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(19) **United States**(12) **Patent Application Publication****Allen et al.**(10) **Pub. No.: US 2012/0006053 A1**(43) **Pub. Date: Jan. 12, 2012**(54) **VORTEX-INDUCED VIBRATION (VIV)
SUPPRESSION OF RISER ARRAYS****Related U.S. Application Data**

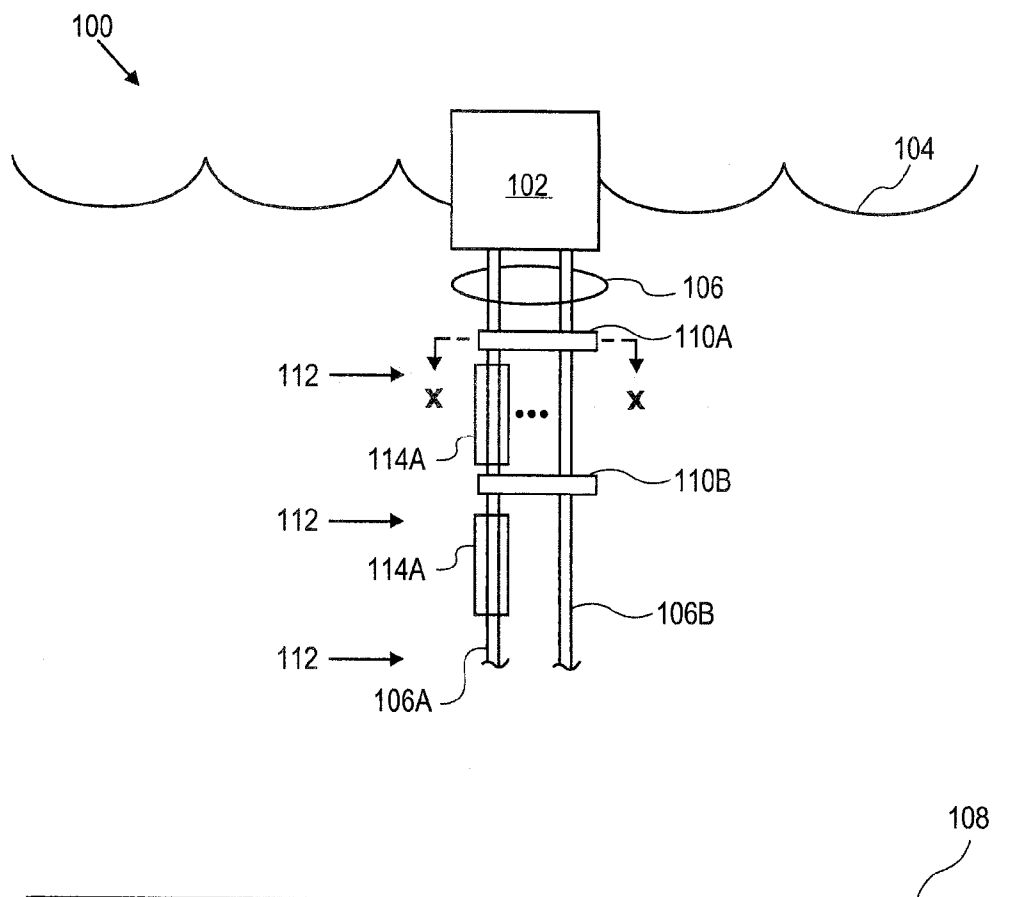
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F25J 1/00 (2006.01)
E02D 5/60 (2006.01)(52) **U.S. Cl.** **62/611; 405/211**(21) Appl. No.: **13/145,349**(22) PCT Filed: **Dec. 17, 2009**(86) PCT No.: **PCT/US2009/068513**

§ 371 (c)(1),

(2), (4) Date: **Sep. 26, 2011**(57) **ABSTRACT**

A system comprising an array of structures in a flowing fluid environment, the array comprising at least 3 structures; and vortex induced vibration suppression devices on at least 2 of the structures.



