

SPECIFICATION

Spar Buoy

This invention relates to spar buoys, and more particularly to an improved arrangement of spar
5 buoys for preventing oscillation due to water flow.

A spar buoy comprises an elongated spar provided with a buoyancy chamber at its intermediate portion and a weight known as a
10 in water the spar adapts a substantially upright position with said one end disposed adjacent to the bottom of the body of water, due to the weight of the sinker, and the other end of the spar above the water surface. The end above the water
15 surface may be provided with a lantern or similar indication, depending on the application. Such a spar buoy has superior characteristics compared to floating type buoys in so far as the spar buoy is less sensitive to waves and oscillates only a very
20 small amount, resulting in a smaller amount of whirling.

The spar buoy includes two types; that is, one type wherein the lower end of the spar is connected to the sinker through a joint such as a
25 universal joint or a shackle, and the other wherein the spar is connected to the sinker through a relatively short length of chain providing for adjustment of the overall length of the buoy assembly to meet the depth at the site.

With the first type of spar buoy, it is extremely difficult to adjust the overall height of the spar buoy assembly to meet the water depth. When
30 adjustment to the water depth is necessary due to an error in depth measurement or change of deployment location, which is discovered only at the time of actual deployment, the excessively long or too short spar must be shortened or
35 lengthened, respectively, to meet the depth condition. However, since the length change of a very long spar requires workshop machining, and it is usual that there is no factory or workshop
40 capable of handling the very long spar around the deployment site, the long spar buoy must be brought to a distant factory to adjust the length, requiring much expense and time.

With the second type spar buoy, its length can easily be adapted by properly adjusting the length of the chain cable to meet the actual water depth, creating no problem as above mentioned.

However, since the spar and the buoyancy chamber of the spar buoy are vertically oriented from the water bottom to the water surface, the spar buoy is easily heeled and whirled by a lateral water flow such as a tidal current because of the
55 large drag of its vertical spar. Therefore, this second type of spar buoy has been deemed not suitable to be used in a rapid tidal current notwithstanding the previously mentioned advantage. It is known that excessive heeling of
60 the spar buoy can be countered by a larger buoyancy chamber and a heavier sinker weight so that the buoy maintains a substantially vertical position even in a rapid tidal current. However, whirling or oscillation of the spar buoy is not

65 reduced by the above counter measure.

The whirling or oscillation of the spar buoy is due to hydrodynamic forces exerted on the spar by the flow of water about the spar. One such hydrodynamic force is alternating lateral forces
70 due to von Karman's vortex street generated downstream of the spar. These forces cause the spar buoy to oscillate with the relatively large buoyancy chamber intermediately disposed on the spar as its centre of rotation or swing
75 combined with another oscillation restricted by the chain cable connected between the lower end of the spar and the sinker. Thus, the lower end of the spar oscillates with the sinker-end of the chain cable as the centre of oscillation, and the
80 buoyancy chamber oscillates substantially vertically. The frequency of such oscillation may be from 2 to 3 seconds for an ordinary sized spar buoy having a 50 cm diameter spar, the oscillating frequency due to von Karman's vortex
85 street is about 2 seconds when the water speed is approximately 2.5 knots. Such frequency may well cause the spar buoy to oscillate in resonance with the above described oscillation about the buoyancy chamber. Such oscillation of the spar
90 buoy may cause damage to a lantern system surmounting the spar, destruction of a gimbal due to its resonance, and/or fatigue of the spar.

Accordingly, the present invention seeks to provide a spar buoy in which the above
95 mentioned disadvantages of the conventional spar buoy are minimized.

According to the present invention there is provided a spar buoy comprising a spar, a buoyancy chamber attached to an intermediate
100 portion of said spar, a length of chain cable extending between one end of said spar and a sinker and damping means disposed on said spar for hydrodynamically reducing oscillation of said spar due to water flow, said buoyancy chamber
105 being a substantially cylindrical hollow member having a diameter larger than that of said spar, and being substantially concentrically disposed with respect to said spar, whereby, when the spar buoy is deployed in a body of water, said sinker causes said spar to be in a substantially vertical
110 position with said one end and said buoyancy chamber submerged in the water and the other end of said spar emerging from the water surface, wherein said damping means includes a substantially truncated cone fairing disposed
115 between the outer periphery of said cylindrical member and said spar, with its larger diameter end connected to said cylindrical member and its smaller diameter end connected to said spar and means adjacent said one end providing resistance to movement of said one end in the water.

