Feb. 2, 1971 G. S. LOCKWOOD, JR., ET AL 3,559,223

LONG SPAR BUOY CONSTRUCTION AND MOORING METHOD

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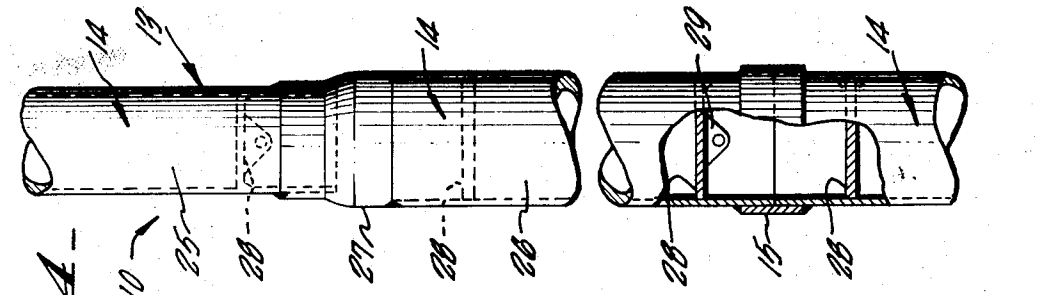


FIG. 4

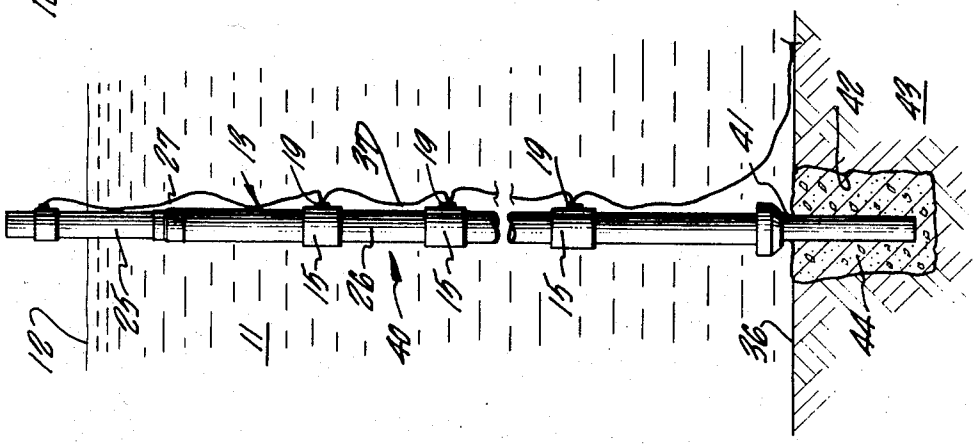


FIG. 3

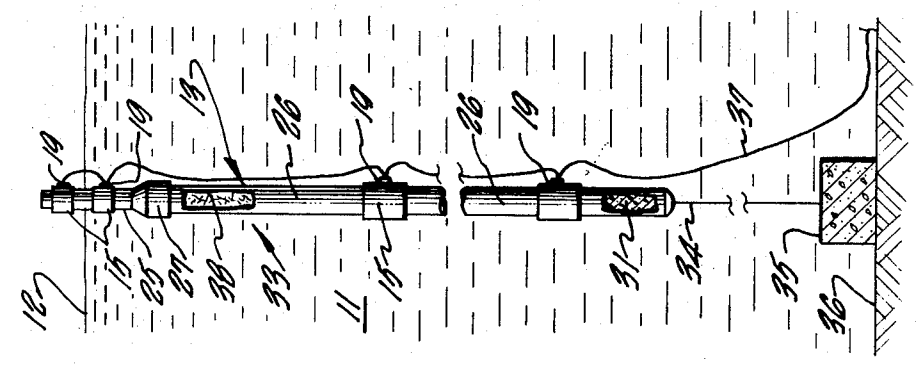


FIG. 2

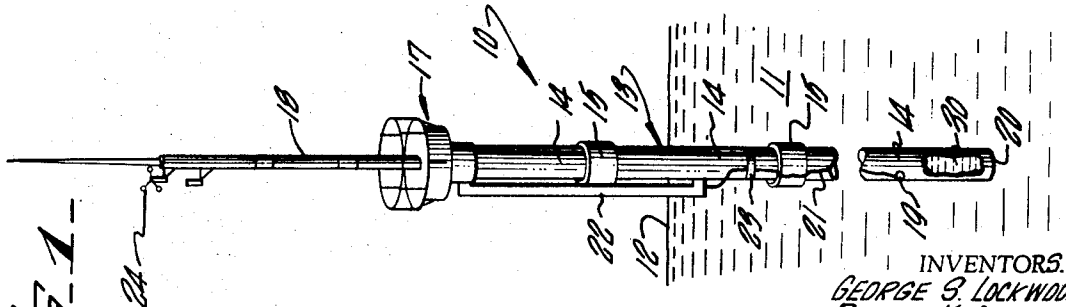