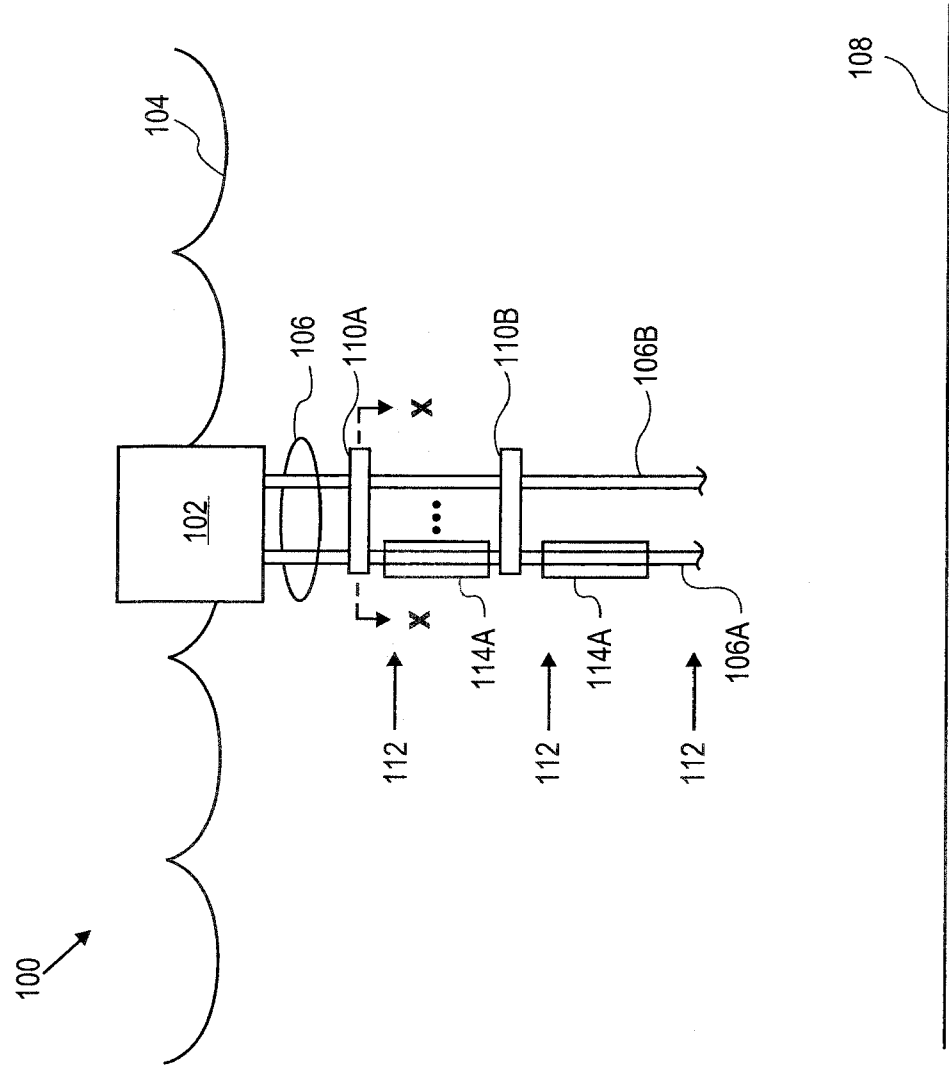


FIG. 1

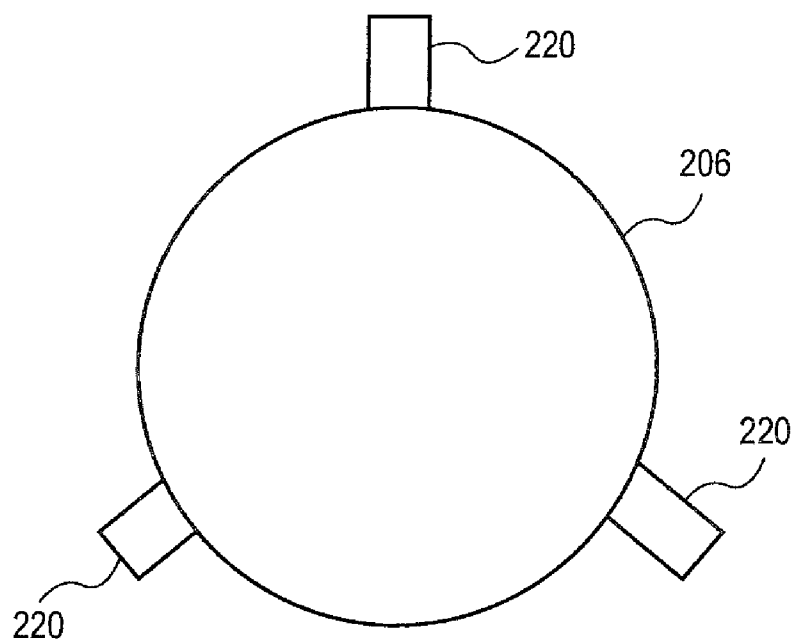


FIG. 2A

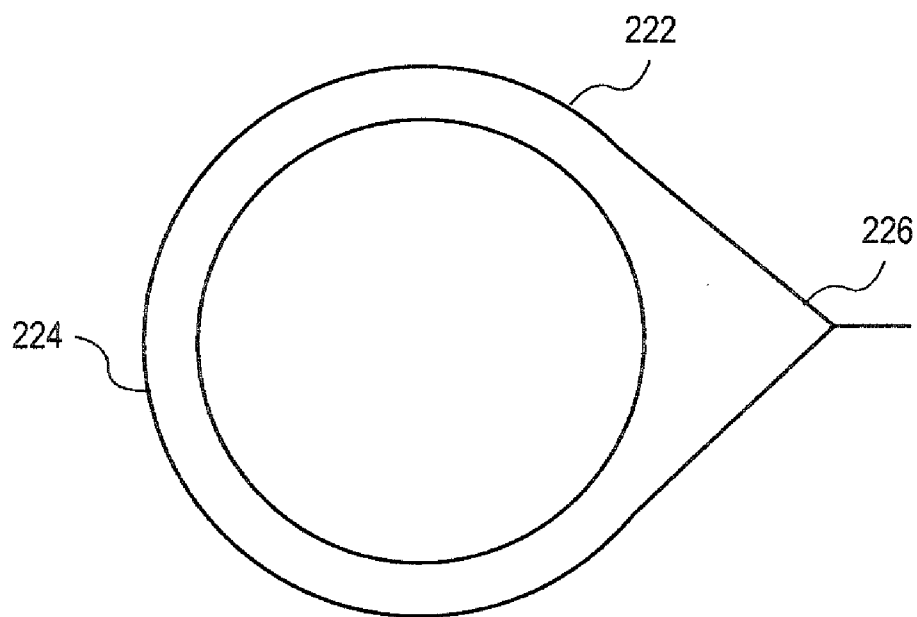


FIG. 2B

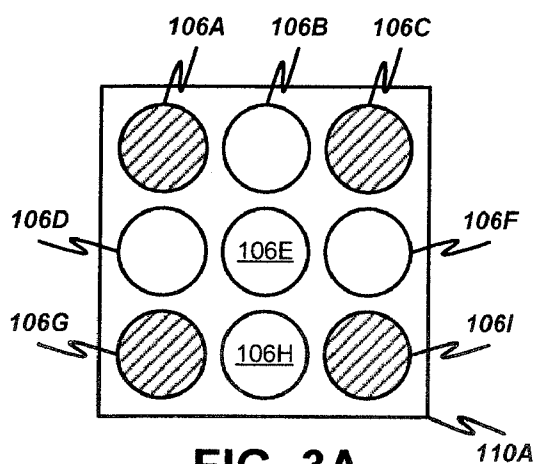


FIG. 3A

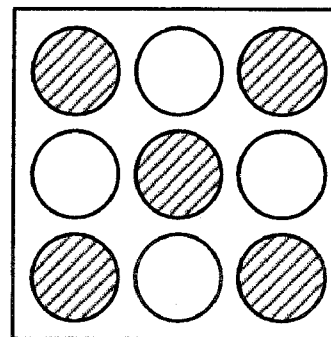


FIG. 3B

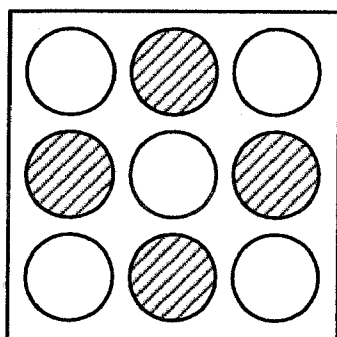


FIG. 3C

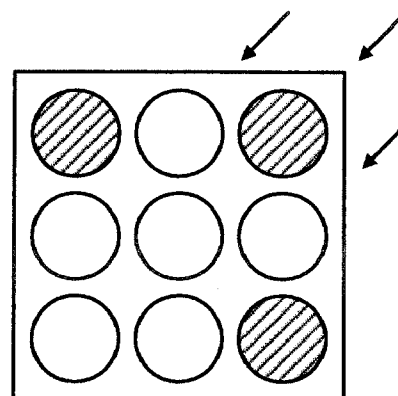


FIG. 3D

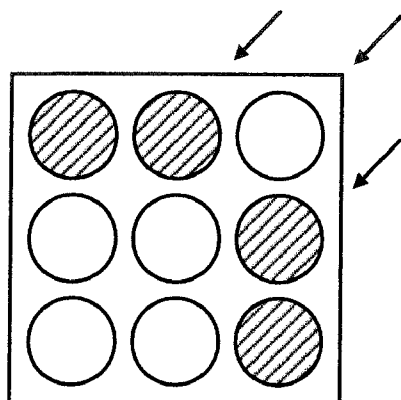


FIG. 3E

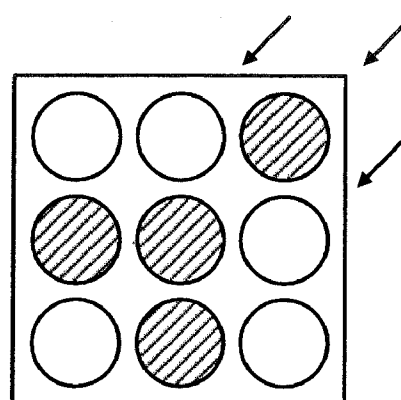


FIG. 3F

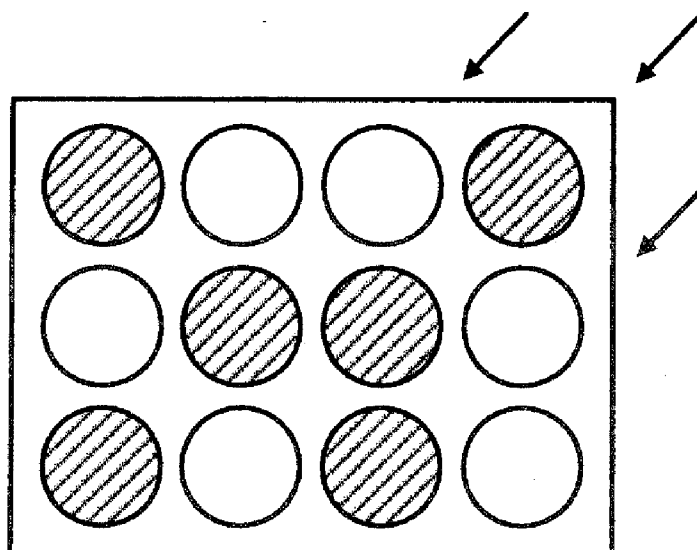


FIG. 3G

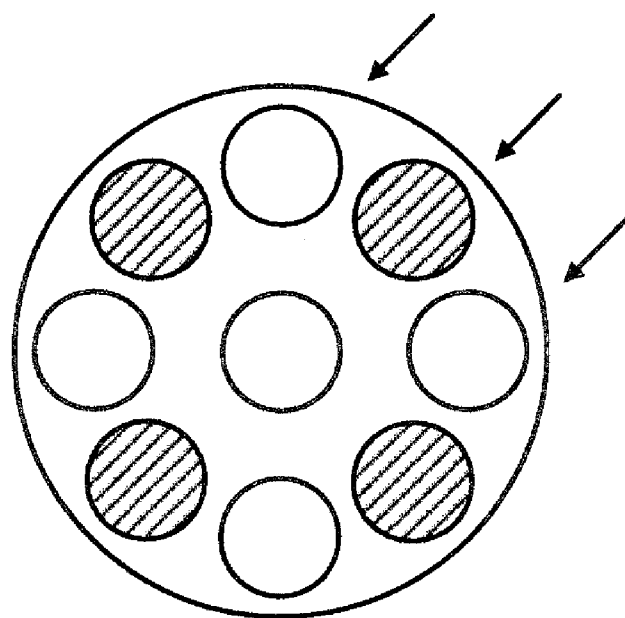


FIG. 3H

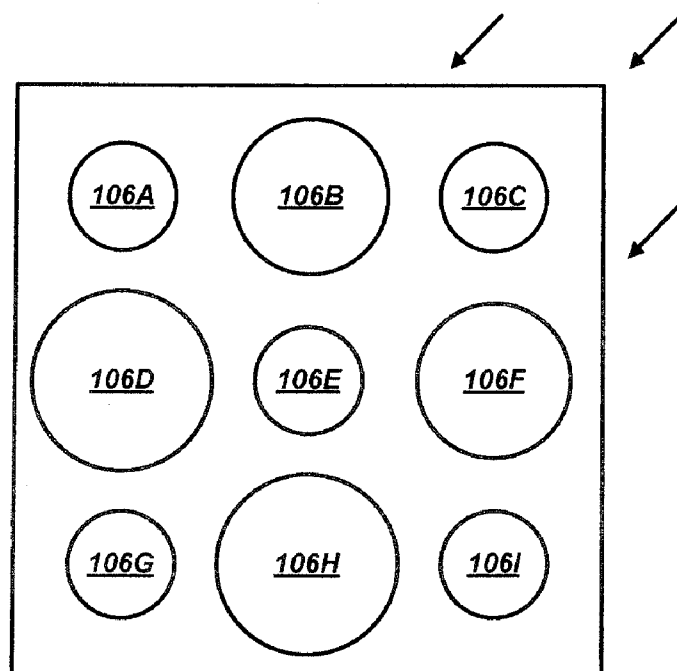


FIG. 4

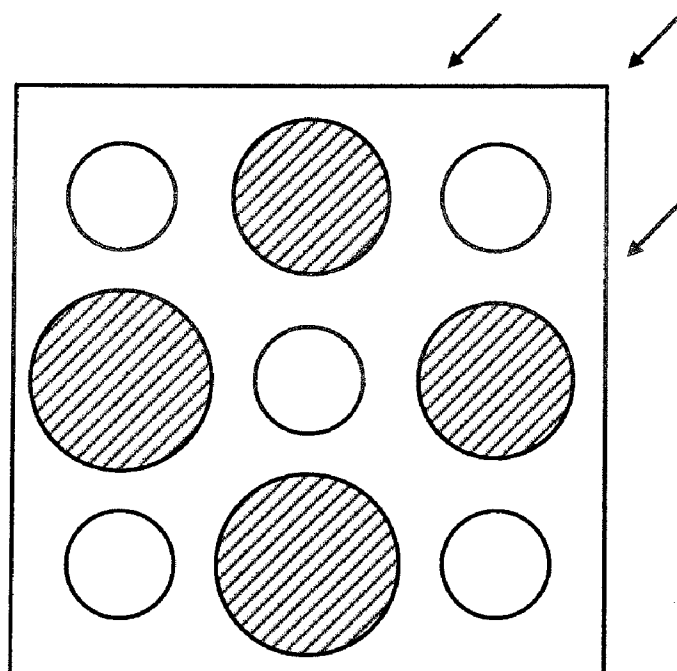


FIG. 5

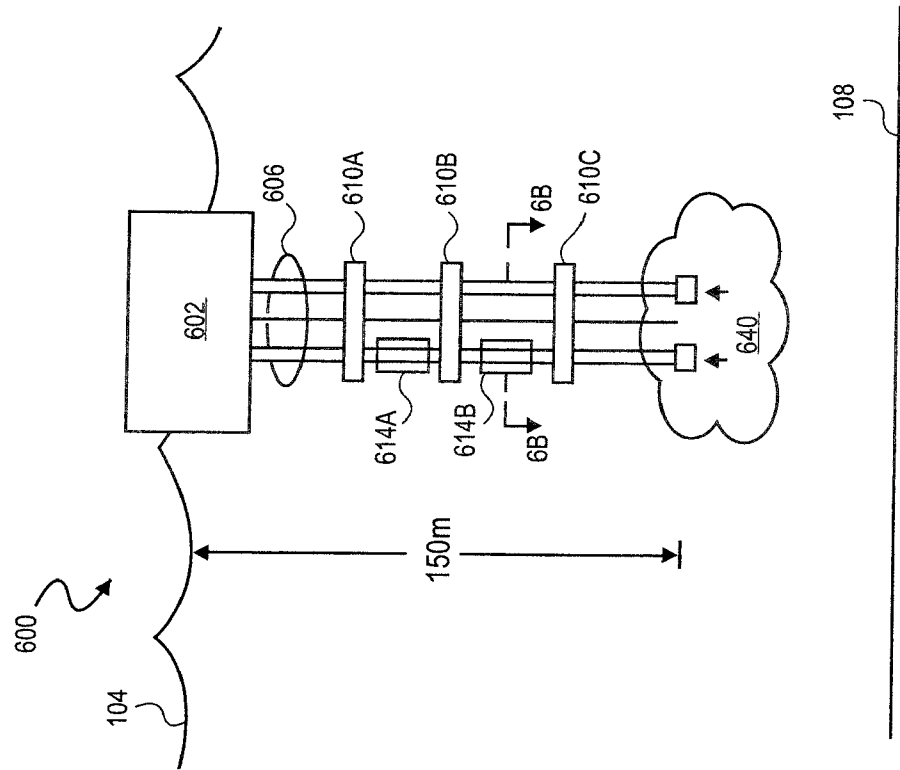


FIG. 6A

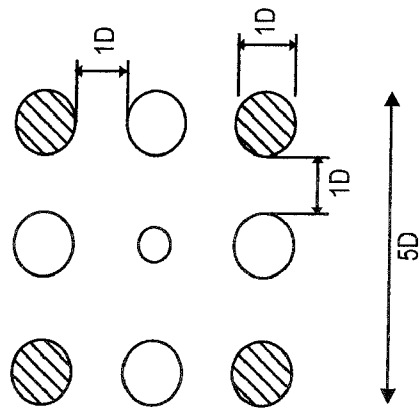


FIG. 6B

VORTEX-INDUCED VIBRATION (VIV) SUPPRESSION OF RISER ARRAYS

FIELD OF THE INVENTION

[0001] The present invention relates to systems and methods for reducing drag and/or vortex-induced vibration ("VIV") of a plurality of structures.

BACKGROUND INFORMATION

[0002] Whenever a bluff body, such as a cylinder, experiences a current in a flowing fluid environment, it is possible for the body to experience vortex-induced vibration (VIV). These vibrations may be caused by oscillating dynamic forces on the surface, which can cause substantial vibrations of the structure, especially if the forcing frequency is at or near a structural natural frequency.

[0003] Floating vessels may be used to liquify and gasify natural gas. Sea water may be used to cool or heat the natural gas. It may be desired to separate the water inlet from the water outlet due to the temperature differences. A plurality of risers may be used to collect or deposit water at a depth from the floating vessel. These risers may be exposed to VIV.

[0004] Drilling for and/or producing hydrocarbons or the like from subterranean deposits which exist under a body of water exposes underwater drilling and production equipment to water currents and the possibility of VIV. Equipment exposed to VIV includes structures ranging from the smaller tubes of a riser system, anchoring tendons, or lateral pipelines to the larger underwater cylinders of the hull of a mini spar or spar floating production system (hereinafter "spar").

[0005] The magnitude of the stresses on the riser pipe, tendons or spars may be generally a function of and increases with the velocity of the water current passing these structures and the length of the structure.

[0006] It is noted that even moderate velocity currents in flowing fluid environments acting on linear structures can cause stresses. Such moderate or higher currents may be readily encountered when drilling for offshore oil and gas at greater depths in the ocean or in an ocean inlet or near a river mouth.

[0007] There are generally two kinds of current-induced stresses in flowing fluid environments. The first kind of stress may be caused by vortex-induced alternating forces that vibrate the structure ("vortex-induced vibrations") in a direction mainly perpendicular to the direction of the current. When fluid flows past the structure, vortices may be alternately shed from each side of the structure. This produces a fluctuating force on the structure transverse to the current. If the frequency of this harmonic load is near one of the natural frequencies of the structure, large vibrations transverse to the current can occur. These vibrations can, depending on the stiffness and the strength of the structure and any welds, lead to unacceptably short fatigue lives. In fact, stresses caused by high current conditions in marine environments have been known to cause structures such as risers to break apart and fall to the ocean floor.