A plurality of fins extending radially and substantially perpendicularly to the axis of the spar may be secured adjacent to the lower end of the spar to minimize lateral movement of the
125 lower end of the spar. Also, the damping means may be adapted to prevent generation of von Karman's vortex street downstream of the spar. The damping means may comprise a plurality of

elongated fins extending along the axis of the spar and attached to the spar, or may be a hollow tube portion of the spar having a plurality of openings. The fins may extend radially from the spar or may be spaced from the spar and extend circumferentially.

Preferred embodiments of the present invention will now be described by way of example with reference to the accompanying drawings, in which:—

Figure 1 is a view illustrating a spar buoy constructed in accordance with the present invention;

Figure 2 is a detailed view of the buoyancy chamber shown in Figure 1;

Figures 3 to 5 are sectional views taken along the line III—III of Figure 1 illustrating embodiments of the present invention;

Figures 6 to 13 are views illustrating other embodiments of the present invention.

Referring now to the drawings and in particular to Figure 1 thereof, there is shown a spar buoy of the present invention. The spar buoy comprises a spar 1 made of a steel pipe, a lantern system 2 mounted on the top end of the spar 1, a buoyancy chamber 3 mounted on the intermediate portion of the spar 1, a damper 4 disposed at the bottom end of the spar 1, a chain cable 5 attached to the bottom end of the spar 1, and a sinker 6 attached to the chain cable 5.

It is seen from the figure that the sinker 6 is on the bottom of the body of water, that the spar is positioned substantially vertically due to the buoyancy obtained by the buoyancy chamber 3 and the weight of the sinker 6 connected through the chain cable to the bottom end of the spar 1. The spar buoy, except for the lantern system 2 surmounting the spar 1 and an upper part of the spar 1, is submerged under the water level 7.

The buoyancy chamber 3, which is shown in detail in Figure 2, is a generally cylindrical hollow member with frusto-conical fairings 8 and 9 attached to the upper and lower ends respectively of a central hollow cylindrical buoyancy chamber 10. The cylindrical chamber 10 is substantially concentric with the spar 1 and has a much larger diameter than that of the spar 1. The upper end of the central chamber 10 is connected such as by welding to the larger diameter bottom end of the fairing 8. The top end or the smaller diameter end of the fairing 8 is connected, by welding for example, to the spar buoy 1. The lower fairing 9, which is also in the shape of a truncated cone, is also connected such as by welding between the lower end of the cylindrical central chamber 10 and the outer surface of the spar 1. The connections between the lower fairing 9 and the cylindrical wall 10 and the spar 1 may either be made water tight or be made to allow water passage by forming several slits 11 in the fairing 9 or merely by intermittent welding. Making the interior of the fairing 9 in fluid communication with the exterior is convenient when a sufficient buoyancy is obtained with a cylindrical central buoyancy chamber 10 and the upper fairing 8,

and a water ballast tank is advantageously used for the stabilization of the buoy. As is apparent from the figure, the buoyancy chamber 3 may have three separate buoyancy chambers (cylindrical centre chamber, and two chambers defined within the fairings), or two buoyancy chambers (one centre chamber and one buoyant fairing) or a single chamber (one large chamber unitarily formed of a centre chamber and one or two buoyant fairings).

The buoyancy chamber 3 constructed as above described minimizes the disturbance of a water flow such as a turbulent flow downstream of the buoyancy chamber and von Karman's vortex street, thereby minimizing the oscillation of the spar buoy. Also, when an additional buoyancy chamber is formed in the fairing, buoyancy of the buoy is greatly increased, also providing a damping effect on oscillation. Further, the fairings 8 and 9 serve as structural members, reducing the stress concentration at the point where the central cylindrical chamber 10 is attached to the spar 1, and increasing the rigidity of the spar 1.

The oscillation damper 4 may be of various configurations, some examples of which are shown in Figures 3 to 5. In Figure 3, the damper 4 has four fins extending radially and substantially perpendicularly to the axis of the spar 1 to form, in cross-section, a cross. Four plate members 13 bridging between the midpoints of the adjacent fins 12 provide rigidity for the fins. The damper 14 illustrated in Figure 4 has similar fins 12 arranged in a cross and an annular plate ring 15 attached at each of the outer ends of the four fins 12 to encircle the fins 12. The arrangement 16 shown in Figure 5 is formed of only four fins 12 attached, by welding for example, to the spar 1 to again form, in cross-section, a cross.

