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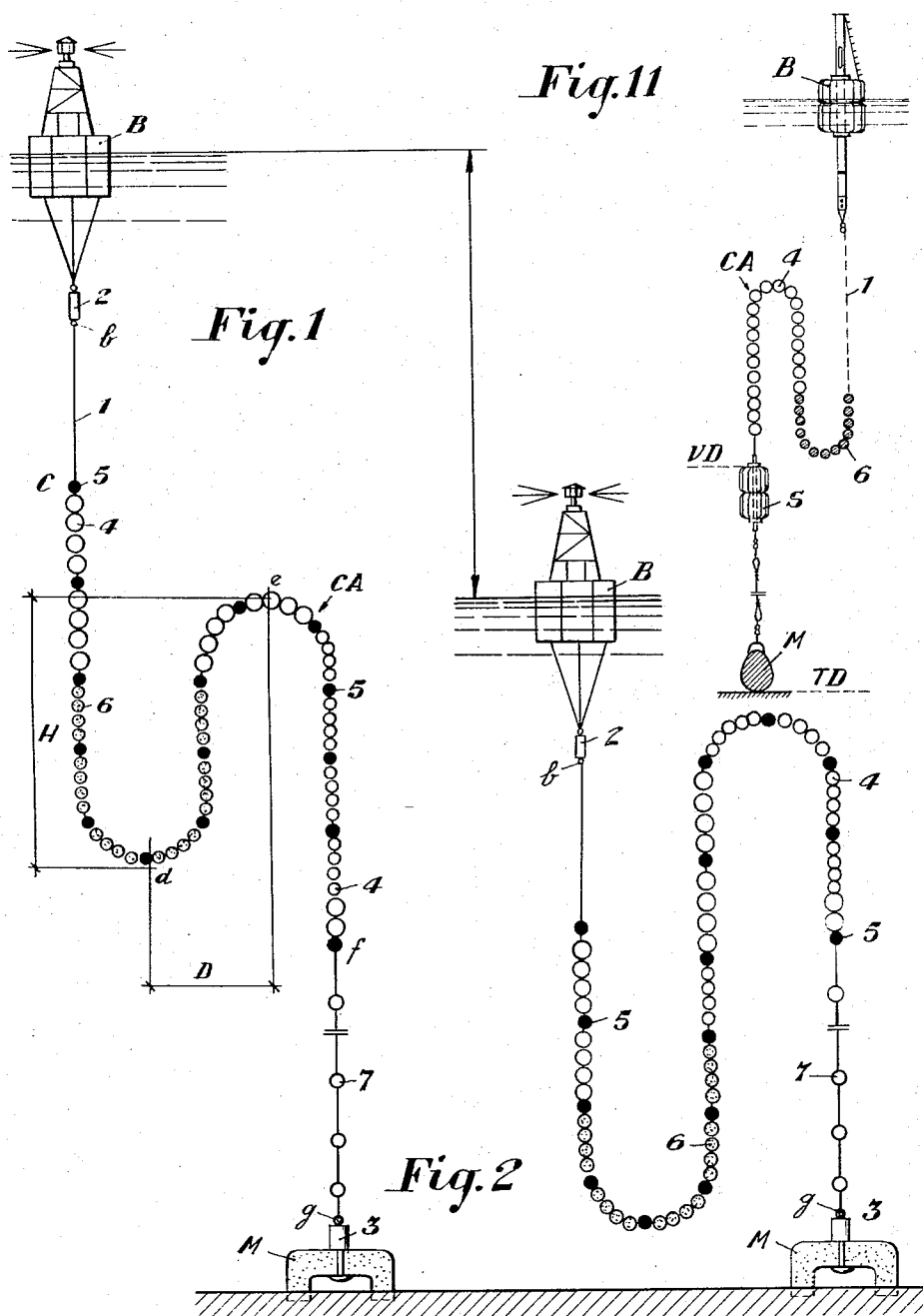
E. BOSSA