[0008] The second type of stress may be caused by drag forces, which push the structure in the direction of the current due to the structure's resistance to fluid flow. The drag forces may be amplified by vortex-induced vibration of the structure. For instance, a riser pipe that is vibrating due to vortex shedding will generally disrupt the flow of water around it

more than a stationary riser. This may result in more energy transfer from the current to the riser, and hence more drag.

[0009] Many types of devices have been developed to reduce vibrations and/or drag of sub sea structures. Some of these devices used to reduce vibrations caused by vortex shedding from sub sea structures operate by stabilization of the wake. These methods include use of streamlined fairings, wake splitters and flags.

[0010] Devices used to reduce vibrations caused by vortex shedding from sub-sea structures may operate by modifying the boundary layer of the flow around the structure to prevent the correlation of vortex shedding along the length of the structure. Examples of such devices include sleeve-like devices such as helical strakes, shrouds, fairings and substantially cylindrical sleeves.

[0011] Elongated structures in wind or other flowing fluids can also encounter VIV and/or drag, comparable to that encountered in aquatic environments. Likewise, elongated structures with excessive VIV and/or drag forces that extend far above the ground can be difficult, expensive and dangerous to reach by human workers to install VIV and/or drag reduction devices.

[0012] Fairings may be used to suppress VIV and reduce drag acting on a structure in a flowing fluid environment. Fairings may be defined by a chord to length ratio, where longer fairings have a higher ratio than shorter fairings. Long fairings are more effective than short fairings at resisting drag, but may be subject to instabilities. Short fairings are less subject to instabilities, but may have higher drag in a flowing fluid environment.

[0013] U.S. Pat. No. 6,223,672 discloses an ultrashort fairing for suppressing vortex-induced vibration in substantially cylindrical marine elements. The ultrashort fairing has a leading edge substantially defined by the circular profile of the marine element for a distance following at least about 270 degrees thereabout and a pair of shaped sides departing from the circular profile of the marine riser and converging at a trailing edge. The ultrashort fairing has dimensions of thickness and chord length such that the chord to thickness ratio is between about 1.20 and 1.10. U.S. Pat. No. 6,223,672 is herein incorporated by reference in its entirety.

[0014] U.S. Pat. No. 3,978,804 discloses a structure floating on a body of water, and particularly a structure for drilling or producing wells from below the water. Buoyant members support at least a part of the structure above the surface of the water. The structure is connected to anchors in the floor of the body of water by a series of parallel leg members. Each leg member is composed of a plurality of elongated members, such as large diameter pipe usually called risers. These risers are parallel. Vertically spaced spacers are provided along the risers of each leg to (1) maintain the risers a fixed distance apart and (2) change the natural or resonant frequency of the individual riser pipes to be greater than the flutter frequency caused by the motion of the water past the risers. U.S. Pat. No. 3,978,804 is herein incorporated by reference in its entirety.