These dampers 4, 15 and 16, when attached at the bottom end of the spar in the position shown in Figure 1, serve as a hydrodynamic oscillation reducing means in so far as they exhibit a massive drag when exposed to a water flow and thereby damp oscillations of the bottom end of the spar 1. Therefore, even when a vortex street is generated downstream of the spar 1 and the chain cable is long enough to otherwise allow the bottom end of the spar to whirl around the sinker 6, the hydrodynamic oscillation reducing means 4 exhibits a strong resistance against quick movement of the bottom end of the spar 1, thereby minimizing the oscillation or whirling of the spar 1 due to the water flow.

Figures 6 to 13 show other embodiments of hydrodynamic oscillation damping means which are arranged to prevent generation of von Karman's vortex street downstream of the spar 1.

The embodiment shown in Figures 6 and 7 comprises four elongated fins 17 attached to the lower portion of the spar 1 to extend radially and along the axis of the spar 1. The radial dimensions of these fins 17 are preferably relatively small but dimensioned to be enough to prevent the generation of von Karman's vortex street in relation to the spar 1. In Figures 8 and 9, wherein

a modification of the embodiment shown in Figures 6 and 7 is illustrated, four elongated fins 18 are seen extending circumferentially rather than radially as in the previous embodiment, and each fin 18 is supported and spaced from the spar by a plurality of supports 19 to form a slit between the outer surface of the spar 1 and the inner surface of each of the fins 18. The fins 18 may be in the form of sections of a cylindrical plane as shown in the figure. In Figures 10 and 11, a lower portion of the tubular spar 1 is provided with a plurality of axially extending slits 20. In Figures 12 and 13, a lower portion of the tubular spar 1 is provided with a plurality of holes 21. These slits 20 and holes 21 are effective for preventing the generation of von Karman's vortex street.

Claims

1. A spar buoy comprising a spar, buoyancy chamber attached to an intermediate portion of said spar, a length of chain cable extending between one end of said spar and a sinker and damping means disposed on said spar for hydrodynamically reduced oscillation of said spar due to water flow, said buoyancy chamber being a substantially cylindrical hollow member having a diameter larger than that of said spar, and being substantially concentrically disposed with respect to said spar, whereby, when the spar buoy is deployed in a body of water, said sinker causes said spar to be in a substantially vertical position with said one end and said buoyancy chamber submerged in the water and the other end of said spar emerging from the water surface, wherein

35 said damping means includes a substantially truncated cone fairing disposed between the outer periphery of said cylindrical member and said spar, with its larger diameter end connected to said cylindrical member and its smaller diameter end connected to said spar and means adjacent said one end providing resistance to movement of said one end in the water.

2. A spar buoy as claimed in claim 1, wherein said means adjacent to said one end of the spar includes a plurality of fins projecting from the spar.

3. A spar buoy as claimed in claim 1 or 2, wherein said damping means is adapted to prevent generation of von Karman's vortex street.

4. A spar buoy as claimed in claim 2 and 3, wherein said fins comprise a plurality of elongated fins attached to said spar adjacent to said one end to extend along the axis of the spar.

5. A spar buoy as claimed in claim 4 wherein said fins extend radially perpendicular to the axis of said spar.

6. A spar buoy as claimed in claim 5 wherein four fins are provided disposed equi-angularly about the axis of the spar.

7. A spar buoy as claimed in claim 1, wherein said damping means includes a hollow tube portion of said spar, said portion having a plurality of openings.

8. A spar buoy substantially as described herein with reference to, and as illustrate in, Figures 1 and 2 or Figures 1 and 2 as modified by any one of Figures 3 to 13 of the accompanying drawings.



(17)

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1. A spar buoy comprising a spar, buoyancy chamber attached to an intermediate portion of said spar, a length of chain cable extending between one end of said spar and a sinker and damping means disposed on said spar for hydrodynamically reduced oscillation of said spar due to water flow, said buoyancy chamber being a substantially cylindrical hollow member having a diameter larger than that of said spar, and being substantially concentrically disposed with respect to said spar, whereby, when the spar buoy is deployed in a body of water, said sinker causes said spar to be in a substantially vertical position with said one end and said buoyancy chamber submerged in the water and the other end of said spar emerging from the water surface, wherein

35 said damping means includes a substantially truncated cone fairing disposed between the outer periphery of said cylindrical member and said spar, with its larger diameter end connected to said cylindrical member and its smaller diameter end connected to said spar and means adjacent said one end providing resistance to movement of said one end in the water.

2. A spar buoy as claimed in claim 1, wherein said means adjacent to said one end of the spar includes a plurality of fins projecting from the spar.

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8. A spar buoy substantially as described herein with reference to, and as illustrate in, Figures 1 and 2 or Figures 1 and 2 as modified by any one of Figures 3 to 13 of the accompanying drawings.