FIG. 1

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FIG_8_

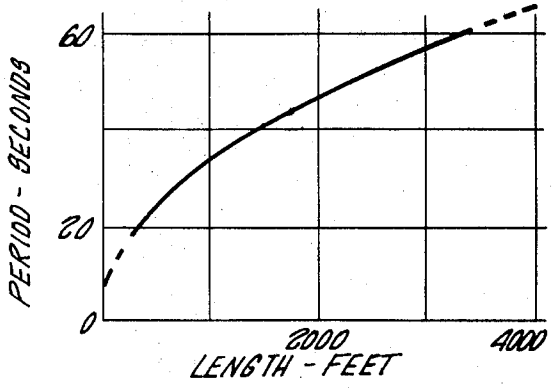


FIG_5_

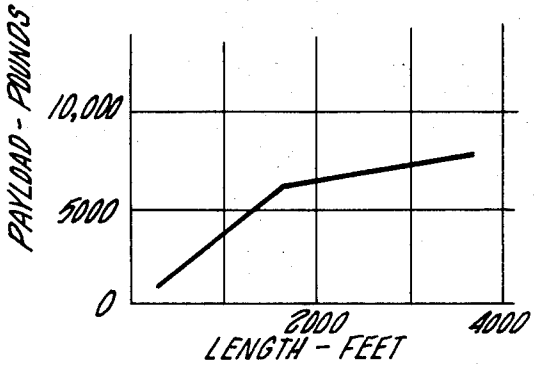


FIG_10_

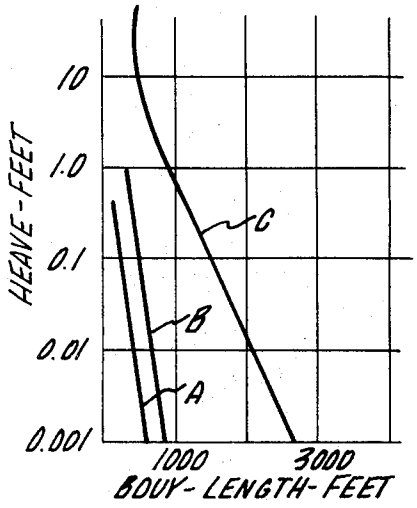


FIG_6_

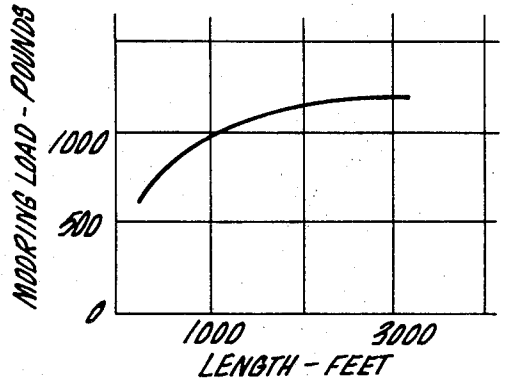
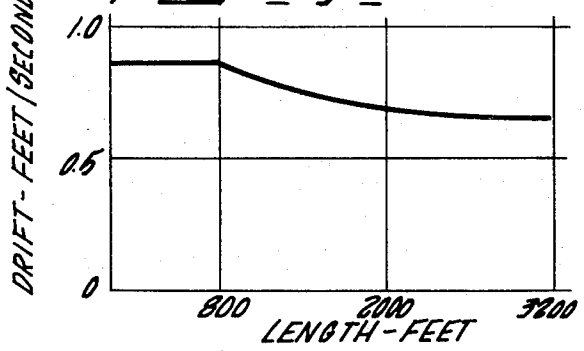