[0015] U.S. Pat. No. 6,089,022 discloses a system and a method for regasifying LNG aboard a carrier vessel before the re-vaporized natural gas is transferred to shore. The pressure of the LNG is boosted substantially while the LNG is in its liquid phase and before it is flowed through a vaporizer(s) which, in turn, is positioned aboard the vessel. Seawater taken from the body of water surrounding said vessel is flowed through the vaporizer to heat and vaporize the LNG back into natural gas before the natural gas is off-loaded to onshore

facilities. U.S. Pat. No. 6,089,022 is herein incorporated by reference in its entirety. U.S. Pat. No. 6,832,875 discloses a floating plant for liquefying natural gas having a barge provided with a liquefaction plant, member for receiving natural gas and with member for storing and discharging liquefied natural gas. The liquefaction plant involves a heat exchange in which heat is removed when liquefying natural gas is transferred to water. The barge is further provided with a receptacle; an open-ended water intake conduit having an inlet; a connecting conduit extending from the outlet of the water intake conduit to the receptacle; a pump for transporting water from the receptacle to the heat exchanger and a water discharge system for discharging water removed from the heat exchanger. The connecting conduit has the shape of an inverted "U" of which the top is located above the receptacle. U.S. Pat. No. 6,832,875 is herein incorporated by reference in its entirety.

[0016] There are needs in the art for one or more of the following: apparatus and methods for reducing VIV and/or drag on structures in flowing fluid environments, which do not suffer from certain disadvantages of the prior art apparatus and methods; apparatus and methods for reducing VIV and/or drag on multiple structures in flowing fluid environments; apparatus and methods for reducing VIV and/or drag on a riser array or bundle.

[0017] These and other needs in the art will become apparent to those of skill in the art upon review of this specification, including its drawings and claims.

SUMMARY OF THE INVENTION

[0018] One aspect of the invention provides a system comprising an array of structures in a flowing fluid environment, the array comprising at least 3 structures; and vortex induced vibration suppression devices on at least 2 of the structures.

[0019] Another aspect of the invention provides a method of suppressing the vortex induced vibration of an array of structures comprising installing vortex induced vibration suppression devices on from 10% to 90% of the structures.

[0020] Advantages of the invention may include one or more of the following: improved VIV reduction of a plurality of structures; improved drag reduction of a plurality of structures; lower cost VIV reduction; and/or VIV reduction of a plurality of structures with fewer VIV suppression devices.

[0021] These and other aspects of the invention will become apparent to those of skill in the art upon review of this specification, including its drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The invention may best be understood by referring to the following description and accompanying drawings that are used to illustrate embodiments of the invention. In the drawings:

[0023] FIG. 1 illustrates an example of a marine system in which embodiments may be implemented.

[0024] FIG. 2A is a cross-sectional top view illustrating one or more representative strakes installed along a length of tubular structure as VIV suppression device(s).

[0025] FIG. 2B is a cross-sectional top view illustrating a representative fairing installed along a length of tubular structure as a VIV suppression device.

[0026] FIGS. 3A-3H illustrate several different exemplary approaches or configurations for coupling VIV suppression devices with only a subset of tubular structures, according to various embodiments.

[0027] FIG. 4 illustrates an exemplary approach or configuration of a plurality of tubular structures in which at least two, in this case at least three, of the tubular structures have different outer diameters, according to one or more embodiments.

[0028] FIG. 5 illustrates an example approach or configuration that is similar to that of FIG. 4 except that, in addition to the different outer diameters, a subset of the tubular structures also have VIV suppression devices coupled therewith, according to one or more embodiments.

[0029] FIG. 6A illustrates an example of a marine system including a Floating Liquefied Natural Gas (FLNG) plant, in which embodiments may be implemented.

[0030] FIG. 6B shows an example approach or configuration for a Floating Liquefied Natural Gas (FLNG) plant in which nine tubular structures are arranged in a three-by-three rectangular array, according to one particular embodiment.

DETAILED DESCRIPTION OF THE DRAWINGS

[0031] In the following description, numerous specific details are set forth. However, it is understood that embodiments may be practiced without these specific details. In other instances, well-known structures and techniques have not been shown in detail in order not to obscure the understanding of this description.

[0032] FIG. 1:

[0033] FIG. 1 illustrates an example of a marine system 100 in which embodiments may be implemented.

[0034] The marine system includes surface structure 102 near a water surface 104, for example a surface of the ocean. By way of example, the surface structure may include a ship, a barge, a vessel, an FPSO (floating production storage and offloading), a TLP (tension leg platform), a spar, an offshore rig, an offshore platform, a floating plant, a floating liquefied natural gas plant, or other floating or surface structures as are known in the art.

[0035] A plurality of tubular structures 106 are coupled with the surface structure. In one particular aspect, the tubular structures may be used in conjunction with providing cold water at depth to cool natural gas in a floating liquefied natural gas plant serving as the surface structure. By way of example, the tubular structures may be connected to a marine riser tensioner, a swivel joint, a ball joint, or the like. In one embodiment, a tubular structure has a circular or oval cross-section. In another embodiment, a cross-section of a tubular structure need not be circular or oval, but can include other shapes such as, but not limited to, rectangular.

[0036] In the illustration of FIG. 1, two tubular structures 106A, 106B are visible. More tubular structures may optionally be included, such as, for example, at least three, at least four, at least six, at least nine, or more. Examples of suitable tubular structures include, but are not limited to, cables, umbilicals, risers, marine risers, riser pipes, marine pipes, pipes, tubes, or the like, or combinations thereof. The structures may extend all the way to a seafloor 108, or only part way to the seafloor. In some cases, mud, crude, water, and/or other fluids or electricity or electrical signals may be conveyed through the structures.

[0037] The tubular structures are physically connected together, or held in a position relative to one another, with one

or more interconnected guide sleeves or other spacers **110A**, **110B**. The spacers connect or hold in position the tubular structures as an array, bundle, grouping, other ordered arrangement, or other joined plurality. By way of example, the spacers may include a metal, plastic, or otherwise sufficiently strong material in a disc, plate, rectangle, interconnected polygonal bars, wheel and spoke shape, or other shape. The spacers may have holes or other openings therein. Each of the holes or openings may accommodate and have inserted therein one of the tubular structures. The spacers may help to keep the tubulars relatively close together, but separated so that they do not significantly strike into one another or otherwise damage one another. One or more of the tubular structures may serve as a structural support for the spacers. A tubular structure serving as a structural support for a spacer may be connected (directly or indirectly) to the spacer. For other tubular structures in an array or grouping, such tubular structures need not be connected to a spacer and in the case of a tubular structure having, for example, a circular or oval shape, may instead have an outer (outside) diameter (including or not including a VIV suppression device) less than a diameter of an opening in the spacer. Alternatively, the outer (outside) diameter of the tubular structure (including or not including a VIV suppression device) may be similar to a diameter of an opening so that the tubular structure or a VIV suppression device on a tubular structure and the spacer may be in contact (e.g., a force fit).

[0038] It is not uncommon that the tubular structures will be disposed in water having current **112**. Current **112** may tend to cause hydrodynamic drag and/or vortex-induced vibration (VIV) of the tubular structures. Further, in an array of tubular structures coupled or positioned together with a spacer (e.g., spacer **110A**), VIV directly induced by current **112** on one tubular structure of the array may be imparted to other tubular structures of the array. Such VIV is generally undesirable, and if not suppressed, may result in damage, fatigue, or even premature failure of the tubular structures. Accordingly, it is generally desirable to reduce the VIV of the tubular structures.

[0039] In some embodiments, VIV suppression devices may be used to help suppress the VIV. Examples of VIV suppression devices or structures suitable for implementing embodiments include, but are not limited to, strakes, fairings, Henning devices, shrouds, wake splitters, and other types of VIV suppression devices or structures.

[0040] Suitable VIV suppression devices are disclosed in U.S. patent application Ser. No. 10/839,781, having attorney docket number TH1433; U.S. patent application Ser. No. 11/400,365, having attorney docket number TH0541; U.S. patent application Ser. No. 11/419,964, having attorney docket number TH2508; U.S. patent application Ser. No. 11/420,838, having attorney docket number TH2876; U.S. Patent Application No. 60/781,846 having attorney docket number TH2969; U.S. Patent Application No. 60/805,136, having attorney docket number TH1500; U.S. Patent Application No. 60/866,968, having attorney docket number TH3112; U.S. Patent Application No. 60/866,972, having attorney docket number TH3190; U.S. Pat. No. 5,410,979; U.S. Pat. No. 5,410,979; U.S. Pat. No. 5,421,413; U.S. Pat. No. 6,179,524; U.S. Pat. No. 6,223,672; U.S. Pat. No. 6,561,734; U.S. Pat. No. 6,565,287; U.S. Pat. No. 6,571,878; U.S. Pat. No. 6,685,394; U.S. Pat. No. 6,702,026; U.S. Pat. No. 7,017,666; and U.S. Pat. No. 7,070,361, which are herein incorporated by reference in their entirety.

[0041] Suitable methods for installing VIV suppression devices are disclosed in U.S. patent application Ser. No. 10/784,536, having attorney docket number TH1853.04; U.S. patent application Ser. No. 10/848,547, having attorney docket number TH2463; U.S. patent application Ser. No. 11/596,437, having attorney docket number TH2900; U.S. patent application Ser. No. 11/468,690, having attorney docket number TH2926; U.S. patent application Ser. No. 11/612,203, having attorney docket number TH2875; U.S. Patent Application No. 60/806,882, having attorney docket number TH2879; U.S. Patent Application No. 60/826,553, having attorney docket number TH2842; U.S. Pat. No. 6,695,539; U.S. Pat. No. 6,928,709; and U.S. Pat. No. 6,994,492; which are herein incorporated by reference in their entirety.

[0042] The VIV suppression devices may be installed on the tubular member (e.g. buoyancy material and riser) before or after the tubular member is placed in a body of water.

