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Schulze

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[54] **BUOY WITH ADJUSTMENTS FOR THE REDUCTION OF THE EFFECT OF THE SEA FORCES THEREON**

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[56] **References Cited**

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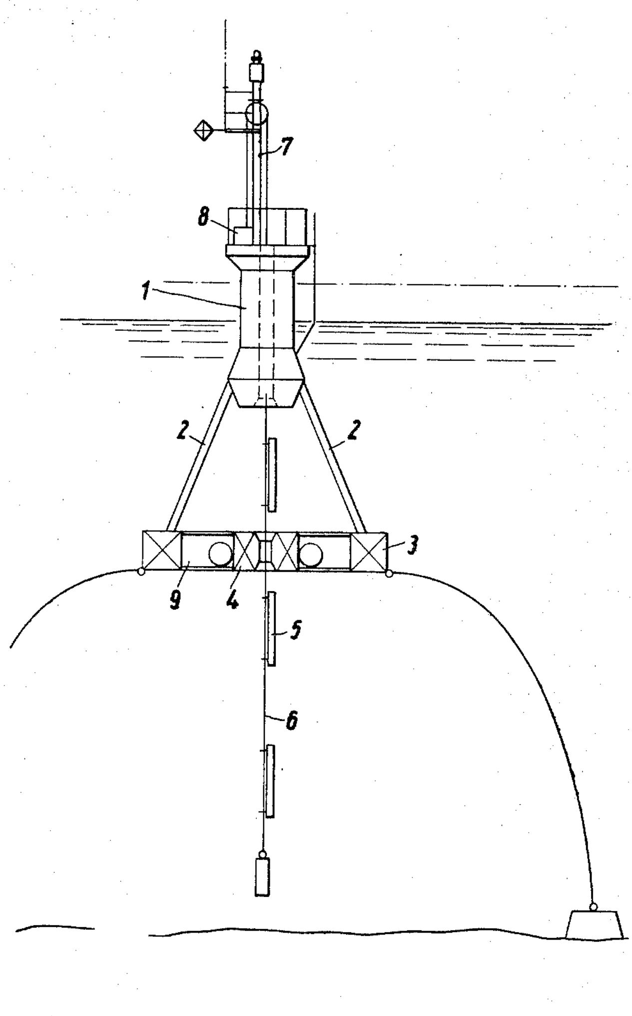
[57] **ABSTRACT**

A buoy specifically constructed for reducing the effect of wave and sea forces thereon. The horizontal diameter of the buoy at the surface of the water is relatively small, with the largest, stabilizing part of the displacement volume of the lower part of the buoy being at a water depth in which the amplitude of the vertical oscillations of the water is smaller than the amplitude movement of the buoy. The stabilizing part of the buoy comprises elongated bodies having an essentially horizontal longitudinal axis.