3,295,489

PLASTIC COMPOUND CATENARY FOR ANCHORAGE AND PIPELINE
AND/OR CABLE SUPPORT IN ANY SEA ZONE AND DEPTH

Filed June 16, 1965

5 Sheets-Sheet 1



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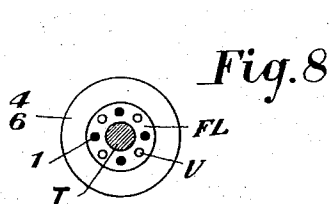
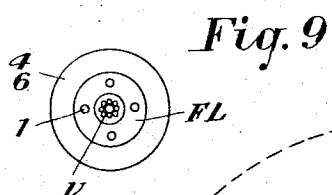
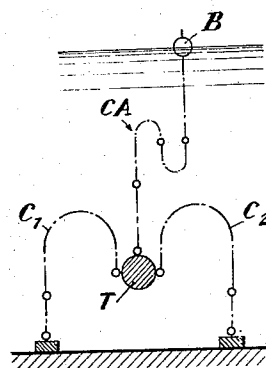
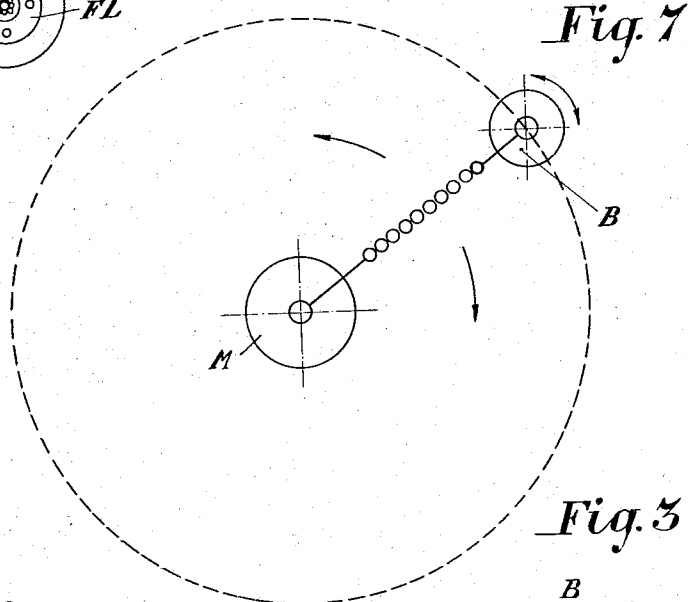
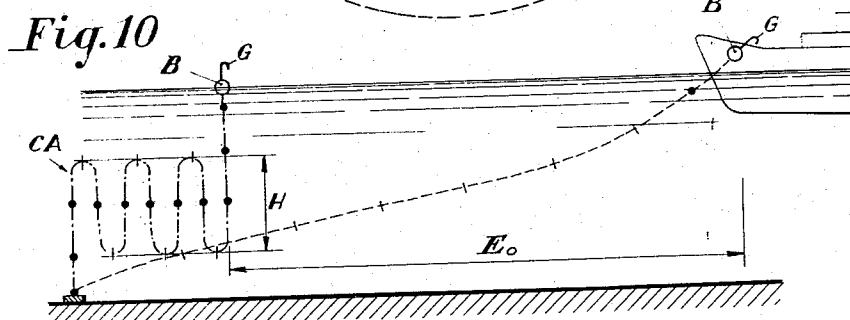
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3 Sheets-Sheet 3