[0043] The VIV suppression devices may have a clamshell configuration, and may be hinged with a closing mechanism opposite the hinge, for example a mechanism that can be operated with an ROV.

[0044] VIV suppression devices may be provided with copper plates on their ends to allow them to weathervane with adjacent VIV suppression devices or collars. VIV suppression devices may be partially manufactured from copper.

[0045] FIGS. 2A-2B:

[0046] FIGS. 2A-2B show two common types of VIV suppression devices or structures. Each of these devices or structures is suitable for implementing one or more embodiments.

[0047] FIG. 2A is a cross-sectional top view illustrating one or more representative strakes **220** installed along a length of tubular structure **206** as VIV suppression device(s). The strake(s) may be helical strakes, which are helically wrapped or coiled around the tubular structure and may be described as connected thereto.

[0048] FIG. 2B is a cross-sectional top view illustrating a representative fairing **222** installed along a length of tubular structure **206** as a VIV suppression device and may be described as connected thereto. The fairing has nose **224** and tail **226**. The fairing may swivel around the tubular structure based on the ocean current.

[0049] Referring again to FIG. 1, the leftmost tubular structure **106A** has one or more VIV suppression devices or structures **114A**, **114B** connected thereto therewith. Conventional collars (not shown) may be used to keep the VIV suppression devices from moving along the length of the tubular structures. The rightmost tubular structure **106B** does not have any VIV suppression devices or structures coupled therewith.

[0050] In accordance with some embodiments, either all or only a subset of the plurality of risers or other tubular structures may have VIV suppression devices connected thereto. In these later embodiments, one or more other tubular structures of the plurality may not have VIV suppression devices connected thereto.

[0051] Omitting the VIV suppression devices from some of the tubular structures (so that only a subset of the tubular structures have the VIV suppression devices) may offer certain potential advantages. For one thing, providing the VIV suppression devices on all of the tubular structures tends to increase the overall equipment cost. For another thing, it tends to be more difficult, time consuming, and/or more expensive to install tubular structures with VIV suppression devices as compared to tubular structures without VIV suppression devices. The VIV suppression devices may tend to

make the tubular structures more bulky, difficult to maneuver, difficult to align, and/or difficult to couple with the spacers. It likewise tends to be more difficult, time consuming, and/or more expensive to retrieve tubular structures with VIV suppression devices, such as, for example, for cleaning, inspection, and/or repair.

[0052] Typically from about 20 percent to about 80 percent of the tubular structures may have the VIV suppression devices coupled with them. Often, from about 30 percent to about 70 percent of the tubular structures may have the VIV suppression devices coupled with them. In some cases, from about 40 percent to 60 percent of the tubular structures may have the VIV suppression devices coupled with them.

[0053] It is not required that a tubular structure have VIV suppression devices along its entire length. In other words, the coverage density (the length of the structure covered with VIV suppression devices compared to the total length) may be less than 1. The coverage density may also be expressed as a percentage of the tubular structure length, and may be less than 100 percent. Typically, the coverage density may range from about 50 percent to about 100 percent, for example from about 60 to about 90%. The number or percentage of tubular structures having VIV suppression devices may be decreased by increasing the coverage density of a selection of the tubular structures. In converse, if desired, the coverage density may be decreased by increasing the number or percentage of tubular structures having VIV suppression devices.

[0054] FIGS. 3A-3H:

[0055] FIGS. 3A-3H illustrate several different example approaches or configurations of VIV suppression devices connected with a subset of tubular structures of an array, bundle, group, or other plurality of tubular structures, according to various embodiments. These figures represent cross-sectional views taken along section line 3/4/5 of FIG. 1 through spacer 110A and the plurality of tubular structures 106. The spacers couple the tubular structures together, or hold the tubular structures in position relative to one another, as arrays, bundles, groups, other ordered arrangements, or other coupled pluralities.

[0056] In these illustrations, circles indicate tubular structures. It is to be appreciated that a tubular structure need not occupy an entire cross-sectional area of an opening in spacer 110A. Hatched circles indicate tubular structures that have VIV suppression devices coupled therewith. Un-hatched circles indicate tubular structures without VIV suppression devices. While FIGS. 3A-3H show different examples of VIV suppression devices connected with a subset of tubular structures of an array (e.g., less than all tubular structures), in another embodiment, VIV suppression devices may be connected to each of the tubular structures in the array. Any of the aforementioned VIV suppression devices are suitable.

[0057] FIGS. 3A-3F illustrate approaches or configurations for nine tubular structures arranged in a three-by-three rectangular array, in this particular case a substantially square array.

[0058] FIGS. 3A illustrates a first configuration in which only tubular structures at all four corner positions of the three-by-three rectangular array have VIV suppression devices connected thereto, according to one embodiment.

[0059] The three-by-three rectangular array has tubular structures at four corner positions 106A, 106C, 106G, and 106I, respectively. These corner positions are referred to herein as upper left corner 106A, upper right corner 106C, lower left corner 106G, and lower right corner 106I. The array

also has tubular structures at four central side positions 106B, 106D, 106F, and 106H, respectively. These central side positions are referred to herein as upper side 106B, lower side 106H, right side 106F, and left side 106D, respectively. The corner positions and the side positions in combination form a periphery of the array. The three-by-three rectangular array also has one tubular structure at a center position 106E.

[0060] The four tubular structures at the four corner positions are the only tubular structures that have VIV suppression devices connected thereto. These four tubular structures help to suppress VIV for the entire array. Advantageously, this arrangement is robust and does not show very much sensitivity to the angle of an oncoming ocean current.

[0061] In addition to suppressing VIV, the vortex shedding frequency for the tubular structures with the VIV suppression devices are often lower than that of the tubular structure without the VIV suppression devices. In other words, the VIV suppression devices may tend to help “detune” or reduce the excitation frequency of the VIV of the tubular structures relative to bare tubular structures. This may increase the ‘frequency dissociation’ of the array. These tubular structures with different frequencies will be less likely to couple their vibrations. As a result, vibration of the array may be reduced.

[0062] The tubular structures that have the VIV suppression devices are substantially interspersed, interleaved, or otherwise staggered with other tubular structures that do not have VIV suppression devices coupled with them. On the periphery of the array only every other tubular structure has a VIV suppression device connected thereto. In such a staggered arrangement, adjacent tubular structures tend to have different excitation frequencies. As discussed, with such frequency dissociation the vibrations on these tubular structures are less likely to couple and the overall vibration of the array may be reduced.

[0063] In this configuration four out of nine or about 44 percent of the tubular structures include VIV suppression devices connected thereto. On the periphery, four out of eight or a higher percentage of 50 percent of the tubular structures have VIV suppression devices connected thereto.

[0064] FIGS. 3B illustrates a second configuration in which only a tubular structure at a center position and tubular structures at all four corner positions of the array have VIV suppression devices connected thereto, according to one embodiment. This configuration is similar to the configuration of FIG. 3A except that the tubular structure at the center position also has VIV suppression devices connected thereto.

[0065] As before, in this configuration, tubular structures with VIV suppression devices are substantially staggered with tubular structures without VIV suppression devices. As before, on a periphery, only every other tubular structure has VIV suppression devices. Such staggering may tend to increase the amount of frequency dissociation, which may also help to reduce damage due to VIV.

[0066] In this configuration five out of nine, or about 55 percent of the tubular structures, have VIV suppression devices connected thereto. On the periphery, four out of eight, or a higher percentage of 50 percent of the tubular structures, have VIV suppression devices connected thereto.

[0067] FIGS. 3C illustrates a third configuration in which only tubular structures at four central side positions of the array have VIV suppression devices connected thereto, according to one example embodiment. This configuration is substantially opposite to the configuration of FIG. 3A in that

tubular structures at the sides positions instead of at the corner positions have VIV suppression devices.

[0068] As before, in this configuration, tubular structures with VIV suppression devices are substantially staggered with tubular structures without VIV suppression devices. As before, on a periphery, only every other tubular structure has VIV suppression devices. Such staggering may tend to increase the amount of frequency dissociation, which may also help to reduce damage due to VIV.

[0069] In this configuration four out of nine, or about 44 percent of the tubular structures, have VIV suppression devices connected thereto. On the periphery, four out of eight, or a higher percentage of 50 percent of the tubular structures, have VIV suppression devices connected thereto.

[0070] Sufficient suppression or dampening may be achieved with even lower numbers or percentages of tubular structures having VIV suppression devices when a predominant ocean, river, or other flowing fluid current is known. In particular, in one or more embodiments, the array may be aligned so that a higher percentage of the tubular structures having the VIV suppression devices are on a front row that faces the predominant ocean current.

[0071] FIGS. 3D illustrates a fourth configuration in which only tubular structures at three corner positions of a front row of the array that would first experience a predominant ocean current have VIV suppression devices connected thereto, according to one example embodiment. This configuration is similar to the configuration of FIG. 3A except that the tubular structure at the lower left corner position does not have VIV suppression devices.

[0072] Arrows are used to indicate a predominant ocean current. As used herein, a 'predominant' ocean current is the average or most common ocean current including its average or most common direction.

[0073] Five tubular structures on the top and right sides of the array constitute a front row. This front row first experiences the predominant ocean current.

[0074] In this configuration three out of nine, or about 33 percent of the tubular structures, include VIV suppression devices coupled therewith. On the periphery, three out of eight, or a higher percentage of about 37 percent of the tubular structures, include VIV suppression devices. On the front row, three out of five, or an even higher percentage of about 60 percent of the tubular structures, have VIV suppression devices.