FIG_9_



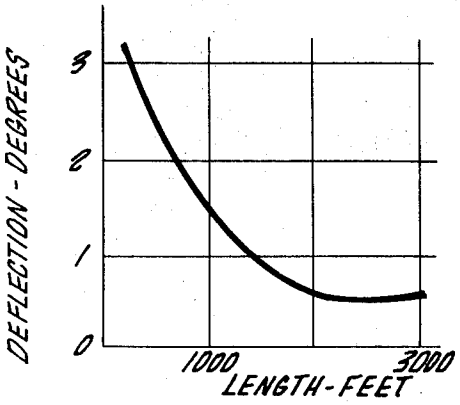


FIG_7_

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FIG 11

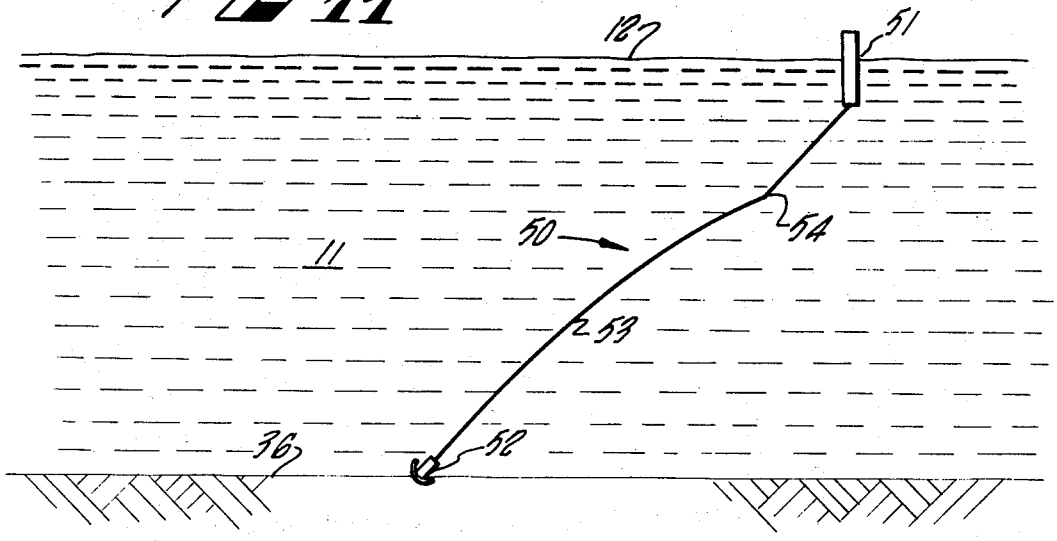
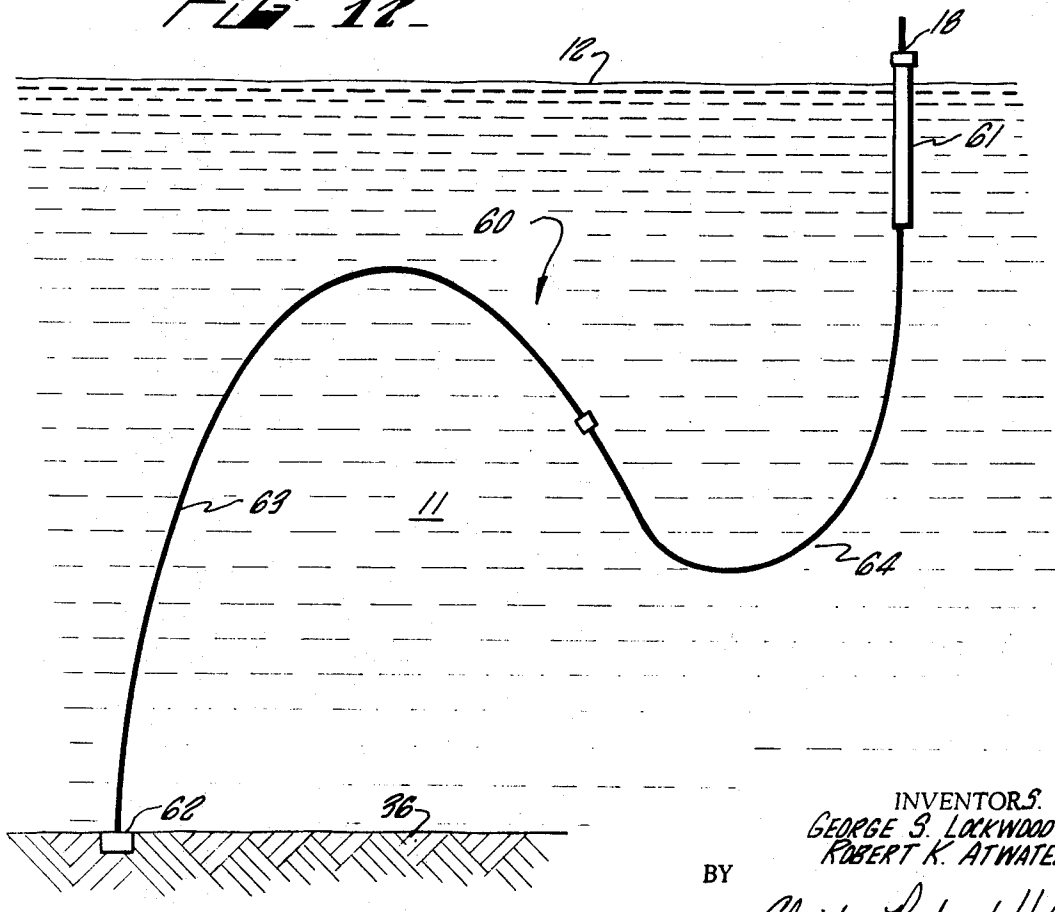


