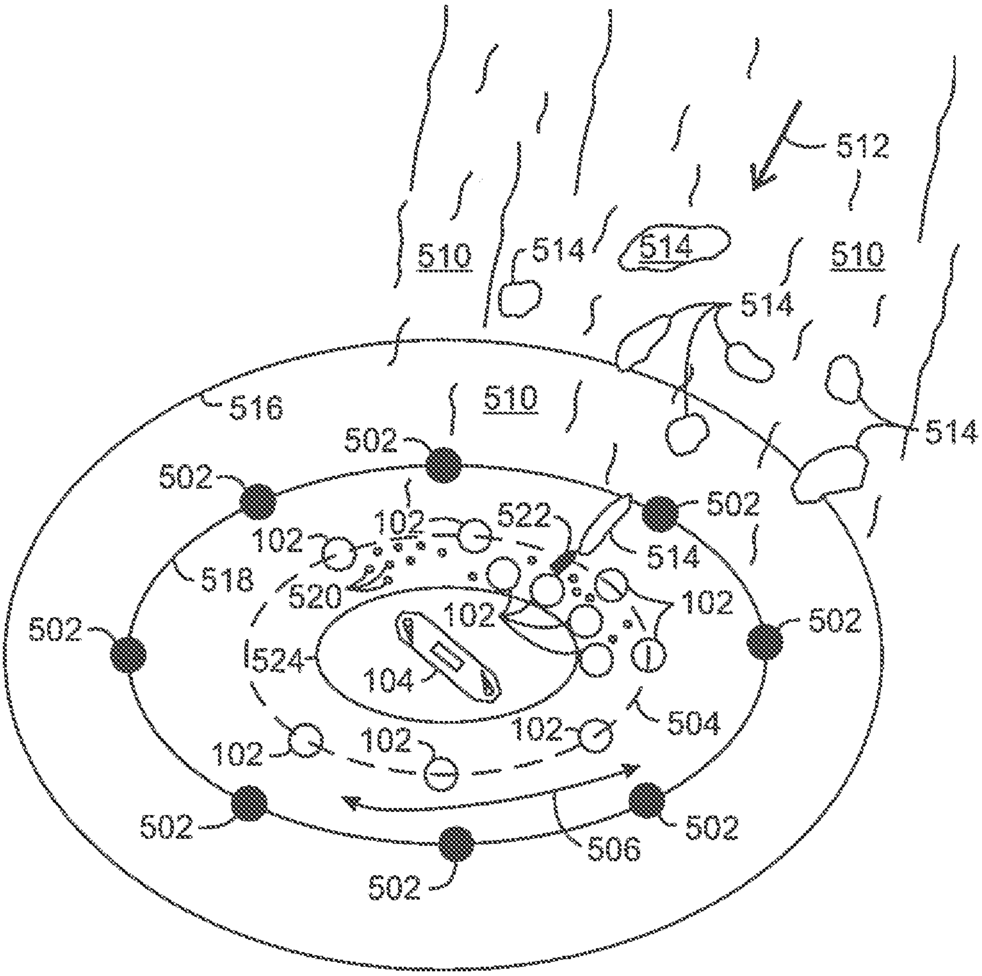
102
FIG. 4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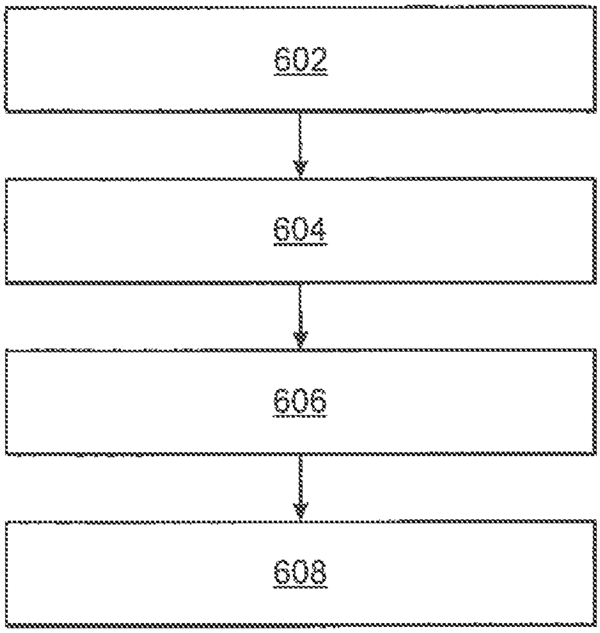
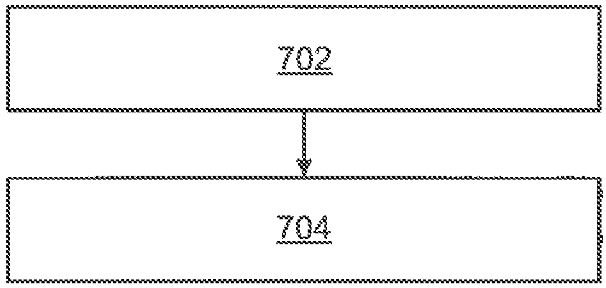
500
FIG. 5



600
FIG. 6



700
FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/054418

A. CLASSIFICATION OF SUBJECT MATTER
INV. B63B35/08 E02B17/00 E02B1/00
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)
E02B B63B

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2 991 622 A (OSTER THOMAS H) 11 July 1961 (1961-07-11) column 1, line 7 - column 3, line 65; figures 1,2	1-22
X	US 6 231 268 B1 (HAUSENBAUER THOMAS CHARLES [US]) 15 May 2001 (2001-05-15) the whole document	1-22
X	US 3 083 538 A (GROSS GEORGE E) 2 April 1963 (1963-04-02) the whole document	1-22
X	US 5 017 093 A (NAES OSCAR L [US]) 21 May 1991 (1991-05-21) the whole document	1-22

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

☒ See patent family annex.

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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
16 February 2016	23/02/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Martínez, Felipe

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2015/054418

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 2991622	A	11-07-1961	NONE	
US 6231268	B1	15-05-2001	NONE	
US 3083538	A	02-04-1963	NONE	
US 5017093	A	21-05-1991	NONE	