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3 Sheets-Sheet 3

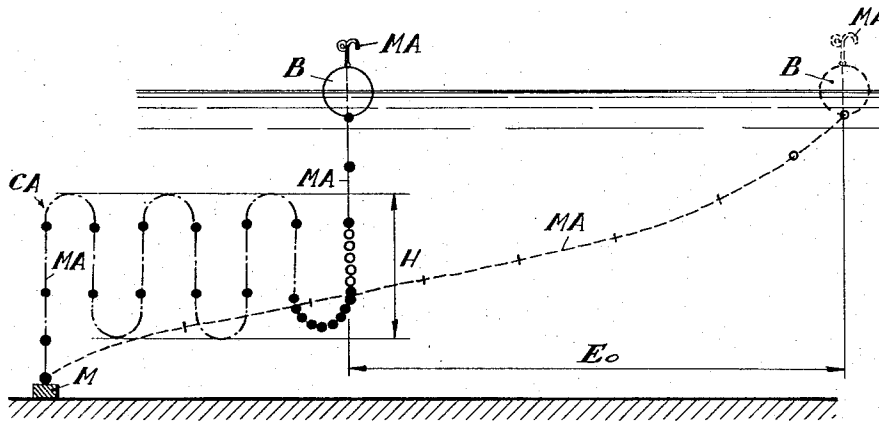


Fig. 4

Fig. 5

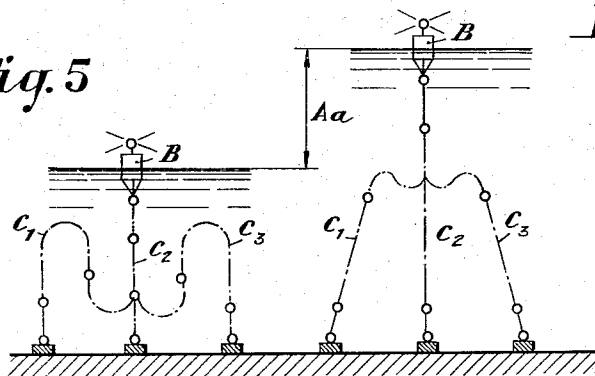
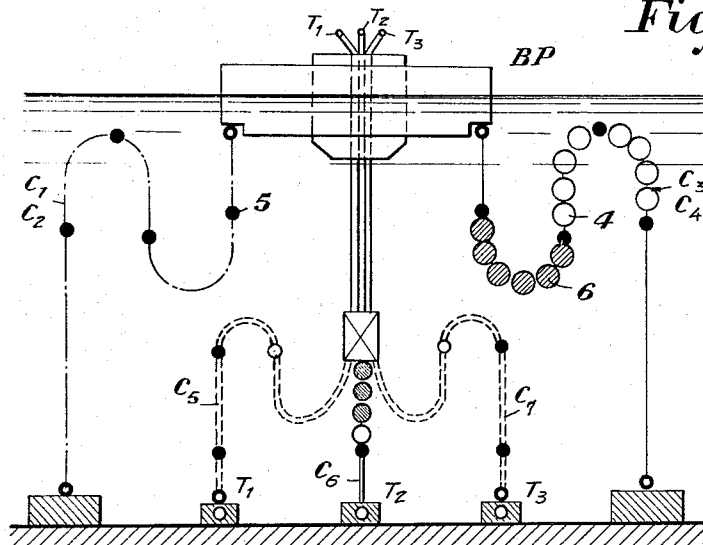


Fig. 6



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13,431/64

10 Claims. (Cl. 114—206)

This invention relates to a marine catenary composed of alternate floating and ballast elements forming, in its complex, an elastic system which may be balanced in its weight, adjustable in its stretch and pattern, as much retractable as it is extendable, so as to respond in the best way possible to dynamic stresses of wave-motion, at any depth. The system is suitable for the anchorage of buoys, floats and watercraft of all sorts and tonnage, as well as for supporting and controlling cables and marine pipelines which may be incorporated therein.

The invention concerns, substantially, a catenary immersed or submerged in the water and composed of a train of solid elements inter-connected in any manner, each having a positive, negative or null weight according to the prevalence of gravity, buoyancy or balance between the forces acting thereon. These elements are arranged, alternated and graded in continuous or discontinuous sets along a predetermined and precalculated pattern, in order to obtain an elastic oscillating system capable of solving any problem of anchorage and support of solid bodies immersed or submerged in the water.

There is, at present, in the marine field, no other catenary system having the above-mentioned features, and even less are there catenary systems which permit the housing, support and control of cables and/or marine pipelines.

The traditional system of catenary for anchorage of buoys and floats comprises, as is well known, one or more chains from the floating member to a dead-body or anchor which lies on the depth, whose pattern is imposed by the law of gravity; chain slack is little greater than the highest waveheight in the neighbourhood.

Such a traditional system, while satisfying anchorage necessities in sheltered coastal waters (i.e. bays, outer-harbours, coves, etc.) and in waters of limited depth, is not suitable for solving the problem of anchorage in open sea with prevailing winds and, even less, in waters of great depth, as progress in marine technique at present categorically imposes for new out-of-harbour or for oceanic installations (e.g. islands, buoys, oil hoses and pipelines, pumping stations for liquids and gases, signalling buoys, shelter buoys and islands, oceanic buoys and islands for navigation and communications, buoys and islands to fix the boundaries of territorial waters, fishing fields and operative zones, etc.).

Furthermore, the traditional system appears expensive and insecure when some other important factors are taken into consideration, i.e. the considerable chain weight requiring the use of floating means of great overall dimensions; the serious trouble in the case of the sanding or entangling and wear of said chains on the sea-bottom, which is a determining motive of tearing and of breakage of anchorage; the impossibility of realizing anchorage in waters of great depth, and the possibility of a single way anchorage only in sheltered docks (harbours, wet basins, etc.); and, lastly, the impossibility of incorporating any cables and/or marine pipelines therein.