FIG 12



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LONG SPAR BUOY CONSTRUCTION AND MOORING METHOD

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Continuation of application Ser. No. 548,566, May 9, 1966. This application July 30, 1969, Ser. No. 863,402

Int. Cl. B63b 21/26, 21/52

U.S. Cl. 9—8 5 Claims

ABSTRACT OF THE DISCLOSURE

A positively buoyant long spar buoy having a length of at least about 100 feet and a maximum body diameter of about 36 inches, the body being fabricated of lengths of pipe rigidly connected in end-to-end relation, the body including anti-flooding means adjacent each interpipe connection and being ballasted to float upright with a selected minor portion of its length out of water.

This application is a continuation of application Ser. No. 548,566 filed May 9, 1966 and now abandoned.

This invention relates to a novel marine buoy and to a method for mooring the buoy for minimum loading on the buoy.

There presently exists a significant need for increased knowledge about the earth's oceans and about the weather over the oceans. Such information is required both for military purposes and for commercial purposes. For example, military personnel, seeking to improve or accurately predict sonar performance, require data regarding the existence of thermoclines. Oceanographic data is required to determine the existence and location of profitable undersea mining areas and undersea agricultural areas, as well as to predict optimum shipping routes. In the latter instance, optimum routing of surface vessels to avoid adverse sea-state conditions can increase the efficiency of shipping by approximately 20%. A 20% increase in efficiency is equivalent to approximately a 100% increase in ship horsepower.

Proper instrumentation of the ocean is a major problem in acquiring reliable data regarding the ocean and its weather. Ideally, the instrument platform or vehicle should be relatively motionless, rugged and low in cost. The use of conventional surface buoys to carry measuring instruments is not satisfactory since a surface buoy responds directly to wind and wave action. As a result, the sensitive instruments required for oceanographic measurements are continuously subjected to adverse dynamic loadings when mounted on surface buoys. Moreover, where the instrument vehicle is a surface buoy, wind and wave action causes the buoy to move rapidly from its desired location unless the buoy is moored in position. Movement of a surface buoy across the ocean surface can be avoided successfully by mooring the buoy to the ocean bottom if the mooring system is capable of withstanding the extreme sea condition loads imposed upon the buoy. Complicated and costly mooring systems must be used with surface buoys, particularly where water depth is great.

This invention provides a novel buoy which is particularly suited for use as a vehicle for oceanographic instrumentation. The buoy provides an instrumentation platform which is relatively motionless even in a severely agitated sea. The buoy is rugged and exceptionally low in cost. Moreover, such a buoy may be moored easily and satisfactorily by a simple and economic mooring system provided by this invention. The buoy has a feature that it may provide a secure mounting platform for a plurality of instruments spaced apart from each other over

a considerable distance vertically through the ocean adjacent the ocean surface.

Generally speaking, this invention provides a surface piercing buoyant marine structure which is of a type referred to herein as a long spar buoy. The buoy has an elongate, substantially hollow tubular body having a length many times greater than the maximum transverse dimension of the body. The body is comprised of a plurality of substantially identical hollow tubular members. The buoy includes means for connecting the tubular members together in end-to-end relation. Watertight bulkhead means are provided transversely of the interior of each tubular member adjacent each end thereof for preventing flooding of the member in the event of leakage of the adjacent connecting means. Ballast means are carried by the body adjacent one end thereof for causing the buoy to have a center of gravity closer to the one end of the body than the center of volume of the portion of the body lying within a body of water within which the buoy may be disposed.