5 Claims, 1 Drawing Figure



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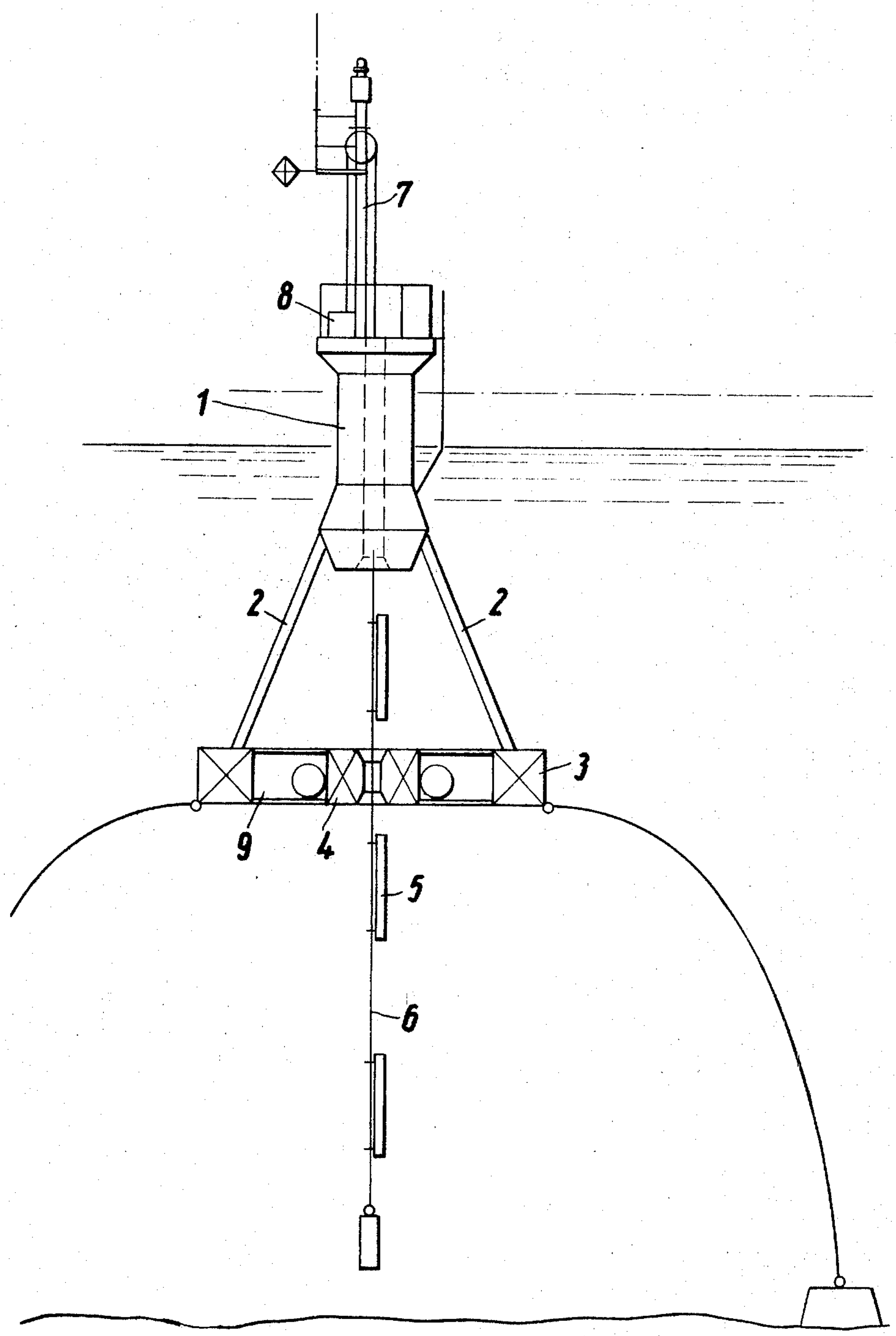

BUOY WITH ADJUSTMENTS FOR THE REDUCTION OF THE EFFECT OF THE SEA FORCES THEREON

The invention relates to a buoy with adjustments for the reduction of the effect of sea forces thereon.

On the sea surface, floating bodies are constantly exposed to the accelerating forces of the sea. If a platform is sought which will stand still on the sea surface (for example for signal or measuring purposes), mast constructions resting on the sea bed are presently used, where the depth of water allows. In deeper waters, the use of floating bodies cannot be avoided. In shallow waters, floating bodies are preferred, on account of the lower costs. Nevertheless, special measures must be taken so that these floating bodies, which are hereafter referred to as buoys, give the greatest possible stability against the surrounding water surface. Tight anchorage is no use for this, because the buoy suddenly loosens, by upward movement against the water surface, which frequently leads to the breaking of the anchorage and the loss of the buoy. A rigid fastening of this kind only comes into consideration in the case of underwater floating bodies, which are not, however, usable when the function of the buoy, or the contrivance developed from it are bound to the water surface. The invention relates only to buoys, and not to buried floating bodies.