The catenary which is the object of the present invention overcomes said disadvantages and solves the new requirements in the art for out-of-harbour or oceanic installations by virtue of the elastic-oscillating system characterizing the invention.

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As mentioned above, the catenary is composed of alternate sets of floating and ballast elements interconnected by means of a chain, metal or plastic rope, as well as by a flexible piping or stiff piping having flexible joints, or by a cable, forming in the assembly an elastic system which may be balanced in its weight, adjusted for tension and pattern, as much retractable as it is extendable in order to respond in the best way possible to dynamic stresses of wave-motion both in vertical and in horizontal directions.

The balancing of ballast weights and buoyancies, the pattern and oscillating amplitude, as well as the resisting cross-section of the catenary are obviously to be calculated on the ground of the following factors, by applying known mathematical formulas relating to marine hydraulics:

Maximum waveheight and wavelength in the neighbourhood;

Maximum speed of wind and marine streams;

Spring and neap tide;

Depth;

Maximum displacement and draft of watercraft or floats or pipelines or cables acting on the catenary;

Special limitations of use.

Additional objects, features and advantages of the present invention will become apparent, to those skilled in the art, from the following detailed description and attached drawings, in which, by way of example, is illustrated, first an embodiment of a one-way catenary for anchorage of a signalling buoy, and then some other possibilities of application.

In the drawings:

FIG. 1 is an elevation view of a catenary connecting a floating member and its dead-body, with a sinusoidal pattern embodying the principles of the present invention, where the signalling buoy is in its position of maximum upward movement relative to the maximum wave during the spring tide.

FIG. 2 is an elevation view of FIG. 1 catenary, with the buoy in its position of maximum downward movement relative to maximum wave during the neap tide.

FIG. 3 is a top view, at sea level, of the same connecting catenary, the arrows being in relation to possible oscillating movements.

FIG. 4 is an elevation view of a compound catenary in a modified embodiment, with several sets of inverted catenary curves, repeated from the buoy to the anchor or dead-body.

FIG. 5 is an elevation view of a further compound catenary embodiment of this invention, comprising three distinct catenaries of FIG. 1, indicated below as a three-way compound catenary, in the end positions relating to maximum oscillation.

FIG. 6 is an elevation view of a compound catenary system in accordance with the present invention, as applied to a buoy and its feeding pipelines, with a four-way compound catenary for anchorage of the buoy and a three-way catenary for elastic connection of the pipelines.

FIG. 7 is an elevation view of a further special utilization of this compound catenary for a pipeline immersed at a predetermined depth.

FIGURES 8 and 9 are schematic cross-sections of a pipeline surrounded by cables and incorporated in this compound catenary.

FIG. 10 shows a floating member directly dockable by watercraft and connected to an anchor or dead-weight through several sets of such catenary curves so as to permit a very large horizontal movement of the floating member.

FIG. 11 is an elevation view of a modified embodiment of the catenary of FIG. 1, with an added intermediate stabilizer formed of a floating element having the func-

tion of providing a more useful virtual depth instead of the true depth of the sea.

Referring now to the drawings, in FIGURES 1 and 2 it will readily be seen that buoy B and its dead-body M are connected by the new compound catenary CA in accordance with the present invention. In this case, the catenary consists of a suitable flexible core 1 surrounded by ballast elements 6 and floating elements 4 which are locked in their predetermined position along core 1 by means of interposed locking elements 5. These locking elements 5 may, in turn, accomplish the function of ballast or floating elements like elements 4 and 6. All these elements are preferably spheric in shape and core 1 passes along the diameter thereof.

Core 1 is connected at one end to revolving head 2 under signalling buoy B and at the other end to revolving head 3 above dead-body M. This arrangement of such catenary elements provides a first catenary curve by means of the ballast elements, i.e. a first catenary curve due to the law of gravity, and a consecutive second catenary curve means of the floating elements, i.e. a second catenary curve due to buoyancy. The two catenary curves are, thus, interconnected and inverted with respect to each other, their cambers clearly being at any moment in relation to the several factors mentioned above.