[0075] Notice that a higher percentage of the front row tubular structures have VIV suppression devices than the rest of the non-front row tubular structures. It is these tubular structures that would first experience the predominant ocean current, and that would tend to experience the ocean current at its highest velocity. These higher velocities would tend to make these tubular structures have the most severe VIV. However, using the VIV suppression devices on a higher percentage of these front row tubular structures tends to suppress a large part of the VIV. Additionally, staggering has been used along the front row. This helps to increase the amount of frequency dissociation.

[0076] Moreover, the array is aligned so that the tubular structure at the upper right corner position first experiences the predominant ocean current before all other tubular structures. This tubular structure would tend to experience the ocean current at its highest velocity and would tend to have a

relatively large amount of VIV. However, advantageously, this tubular structure has one or more VIV suppression devices.

[0077] Notice also that this alignment places more of the tubular structures immediately downstream from or immediately in the wakes of other upstream or front row tubular structures. A wake refers to a region of separated flow, in some cases turbulent, downstream of a solid body caused by flow of the fluid around the body. Average fluid velocity tends to be lower in a wake. As a result, these downstream tubular structures tend to experience lesser velocity ocean currents and tend to have less VIV. In addition, tubular structures in the wake of other tubular structures, and experiencing a lower velocity current, tend to have a lower vortex shedding frequencies and/or excitation frequencies. This adds frequency dissociation to the array, which helps to reduce vibrations.

[0078] As compared to FIG. 3A, the tubular structure at the lower left corner position does not have one or more VIV suppression devices. This tubular structure is downstream from several upstream tubular structures and should tend to experience the ocean current at a relatively reduced velocity. This makes it a relatively good candidate to omit VIV suppression device(s). Accordingly, in one or more embodiments, a tubular structure that would last experience a predominant ocean current, after all other tubular structures of the array, may not have one or more VIV suppression device(s).

[0079] Arrangements or configurations that have an even stronger amount of suppression on the front row are contemplated. FIGS. 3E illustrates a fifth configuration in which four tubular structures at positions on a front row of the array that would first experience a predominant ocean current have VIV suppression devices connected thereto, according to one example embodiment.

[0080] As before, arrows are used to indicate a predominant ocean current. The array is aligned so that the tubular structure at the upper right corner position first experiences the predominant ocean current. This alignment places more of the tubular structures in the wakes of upstream tubular structures.

[0081] Five tubular structures on the top and right sides of the array constitute a front row that first experiences the predominant ocean current. In this embodiment, all four of the tubular structures with VIV suppression devices are on the front row.

[0082] In this configuration four out of nine, or about 44 percent of the tubular structures, have VIV suppression devices. On the periphery, four out of eight, or a higher percentage of 50 percent of the tubular structures, have VIV suppression devices. On the front row, four out of five, or an even higher percentage of 80 percent of the tubular structures, have VIV suppression devices. Accordingly, in this arrangement or configuration, an even higher percentage of the front row tubular structures have VIV suppression devices than the rest of the non-front row tubular structures.

[0083] FIGS. 3F illustrates a fifth configuration in which only one tubular structure on a front row of the array and three tubular structures at positions downstream from the front row have VIV suppression devices connected thereto, according to one example embodiment. This design relies more upon frequency dissociation than upon strong suppression on the front row.

[0084] Arrows indicate a predominant ocean current. Five tubular structures on the top and right sides of the array

constitute a front row that first experiences the predominant ocean current. In this case, only one tubular structure with VIV suppression devices is on the front row.

[0085] The array is aligned so a tubular structure at the upper right corner position, which first experiences the predominant ocean current, has VIV suppression devices connected thereto. This alignment also places more of the tubular structures in the wakes of upstream tubular structures. Notice that the lower left tubular structure, which would last experience the predominant ocean current after all other tubular structures of the array, does not have a VIV suppression device(s).

[0086] In this configuration four out of nine, or about 44 percent of the tubular structures, have VIV suppression devices connected thereto. On the periphery, three out of eight, or about 37 percent of the tubular structures, have VIV suppression devices. On the front row, one out of five, or 20 percent of the tubular structures, have VIV suppression devices.

[0087] The three-by-three rectangular array of FIGS. 3A-3F is not required. In alternate embodiments, the plurality of tubular structures may have various other numbers of tubular structures and/or various other shapes (e.g., circular, star, triangular, etc.).

[0088] FIG. 3G illustrates another example configuration for twelve tubular structures arranged in a four-by-three rectangular array of twelve tubular structures, according to one example embodiment. In this configuration, a mix of a sufficient amount of front row suppression and a sufficient amount of frequency disassociation has been utilized.

[0089] Arrows indicate a predominant ocean current. The array is aligned so that a tubular structure at the upper right corner position, which has VIV suppression devices coupled thereto, first experiences the predominant ocean current. This alignment also places more of the tubular structures in the wakes of upstream tubular structures.

[0090] Moreover, in relatively larger arrays, there tends to be a relatively larger amount of natural frequency dissociation due to the interferences and wake effects for the larger numbers of tubular structures. In addition, fewer VIV suppressed tubular structures may effectively reduce vibrations. As a result, in relatively larger arrays it is generally possible to use comparatively smaller numbers or percentages of tubular structures having VIV suppression devices than with small to moderate numbers of tubulars. For arrays with more than 12 risers even 20 percent or 25 percent of the tubular structures may have VIV suppression devices depending upon the particular implementation.

[0091] In this configuration six out of 12 or 50 percent of the tubular structures have VIV suppression devices connected thereto. On the periphery, four out of 10 or 40 percent of the tubular structures have VIV suppression devices. On the front row, two out of six or about 33 percent of the tubular structures have VIV suppression devices.

[0092] Non-rectangular arrays are also suitable. FIGS. 3H illustrates yet another example configuration for nine tubular structures arranged in a concentric array, according to one embodiment. In this case, the concentric array is circular. Alternatively, the array may be elliptical, oval, star shaped, triangular, etc.

[0093] Arrows are used to indicate a predominant ocean current. The array is aligned so that a tubular structure that has VIV suppression devices coupled thereto first experiences the predominant ocean current.

[0094] Tubular structures with VIV suppression devices are substantially staggered with tubular structures that lack VIV suppression devices. As before, on a periphery, only every other tubular structure has VIV suppression devices.

[0095] In this configuration four out of nine or about 44 percent of the tubular structures have VIV suppression devices connected thereto. On the periphery, four out of eight or 50 percent of the tubular structures have VIV suppression devices. On the front row, three out of five or 60 percent of the tubular structures have VIV suppression devices.

[0096] In any of the configurations of FIGS. 3A-3H, the VIV suppression devices may optionally be conventional, and may be constructed of any suitable material conventionally used for VIV suppression devices. If desired, in one or more embodiments, protective structures, such as, for example, covers, caps, bumpers, or the like, may optionally be included on the VIV suppression devices to help prevent mechanical damage, if bumping or contact with a VIV suppression device were to occur. The protective structures may comprise pliable, elastic, or soft materials, such as, for example, rubber, plastic, foam, or the like. In one aspect, the ends of the sections of the VIV suppression devices may optionally be tapered to a smaller outside diameter than the outside diameter of a remainder of a section of a suppression device, which may facilitate installation and/or insertion through spacers. Representatively, if a tubular structure having a VIV suppression device installed thereon is inserted through an opening in a spacer, if an end of the suppression device that is to be initially inserted through the opening is tapered to a smaller outside diameter, it tends to be easier to align the suppression device/tubular structure with the opening and insert it into the opening.

[0097] In any of the configurations of FIGS. 3A-3H, in one or more embodiments, rather than using a single type and/or size of VIV suppression device, multiple, different types and/or sizes of VIV suppression devices may optionally be used, although this is not required. For example, some of the subset of risers that have VIV suppression devices may have a first type of VIV suppression device (e.g., strakes), and others of the subset may have a second, different type of VIV suppression device (e.g., fairings). One strategy for using different types of VIV suppression devices might be to change the excitation frequencies of the risers and/or increase the frequency dissociation of the array. The different types may optionally be staggered relative to one another to provide additional frequency dissociation.

[0098] Another way of reducing vibrations is by using tubular structures having a plurality of different outer diameters. Accordingly, other embodiments pertain to a plurality of risers or other tubular structures, in which at least two of the risers or other tubular structures have different outer diameters. In one or more embodiments, at least three of the tubular structures may have different outer diameters.

[0099] The diameter of a tubular structure affects its vortex shedding frequency and its VIV resonant frequency. In particular, tubular structures that have relatively larger hydrodynamic diameters will tend to have lower vortex shedding frequencies and lower excitation frequencies compared to tubular structures that have relatively smaller hydrodynamic diameters. As a result, including tubular structures with different outer diameters in a group, array, bundle, or other coupled plurality, may help to “detune” the vibratory frequency of the group, array, bundle, or other plurality by increasing the level of frequency dissociation of the array.

Additionally, an upstream tubular structure typically has a higher shedding frequency than a downstream tubular structure that is in its wake. As a result, greater frequency disassociation is generally possible when a relatively larger diameter tubular structure is downstream of a relatively smaller diameter tubular structure.

[0100] In one or more embodiments, for a predominant ocean current, a tubular structure having a relatively larger diameter may be in a wake of, or downstream from, a structure having a relatively smaller diameter. In one or more embodiments, for a predominant ocean current, an average diameter of a plurality of upstream tubular structures may be less than the average diameter of a plurality of downstream tubular structures in their wake.