The damping of the movement of buoys has already been proposed by damping plate lying under the surface of the water. These buoys, which are known as so-called pile buoys, have, however, only a relatively small damping effect, inasmuch as the article must not be uneconomically large. They also have the disadvantage that the damping plates, when in a diagonal position, are sensitive to horizontal current, and can produce considerable, unwanted vertical forces. Also, these damping contrivances give no noteworthy resistance to the rolling movement of the buoy.

The invention is thus based on the task of creating a buoy of the kind described, which, with moderate construction costs, possesses a good stability against the accelerating forces of the sea.

The invention rests on two facts. The first is that the accelerating forces of the sea surface can be traced back chiefly to oscillations in well-determined frequency and amplitude ranges. These main ranges can, it is true, be very different in different waters, but thy are easy to ascertain for a given place. The second fact is that, for the stabilizing of the buoy, the plate shaped construction parts which at first sight appear especially well suited, are less appropriate than elongated bodies, movable transversely in their longitudinal direction, the diameters of such bodies being tuned in a well-determined way to the frequency rates predominating at any given time. The latter fact was suggested by the research of Kuelegan and Carpenter on "on Cylinders Forces Plates in an Oscillating Fluid," published in Journal of Research of the National Bureau of Standards, Washington Vol. 60 No. 5, May 1958.

The solution, therefore, according to the invention, consists in a buoy of the kind described, having the following combination of features:

a. the main part of the displacement volume of the buoy is disposed below the water surface in calmer water ranges
b. the horizontal diameter of the portion of the buoy at the surface of the water is small

c. the largest part of the displacement volume of the lower part of the buoy is laterally adjacent its center of gravity in the form of elongated bodies with essentially horizontal longitudinal axes and
d. the value of $Um \cdot T/D$ of these bodies is smaller than 10, where Um is the amplitude of the relative speed between water and the bodies, T the time of vibration and D the diameter of the bodies.

It has been shown that the lower part of the buoy, in the buoy according to the invention, can exert a very high stabilizing force on the buoy, in relation to the construction costs, whereby an excellent resistance to rolling is also achieved. This success rests in the activation of hydrodynamic reaction forces, which, by constant counterforce on account of an assumed depth variation of the floating body, works as a mass increase of the complete oscillating system. This activation of the hydrodynamic reaction forces rests on the tuning, according to the invention, of the diameter of the elongated bodies of the lower part of the buoy to the frequency and height of the waves most prevalent in the particular area of the sea.

The elongated bodies of the lower part of the buoy are expediently linked to a closed ring. The relation of diameter to length is consequently minimal, so that the best approximation to two dimensional flow conditions is achieved, which is known to be especially desirable. The closed ring, although preferably circular, can be many sides, for example triangular or rectangular. It is particularly preferred that the elongated bodies or the ring body have compact cross-sectional form in the vertical section. The circular section is the most preferred from the point of view of dynamic flow; for reason of construction, however, the square or rectangular cross-section, with a side ratio lying near 1, is frequently chosen.

The stabilizing elongated bodies should lie in a depth of water, in which the like phase movements of the water on the water surface have diminished in a small amount. And, it is true, the amplitude of the like phase vertical movement of the water surface should be lowered at least to a fraction which corresponds to the desired reduced mass in relation to the movement of the buoy relative to the movement of the buoy against the movement of the water surface. In other words, the stabilizing bodies should lie in a depth of water, in which the amplitude of the vertical oscillations of the water is smaller than the amplitude movement of the buoy permitted by the corresponding sea.

The distances of the elongated bodies form each other should be, in a transverse direction, such that the flow planes of these bodies are not substantially influenced. This consideration determines the minimum diameter of a stabilizing body formed as a ring body. Whether the diameter is enlarged beyond the minimum diameter depends on the length or extent of the ring body necessary for the desired stabilizing effect, and on the desired resistance against rolling movements. If necessary, the diametral distance of the elongated bodies, or the diameter of a ring body, can be so proportioned, that the opposite bodies or ring parts lie in such depths of water that the accelerating forces working on them according to phase and/or direction, in comparison with the forces working on the buoy near the surface, work in opposition to the buoy. In principle, however, the diametral distance of the elongated bodies, or the diameter of the the ring body, should not be greater than about 20 percent of the wave length of the sea principally in consideration.