Also, in combination with a long spar buoy having a low increase in displacement per foot of increased draft, this invention provides a novel mooring system for mooring the buoy in a body water. The mooring system comprises an anchor for engaging the bottom of the body of water at a desired location. A length of buoyant cable is secured at one end to the anchor. A length of non-buoyant mooring cable, having a substantially uniform weight per foot of length, is secured at one end to the other end of the buoyant cable. The other end of the non-buoyant cable is adapted to be secured to the lower end of the buoy.

The above-mentioned and other features of the present invention are more fully set forth in the following detailed description of the invention, which description is presented with reference to the accompanying drawings, wherein:

FIGS. 1, 2 and 3 are views of spar buoys in accord with this invention;

FIG. 4 is an enlarged view, in partial cross-section, of a portion of a spar buoy;

FIGS. 5, 6, 7, 8, 9 and 10 are graphs setting forth various physical characteristics of a family of spar buoys;

FIG. 11 is an elevation view of a spar buoy mooring system; and

FIG. 12 is an elevation view of another spar buoy mooring system.

In the following description and in the accompanying drawings, identical numbers are used to indicate identical or substantially identical elements of structure in the several buoys illustrated.

A surface piercing long spar buoy **10** is shown in FIG. 1 floating vertically in a body of water **11** having a free surface **12**. The buoy has an elongate substantially hollow body **13** comprised of an indeterminate number of similar elongate tubular elements **14**. The tubular elements preferably are fabricated from sections of oil well drill pipe or well casing pipe; each pipe section is as long as is convenient and practicable, say from 20 to 40 feet. The pipe lengths are essentially rigidly secured together in end-to-end relation by pipe coupling collars **15**. Preferably, the ends of the pipe lengths are welded to the collars. If desired, however, the ends of the pipe lengths may be accurately machined to define precision threads which are screwed into similar threads machined on the interior of each collar. An epoxy thread-sealing compound is applied to the threads just before the joint is made up and cures in the assembled joint. As a result, the joints between adjacent pipe lengths are made up watertight to seal the interior of the buoy.

A platform **17** is carried by the uppermost pipe length in the body of buoy **10** above water surface **12** and mounts a radio antenna **18**. The antenna is coupled to a

suitable transmitter (not shown) located within the buoy adjacent the platform for transmission of radio signals to a remote receiving station. It will be understood, however, that any desired payload other than, or in addition to the antenna and the transmitter may be carried by the buoy on the platform or elsewhere on or in the buoy. A suitable oceanographic instrument transducer **19** is carried on the exterior of the buoy adjacent its lower end **20**. The transducer is coupled to the transmitter by a signal transmission conductor cable **21** which extends upwardly along the exterior of the buoy to a guide sleeve **22**. The sleeve extends downwardly from platform **17** to an open lower end below water surface **12**. The cable is secured to the buoy at selected locations along the length of the buoy by straps or bands **23**. Also, the antenna mounts additional transducers, such as a wind velocimeter **24**, for monitoring weather conditions over the water in which the buoy floats.

The spar buoys shown in FIGS. 1, 2 and 3 have lengths which are many times greater than their diameters. A buoy in accord with this invention may have a length of from about 100 to 3200 feet or more and the pipe lengths from which the buoy is constructed may have a diameter of from 4 to 24 inches, or even 36 inches. Where the buoy is of considerable length, the lower sections of the body may be fabricated from stronger sections of pipe than are used for the upper buoy sections. Consistent with the hydrostatic loads imposed upon the buoy, it is desired that the buoy be as light in weight as possible to maximize its buoyancy and to minimize the cost of the materials used in its construction. For example, the pipe lengths used to construct the uppermost portion of the length of buoy **10**, such as pipe lengths **25** shown in FIG. 4, may have a 10.75 inch outer diameter and an inner diameter of 10.192 inches and be of H–40 grade steel. Such pipe may be used to fabricate the upper thousand feet of buoy. Below 1000 feet, however, because of the pressure which the water outside the buoy exerts upon the buoy tending to collapse the pipe, stronger pipe sections must be used. Accordingly, the next portion of the length of the buoy, down to approximately 2000 feet from the water surface, is fabricated of larger diameter pipe **26**, or heavier wall pipe or pipe made from higher grade steel, or a combination of these variations. Pipe lengths **26**, for example, may have an outer diameter of 13.375 inches and inner diameter of 12.615 inches and be fabricated of J–55 grade steel. Below 2000 feet, the pipe used to define buoy body **13** may have an outer diameter of, say, 13.375 inches and an inner diameter of 12.515 inches. Where the outer diameters of adjacent pipe lengths change across a connection in the length of the buoy, a bell reducer connector **27** is used, as shown in FIG. 4. It will be understood, however, that in many cases the lower or an intermediate portion of the buoy need not be buoyant, and in instances, the non-buoyant portions of the buoy may be made of small diameter pipe.