[0101] Typically, the largest diameters may range from 5 percent to 200 percent larger than the smallest diameters (expressed as a percentage of the smallest diameters). Often, the largest diameters may range from 10 percent to 150 percent larger than the smallest diameters. In cases, the largest diameters may range from 25 percent to 100 percent larger than the smallest diameters. However, the scope is not limited to any known difference between the diameters.

[0102] In one or more embodiments, a sheath or other coating may be included on the outside of a tubular structure in order to increase the outside diameter of the tubular structure. The term coating is not limited to a paint-like application process or the like but more broadly encompasses a material coupled with the outside of the tubular structure. In one or more embodiments, coatings having a plurality of different thicknesses may be included on the outside of different tubular structures in order to increase the outside diameters of the tubular structures, and to provide a plurality of different outside diameters. The coatings may potentially serve a purpose other than to increase the diameter. For example, the coatings may include thermal insulation to thermally insulate a fluid within the tubular structures. As another example, the coatings may include a buoyancy material.

[0103] FIG. 4:

[0104] FIG. 4 illustrates an example approach or configuration of a plurality of tubular structures in which at least two, in this case at least three, of the tubular structures have different outer diameters, according to one or more embodiments. As before, this figure is a cross-sectional view taken along section line 3/4/5 of FIG. 1 through spacer 110A and the plurality of tubular structures 106.

[0105] Similarly to FIGS. 3A-3F, nine tubular structures are arranged in a three-by-three rectangular array. In this configuration, a tubular structure at a center position 106E, and four tubular structures at four corner positions 106A, 106C, 106G, and 106I, all have a first outer diameter. A tubular structure 106B at an upper center side position and a tubular structure 106F at a right center side position both have a second outer diameter. A tubular structure 106D at a left center side position and a tubular structure 106H at a lower center side position both have a third outer diameter. As shown, the first outer diameter may be less than the second outer diameter, and the second outer diameter may be less than the third outer diameter. If desired, one or more of the tubular structures may have yet another fourth outer diameter different than the other three diameters.

[0106] Arrows indicate a predominant ocean current. The larger diameter tubular structure 106D at the left side position is downstream from and in the wake of the smaller diameter tubular structure 106B at the upper side position. Likewise,

larger diameter tubular structure 106H at the lower side position is downstream from and in the wake of smaller diameter tubular structure 106F at the right side position. An average diameter of the upstream tubular structures (e.g., 106B, 106C, and 106F) is less than the average diameter of the downstream tubular structures in their wake (e.g., 106D, 106H, and 106G).

[0107] FIG. 5:

[0108] It is also possible to use tubular structures having different diameters in combination with including VIV suppression devices on a subset of the tubular structures. FIG. 5 illustrates an example approach or configuration that is similar to that of FIG. 4 except that, in addition to the different outer diameters, a subset of the tubular structures also have VIV suppression devices connected thereto, according to one or more embodiments.

[0109] In one embodiment, the hatched circles are tubular structures with VIV suppression devices. The un-hatched circles represent tubular structures without VIV suppression devices.

[0110] In another embodiment, the hatched circles are tubular structures without VIV suppression devices. The un-hatched circles represent tubular structures with VIV suppression devices.

[0111] Both the different outer diameters and the VIV suppression devices may contribute to reducing vibrations. In general, the greater the variation in the outer diameters, the lesser the number of VIV suppression devices that would be needed to sufficiently reduce vibrations a particular implementation (including potentially none). Likewise, the greater the number of VIV suppression devices, the lesser the variation in the outer diameters needed to sufficiently reduce vibrations for a particular implementation (including potentially no variation).

[0112] The scope is not limited to the particular configurations shown in FIGS. 4 and 5. A wide variety of other arrangements or configurations will be apparent to those skilled in the art and having the benefit of the present disclosure.

[0113] As yet another approach for dealing with vibrations, it is also contemplated that devices or structures, whose primary purpose is to add damping, produce frequency disassociation, or cause a different shedding frequency, as opposed to primarily VIV suppression, may be part of or connected with an array or other associated or connected plurality of tubular structures. This may help to increase the overall suppression of the system. Examples of such devices include helical axial fins, axial non-helical fins, and circumferential fins. In one or more embodiments, the fins or other devices or structures may be flexible or include a flexible material to further provide dampening. In one or more embodiments, a coating that attracts marine growth (instead of suppressing marine growth) may be added to the outside of the tubular structure to enhance dampening.

[0114] Other embodiments pertain to methods of assembly of the associated or connected tubular structures. A method of assembly may include initially installing a structural support tubular structure having one or more spacers connected therewith. For example, in a rectangular array such as illustrated in FIGS. 3A-3F, a center tubular structure (e.g., structure 106E) may be initially connected to one or more spacers along a length of the structural support (e.g., a length of multiple sections of the structural support). Then one or more of other tubular structures, may be separately threaded, inserted, or otherwise introduced through openings in the spacers. The tubular structures may either have VIV suppression devices

connected thereto before being introduced into the openings or the VIV suppression devices may be connected afterwards. In one or more embodiments, in the final assembly, some but not all, or a subset, of the tubular structures have VIV suppression devices connected thereto. In one or more embodiments, in the final assembly, a number of the tubular structures, in some cases at least three of the tubular structures, have different outer diameters.

[0115] Other embodiments pertain to methods of suppressing vibrations in the connected or associated tubular structures. In one or more embodiments, vibrations are suppressed with VIV suppression devices connected with only a subset of the tubular structures of a coupled or associated array or grouping. In one or more embodiments, tubular structures with a number of outer diameters (e.g. at least three different outer diameters) may be vibrated at a plurality of different frequencies.

[0116] FIGS. 6A & 6B:

[0117] FIG. 6A illustrates an example of a marine system 600 in which embodiments may be implemented. The marine system includes a Floating Liquefied Natural Gas (FLNG) plant 602 on/in a surface of the ocean 104. The FLNG plant is one particular example of a surface structure. The FLNG plant may cool and liquefy natural gas, or alternatively heat and gasify LNG. One or more tubular structures of an array or grouping connected with FLNG plant 602 may be used to bring water from the ocean to the plant. Alternatively, riser arrays may be used as drilling riser arrays, production riser arrays, TLP tendons, etc.

[0118] Marine system 600, in this embodiment, includes a number of tubular structures or risers 606 (e.g., nine tubular structures). The risers each have first ends and second ends. The first ends are connected to with the FLNG plant. The second ends project generally downward into the ocean but not necessarily to the seafloor. By way of example, the second ends may have depths of around 130 to 170 meters, although this is not required. Due to the ocean current, tubular structures 606 may deflect from vertical by around 40 degrees or so (not shown). To accommodate for such deflection, tubular structures 606 may be connected with the FLNG plant through a swivel joint, a ball joint, a riser hanger, or other pivotable or hingeable coupling.

[0119] Tubular structures 606 are physically associated or connected together with a plurality of guide sleeves or spacers 610A, 610B, 610C. The spacers may have openings through which respective ones of the tubular structures are disposed. In one embodiment, enough spacers may be provided to keep the tubular structures from striking into one another.

[0120] In one embodiment, some or all of tubular structures 606 may serve as water intake risers. The water intake risers may take in cold water 640 at depth, and convey the cold water upward to the FLNG plant. The cold water may be input to heat exchangers of the FLNG plant in order to cool natural gas to help liquefy the natural gas. The heated ocean water from the outlet of the heat exchangers may be discharged back into the ocean at the surface, or alternatively conveyed back into depth with a different riser or set of risers.

[0121] If desired, filters may optionally be coupled to each of the bottoms of tubular structures 606. The filters may help to prevent soil, marine life (e.g., seaweed, algae, fish, etc.), and the like, from entering the tubular structures. Over time, the filters may tend to become clogged. It tends to be relatively difficult to clean the filters. For example, removing one or more tubular structures 606 from an array so that the filters

may be cleaned tends to be costly, labor intensive, and/or time consuming. In one or more embodiments, rather than removing the tubular structures each time the filters become clogged, an array or grouping may include surplus water intake tubular structures (risers) so that the surplus water intake tubular structures may optionally be included to provide adequate water intake even after some of the filters clog. In one aspect, a tubular structure may be used until its filter clogs and then may be taken off line and a new tubular structure having a clean filter may be newly brought online. In another aspect, tubular structures with VIV suppression devices may not be used for water intake and may not have filters, but rather may be used primarily for VIV suppression, while bare tubular structures without VIV suppression devices may have filters and be used for water intake. These bare tubular structures tend to be easier to retrieve when their filters become clogged.

[0122] FIG. 6B shows an example approach or configuration for nine tubular structures (risers) arranged in a three-by-three rectangular array, according to one particular embodiment. This figure is a cross-sectional view taken along section line 6B of FIG. 6A through the plurality of tubular structures 606.

[0123] The array has eight tubular structures along the periphery and one riser at the center. The eight tubular structures along the periphery may serve as water intake risers to provide cold water to the FLNG plant. The tubular structure at the center may serve as a structural support structure (riser) for the spacers. The riser at the center may, or may not, convey water to the surface (i.e., may or may not serve as a water intake riser).

[0124] In one particular embodiment, the eight tubular structures along the periphery may have outer diameters of about 42 inches and wall thicknesses of about 1 inch, while the structural tubular structure at the center may have an outside diameter of about 24 inches and a thickness of about 0.75 inches. The eight tubular structures along the periphery may be equally spaced apart by a distance of about one outer diameter or about 42 inches. To provide sufficient cooling water to FLNG plant 602, in one embodiment, each of tubular structures may not be necessary to be in operation at any one time. Thus, one or more of the tubular structures may serve as a surplus water intake riser.