The invention is more closely described in the following paragraphs with reference to the drawing, which shows in the single FIGURE a schematic side view of a preferred embodiment.

Represented is a buoy, according to the invention, from which are suspended measuring means for determining horizontal and vertical ocean speeds for which, therefore, high stability is required.

It consists of a floating body **1**, which is joined by support legs **2** to a ring body **3** having rectangular cross-section which, according to the above given view points and in agreement with the cited literature reference, is adjusted with regard to the most frequently met sea frequencies and has a circular outline.

In the middle of the ring body, a ballast tank **4** is provided, which in the sense of the invention is not formed as a stabilizing body, but which nevertheless can exert a certain dampening effect. It is joined to the ring body by struts **9** whereby the distance of the ballast tank from the ring body and the struts is so laid out that the hydrodynamic operation of the ring body is not jeopardized. The oceanographic measuring means **5** are hung from a mast **7** by a measuring cable **6**. With the help of a winch **8** the measuring cable can be raised and lowered.

The cross-section of the floating body **1** at the water line in the range of the expected wave heights is held as small as possible with respect to the smallest possible counterforce in relation to the mass of the system. The lower limit for this cross-section is determined by the above-mentioned permissable depth owing to permissable expected loads such as ice formations. Secondly, the danger of the buoy being cut underneath by strong current requires a not too small cross-section at the water line.

The joining of the floating body with the lower part of the buoy through the support legs **2** is necessary, so that in the uppermost water layers measurements can be carried out without important disturbance of the water condition by parts of the buoy. If requirements of this kind do not obtain, the upper and lower parts of the buoy can naturally be held fast together also in another way.

The buoy is positioned by means of three anchor cables which are set at 120° to each other. For this, as may be appropriate, either buoyant ropes or steel cables with quasi-homogenous distributed buoyancy bodies are used, so that a minimum influence of the anchorage on the oscillating movements of the buoy results. The anchoring of buoy should only prevent drifting over a large area, since the construction of the buoy according the the invention affords a sufficient stabilizing effect against the direct action of the waves.

The center of gravity of the buoy should lie as deep as possible, not far under the center of displacement. The desired position for the center of gravity can be obtained by suitable ballasting of the stabilizing bodies and the ballast tank.

What we claim is:

1. An adjustable buoy for reducing the effect of wave and sea forces thereon, comprising an upper buoy section extending above the surface of the water, said upper buoy section being relatively small in diameter in the region thereof normally exposed to the wave force at the surface, a lower buoy section submerged below the water surface, means for loosely anchoring said buoy to the sea floor, means for interconnecting said upper and lower buoy sections, said lower buoy section including a plurality of elongated bodies arranged along a generally horizontal axis in radially spaced relation relative to the vertical axis of the buoy, the center of gravity of said buoy being × but relatively adjacent said horizontal axis of said bodies, the desired diameter of the bodies being variable depending upon local sea conditions and expressed by the formula

$$(Um \times T)/D < 10,$$

wherein Um is the amplitude of the relative speed between the water and said bodies, T is the time of vibration and D is the diameter of said bodies.

2. The buoy of claim **2** wherein said elongated bodies are assembled in the form of a closed, circular ring.

3. The buoy of claim **2** wherein said closed circular ring has a compact cross-sectional form.

4. The buoy of claim **1** wherein the distance of said elongated bodies from the water line corresponds to a depth of water in which the amplitude of the vertical oscillations of the water in the particular local sea environment is less than the permitted amplitude of movement of the buoy in that sea.

5. The buoy of claim **1** wherein the transverse distance between said elongated bodies is such that the flow planes of these bodies are not substantially influenced, with such transverse distance not being greater than about 20 percent of the expected wave length.

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