FIGURES 1 and 2 show these consecutive catenary curves, and also their connection to buoy B and dead-body M at the ends of flexible core 1, in stationary conditions. It will be understood that a proper distribution of elements 4 and 6, as well as locking elements 5, may satisfy not only the two different conditions of spring tide (FIG. 1) and neap tide (FIG. 2), but also any condition with the greatest movements being foreseen in the buoy zone in consequence of prevailing winds. The continuous or discontinuous arrangement of elements 4 and 6 and interposed locking elements 5 may be designed for giving the characteristic sinusoidal shape of the *c-f* portion of the connection assembly capable of taking up all dynamic stresses due to wave motion, both vertically and horizontally, with no possibility of tearing and breaking in any oscillation amplitude of this compound catenary assembly. The assembly, is evidently, elastic, extendable and retractable to satisfy best utilization requirements.

During the pendular movements of the compound catenary assembly, a tension stress is provided, the limit of which is in relation to all ballast weights 6 to be lifted and all floating elements 4 to be lowered against buoyancy, as suggested by calculation and/or experience and considering the casual tensile strength on the catenary assembly.

Another principle of this invention concerns the possibility of subdividing the hydrostatic balancing of the compound catenary in relation to the weight and depth of anchorage, and of adjusting the sinusoidal curve along a predetermined pattern, for example *c-d-e-f*. When height H is established, said balancing may be obtained by a proper distribution of ballast elements 6 and floating elements 4, with additional floating elements 7 if necessary, elements 5 having aforesaid function of locking said main elements along the pattern of compound catenary CA.

Taking distance D between the crests of sinusoid as an harmonic function of the volume of elements 4, 5 and 6 and determinable by calculation, the size, sequence, distribution and assemblage of said elements may be predetermined as follows:

Along section *b-d* ----- $P > S$.
 At *c* ----- $P > S$.
 At *f* ----- $P < S$.
 Along sinusoidal section *b-f* ----- $P_t = S_t - X_1$.
 Along vertical section *f-g* ----- $P_t = S_t - X_2$.
 Along total section ----- $S_t = P_t + X_1 + X_2$.

where:

P is weight acting to a point of this catenary

S is buoyancy acting to that point

P_t is the total weight of elements which load on the section

S_t is the total buoyancy acting in that section

X_1 and X_2 are variable values of balancing or reserve buoyancy being necessary to assure the floatage of sections *b-f* and *f-g* respectively, as components of this compound catenary assembly CA.

The possibility of varying as desired the values concerning the balancing referred to herein as an example of application clearly makes it possible, in turn, to vary the shape of the catenary as required by its use as a connecting assembly between 2 and 3 (FIG. 1). Further, in the case of disengagement from retaining points *b* and *g*, portions *e* of this catenary would surface, in consequence of the reserve buoyancy $X_1 + X_2$.

This feature is very important since, by said balancing, the new catenary assembly, standing alone, may be rendered non-sinkable, and may be submerged at any desired depth by using a dead-body M connected to upward section *f-g*, with the interposition of floating elements 7 or a single stabilizer element S (FIG. 11). The total weight of dead-body M must clearly be greater than the total buoyancy of compound catenary assembly.

Another advantage appears at once to those skilled in the art, and relates to the fact that the floating member, i.e. buoy B in this case, may be completely released from the anchorage weight, if desired. The buoy may, thus, be greatly reduced in size in respect to conventional mooring buoys, and this results in a considerable saving in cost as well as in greater safety, because of the lesser volume exposed to the weather.

The specification and corresponding drawings have so far been concerned with an example of signalling buoy B with one-way anchorage of this new type. The possibilities of application of such a compound catenary assembly are, however, multifarious, and some are schematically illustrated in FIGURES 4-11.

For example, in FIG. 4 the set of two consecutively inverted catenary curves of FIG. 1 is repeated *n* times to give the possibility of a very large horizontal movement to the compound catenary assembly, herein supposed as applied to a retractable oil hose MA. The horizontal movement of buoy B is indicated at E_0 .

The example of FIG. 5 relates to a signalling buoy B with a three-way anchorage, through compound catenaries C_1, C_2, C_3 . This application is suitable for a large vertical movement A_n and a limited horizontal movement.

In FIG. 6, an oil buoy BP is anchored by a four-way compound catenary C_1, C_2, C_3, C_4 , while the connected oil pipelines T_1, T_2, T_3 are supported by a three-way compound catenary C_5, C_6, C_7 .