[0125] In this example approach or configuration only tubular structures at all four corner positions of the three-by-three rectangular array have VIV suppression devices connected therewith. Alternatively, other arrangements or configurations disclosed herein may optionally be used.

Example 1

[0126] Tank tests have been performed on a three-by-three riser array scaled down model with and without helical strakes. The helical strakes, when included, were included only on four corner risers of the array. This configuration is similar to that shown in FIG. 3A. The tests and test results are summarized in Table 1.

TABLE 1

Water Temp (F.)	Test Description	Speed Range (ft/sec)	max rms A/D
61	bare pipe bundle (9 pipes with 3 spacers 0-deg heading	0.2-3.2	0.602

TABLE 1-continued

Water Temp (F.)	Test Description	Speed Range (ft/sec)	max rms A/D
78	strakes (0.2D height) on 4 corner risers, 0-deg heading	0.2-3.6	0.059
79	strakes (0.2D height) on 4 corner risers, 22.5 deg heading	0.2-3.6	0.008
82	strakes (0.2D height) on 4 corner risers, 45 deg heading	0.2-3.6	0.008

[0127] Different water temperatures were tested. Speed range pertains to the current flow rate. Max rms A/D refers to the maximum motion magnitude (root-mean-square value) in the speed range tested and measures vibration. The lower the max rms A/D, the lower the amount of vibration on the risers. These results indicate that including helical strakes on only four corner risers in a nine-riser array is sufficient to significantly reduce VIV.

[0128] The scope of the invention is not limited to achieving any known particular amount of VIV suppression or dampening. The amount of VIV suppression or dampening appropriate for a particular implementation may vary widely from one implementation to another. This may be due in part to variation in ocean current, tubular length, materials of construction, amount of overdesign, and the like.

[0129] In the description above, for the purposes of explanation, numerous specific details have been set forth in order to provide a thorough understanding of the embodiments. It will be apparent however, to one skilled in the art, that one or more other embodiments may be practiced without some of these specific details. The particular embodiments described are not provided to limit the invention but to illustrate it. The scope of the invention is not to be determined by the specific examples provided above but only by the claims below. In other instances, well-known structures, devices, and operations have been shown in block diagram form or without detail in order to avoid obscuring the understanding of the description. Where considered appropriate, reference numerals or terminal portions of reference numerals have been repeated among the figures to indicate corresponding or analogous elements, which may optionally have similar characteristics.

Illustrative Embodiments

[0130] In one embodiment, there is disclosed a system comprising an array of structures in a flowing fluid environment, the array comprising at least 3 structures; and vortex induced vibration suppression devices on at least 2 of the structures. In some embodiments, the array of structures are within a body of water. In some embodiments, at least one end of the structures are connected to a floating vessel. In some embodiments, the vortex induced vibration suppression devices are installed on from 20% to 80% of the structures. In some embodiments, the vortex induced vibration suppression devices are installed on from 30% to 60% of the structures. In some embodiments, the structures are coupled to each other at a plurality of locations along a length of the structures. In some embodiments, the array comprises at least one internal structure and a plurality of external structures that form a periphery about the internal structures, wherein the vortex induced vibration suppression devices are installed on from 40% to 65% of the external structures. In some embodiments,

the flowing fluid environment comprises a predominant current direction, and wherein a structure in the array that first encounters the predominant current comprises at least one vortex induced vibration suppression device. In some embodiments, the system also includes the vortex induced vibration suppression devices are selected from strakes and fairings. In some embodiments, the vortex induced vibration suppression devices comprise at least two different types of devices. In some embodiments, the array comprises a first structure having a diameter at least 20% larger than a second structure. In some embodiments, the flowing fluid environment comprises a predominant current direction, and wherein a structure in the array that first encounters the predominant current comprises a diameter at least 15% smaller than another structure in the array. In some embodiments, the array comprises at least 6 structures. In some embodiments, the structures comprise a tubular, each tubular comprising an opening therethrough for transportation of a fluid.

[0131] In one embodiment, there is disclosed a method of suppressing the vortex induced vibration of an array of structures comprising installing vortex induced vibration suppression devices on from 10% to 90% of the structures. In some embodiments, the method also includes connecting a plurality of the structures to each other. In some embodiments, the method also includes modifying a diameter of at least one of the structures, so that a first structure has a diameter at least 30% larger than a second structure.

[0132] It should also be appreciated that reference throughout this specification to “one embodiment”, “an embodiment”, or “one or more embodiments”, for example, means that a particular feature may be included in the practice of the invention. Similarly, it should be appreciated that in the description various features are sometimes grouped together in a single embodiment, Figure, or description thereof for the purpose of streamlining the disclosure and aiding in the understanding of various inventive aspects. This method of disclosure, however, is not to be interpreted as reflecting an intention that the invention requires more features than are expressly recited in each claim. Rather, as the following claims reflect, inventive aspects may lie in less than all features of a single disclosed embodiment. For example, unless specified or claimed otherwise, the floating structure or floating liquefied gas plant shown in a Figure is not intended to be a part of the invention. Thus, the claims following the Detailed Description are hereby expressly incorporated into this Detailed Description, with each claim standing on its own as a separate embodiment of the invention.

1. A system comprising:

an array of structures in a flowing fluid environment, the array comprising at least 3 structures; and
vortex induced vibration suppression devices on at least 2 of the structures,
wherein at least one of the structures comprise no vortex induced vibration suppression devices.

2. The system of claim 1, wherein the array of structures are within a body of water.

3. The system of claim 2, wherein the structures comprise first ends that are connected to a floating vessel, and second ends that project generally downward into the water.

4. The system of claim 1, wherein the vortex induced vibration suppression devices are installed on from 20% to 80% of the structures.

5. The system of claim 1, wherein the vortex induced vibration suppression devices are installed on from 30% to 60% of the structures.

6. (canceled)

7. The system of claim 1, wherein the array comprises at least one internal structure and a plurality of external structures that form a periphery about the internal structures, wherein the vortex induced vibration suppression devices are installed on from 40% to 65% of the external structures.

8. The system of claim 1, wherein the flowing fluid environment comprises a predominant current direction, and wherein a structure in the array that first encounters the predominant current comprises at least one vortex induced vibration suppression device.

9. The system of claim 1, wherein the vortex induced vibration suppression devices are selected from strakes and fairings.

10. The system of claim 1, wherein the vortex induced vibration suppression devices comprise at least two different types of devices.

11. The system of claim 1, wherein a first structure of the array of structures has a diameter at least 20% larger than a second structure of the array of structures.

12. The system of claim 1, wherein the flowing fluid environment comprises a predominant current direction, and wherein a structure in the array that first encounters the predominant current comprises a diameter at least 15% smaller than another structure in the array.

13. The system of claim 1, wherein the array comprises at least 6 structures.

14. The system of claim 1, wherein the structures comprise a tubular, each tubular comprising an opening therethrough for transportation of a fluid.

15. A method of suppressing the vortex induced vibration of an array of structures comprising:

installing vortex induced vibration suppression devices on from 10% to 90% of the structures.

16. The method of claim 15, further comprising connecting a plurality of the structures to each other.

17. The method of claim 15, further comprising modifying a diameter of at least one of the structures, so that a first structure of the array of structures has a diameter at least 30% larger than a second structure of the array of structures.

18. A system comprising:

an array of structures in a flowing fluid environment, the array comprising at least 3 structures, wherein the structures are coupled to each other at a plurality of locations along a length of the structures; and

vortex induced vibration suppression devices on at least 2 of the structures, and wherein at least one of the structures comprise no vortex induced vibration suppression devices.

19. The system of claim 18, wherein the vortex induced vibration suppression devices are installed on from 20% to 90% of the structures.

20. The system of claim 18, wherein the vortex induced vibration suppression devices are installed on from 40% to 70% of the structures.

21. The system of claim 1, wherein the at least 3 structures are risers.

22. The system of claim 21, wherein the risers are arranged parallel to each other, and wherein vertically spaced spacers are provided along the risers to hold the risers in position relative to each other.

23. A method of suppressing the vortex induced vibration of an array of structures comprising:

installing vortex induced vibration suppression devices on at least 2 but not all of the structures.

24. A process for liquefying natural gas, comprising:

providing a system comprising a floating vessel on a body of water, and an array of structures, the array comprising at least 3 structures, wherein the structures comprise first ends that are connected to the floating vessel and second ends that project generally downward into the water, and vortex induced vibration suppression devices on at least 2 of the structures, wherein at least one of the structures comprise no vortex induced vibration suppression devices;

using the at least 3 structures as water intake risers for bringing water from the body of water to an FLNG plant on the floating vessel;

cooling and liquefying natural gas with the FLNG plant, wherein the water is input to heat exchangers of the FLNG plant in order to help liquefy the natural gas.

25. A process for gasifying liquefied natural gas, comprising:

providing a system comprising a floating vessel on a body of water, and an array of structures, the array comprising at least 3 structures, wherein the structures comprise first ends that are connected to the floating vessel and second ends that project generally downward into the water, and vortex induced vibration suppression devices on at least 2 of the structures, wherein at least one of the structures comprises no vortex induced vibration suppression devices;

using the at least 3 structures as water intake risers for bringing water from the body of water to an FLNG plant on the floating vessel;

using the water in the FLNG plant to heat and gasify LNG.

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