The submerged pipeline T shown in FIG. 7 is hung in the water at a predetermined depth by means of the catenaries C_1 and C_2 with a connection to the seasurface by a catenary of FIG. 1 type. In this manner, pipeline T has the function of ballast weight 6, while catenaries C_1, C_2 have the function of floating means.

FIGURES 8 and 9 show the cross-section taken on the plane of joints of this compound catenary in two further embodiments. Embodiment of FIG. 8 relates to a compound catenary assembly with a pipeline T, flexible or stiff with flexible joints, placed at the center of assembly and surrounded by cables V and support members 1 which are distributed peripherally. In this embodiment, the function of support for ballast and floating elements 6 and 4 is carried out by pipeline T, while flange FL has the function of a locking element like element 5. Embodiment of FIG. 9 shows another possibility of application of this new compound catenary, the core being formed of cables V and supporting members 1 encircling the same. As in FIG. 8, the whole is surrounded, in a predetermined sequence, by ballast and floating elements 6 and 4, respectively. FL indicates the joint flange for this assembly.

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FIG. 10 shows a compound catenary assembly in which the two inverted catenary curves of FIG. 1 are repeated n times to permit of a very large extension E_0 . Mooring to buoy B may thus be accomplished directly by the watercraft by means of a hook G.

The compound catenary assembly shown in FIG. 11 for connecting floating member B and dead-body M is particularly suitable for anchorage in deep sea. True depth TD is herein assumed as being replaced by a virtual depth VD at the lower end of the compound catenary, since a special floating member S is interposed between the lower end for core 1 and dead-body M. Member S is a stabilizer which replaces, in turn, the dead-body for said lower end of catenary CA, in order to assure the advantages mentioned above.

While specific embodiments of the invention have been shown and described in detail to illustrate some possibilities of application of the inventive principles, it will be understood that the invention may be embodied in many other ways to solve the most complex problems of anchorage and support in the marine field as well as in the river or lake field, without departing from such principles.

I claim:

1. A compound marine catenary assembly for anchoring an object in a body of liquid, comprising an elongated flexible support having an upper end adapted to be connected to the object which is to be anchored and having a lower end distant from the object, an anchor connected to said lower end of said flexible support, and means carried by and distributed along said flexible support for providing the latter between said upper and lower ends thereof with a predetermined sinusoidal configuration having at least one lower catenary curve followed by at least one upper catenary curve opposed to said lower catenary curve, said means distributed along and carried by said flexible support including a plurality of ballast elements situated at said lower catenary curve and a plurality of float elements situated along said upper catenary curve, said float elements tending to rise in the body of liquid and said ballast elements tending to sink in the body of liquid, and said ballast and float elements which are distributed along said lower and upper curves, respectively, having with respect to each other a state of equilibrium providing the sinusoidal configuration for said flexible support.

2. The combination of claim 1 and wherein a plurality

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of locking elements are carried by said flexible support for locking said ballast and float elements at predetermined locations thereon.

3. The combination of claim 1 and wherein said ballast elements and said float elements form two groups of elements, and said lock elements functioning as part of at least one of said groups.

4. The combination of claim 1 and wherein additional float elements are connected to said flexible support and distributed there along in the region of said anchor.

5. The combination of claim 1 and wherein said means carried by and distributed along said flexible support provides the latter with at least two sets of consecutive opposed catenary curves, each set comprising one of said lower catenary curves followed by one of said upper catenary curves and said ballast elements being carried by said lower curves while said float elements are carried by said upper curves.

6. The combination of claim 1 and wherein a plurality of said flexible supports respectively have upper ends connected to the object and lower ends distant therefrom, a plurality of anchors connected to said lower ends, and a plurality of said means carried by and distributed along said supports, respectively, for providing the latter with said sinusoidal configurations, respectively.

7. The combination of claim 1 and wherein said ballast elements and float elements are respectively formed with openings through which said flexible support extends.

8. The combination of claim 1 and wherein a cable is connected with said ballast and float elements.

9. The combination of claim 1 and wherein a pipe is connected to and extends along said flexible support.

10. The combination of claim 1 and wherein a stabilizer is connected with said flexible support between said anchor and said means providing said support with said sinusoidal configuration, for stabilizing in the body of liquid a portion of said flexible support situated above said anchor between the latter and said means.

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T. M. BLIX, *Assistant Examiner*.