In view of the usual extreme length of the long spar buoys described herein, the buoys are subjected to considerable lateral loading in use by ocean currents and by wind and wave action upon the buoys. Since the buoys may tend to rotate in use, these lateral loadings, particularly the current loadings, induce the buoys to flex cyclically. such cyclic flexing may cause the joints between adjacent pipe lengths to leak. Accordingly, each tubular element, i.e., pipe length, used in fabricating a long spar buoy is provided with a bulkhead plate **28** adjacent each of its ends. Each bulkhead plate is disposed across the interior of the pipe and is welded about its periphery to the walls of the pipe to provide a watertight seal across the interior of the pipe. If a connection between adjacent lengths of pipe should leak, the buoy will flood only to the extent of the volume defined between the bulkhead plates on opposite sides of the joint. If desired, a lifting pad **29** may be welded to one of the bulkheads on each length of pipe so that the pipe may be handled conveniently after the bulkheads have been installed and prior to interconnection of the pipe lengths.

Since it is desired that buoy **10** float with a portion of its length, say 25 feet, projecting above water surface **12**, and since the buoy, in terms of its length, is of substantially constant external diameter along its length, it is necessary to ballast the buoy at its lower end so that the buoy has its center of gravity located below its center of buoyancy. If this relationship is not maintained, the buoy becomes unstable and will not float vertically. (Buoys **33** and **40**, shown in FIGS. 2 and 3, respectively, must possess the same stability characteristics.) Accordingly, a selected length of the buoy at and adjacent its lower end is filled with ballast, such as water **30** shown in FIG. 1 relative to buoy **10**, or concrete **31** shown in FIG. 2 relative to buoy **33**. Sand, steel shot, or other dense materials may also be used to advantage as ballast.

FIG. 2 shows an anchored spar buoy **33** fabricated in accord with the foregoing description. A mooring cable **34** is secured to the lower end of the buoy and extends to an anchor **35** resting on the bottom **36** of body of water **11**. A plurality of oceanographic instrument transducers **19** are carried by the buoy at selected locations along its length and are connected together by a cable **37**. Buoy **33**, however, does not include a platform **17** for mounting a radio antenna or the like. Accordingly, cable **37** is strung downwardly from the buoy to the sea bottom and extends away from the buoy to a suitable instrument metering station located either at shore or at a suitable submerged location remote from the buoy. Transducers **19** may be identical or they may be of different types for sensing different conditions within the body of water. By way of example rather than limitation, the transducers may be provided for sensing temperature, sound or water velocity, electrical conductivity, radioactivity, ambient light, water turbulence, water pressure, magnetic fields, seismic energy or acoustic transmission within the body of water.

FIG. 2 shows another anti-flooding mechanism which is used in long spar buoys according to this invention. The pipe lengths in the upper portion of buoy **33**, as well as of buoys **10** and **40**, are filled with foamed-in-situ closed cell plastic foam material **38**. The foamed material preferably is low density, high pressure polystyrene foam or polyurethane foam. The foam cures to an essentially rigid state and prevents the inner volume of the pipe sections from flooding if a joint should leak or if a leak develops in a pipe section between joints. Flooding of a single pipe section in the upper portion of a long spar buoy could result in the buoy becoming unstable; such a result cannot occur if a pipe section below the center of gravity of the buoy becomes flooded. Also, the foam is so light that its presence in the buoy does not cause an appreciable rise in the buoy's center of gravity. If foamed plastic is installed within the lower portions of the buoy to check flooding, the foam also provides a lightweight device for resisting collapse of the buoy because of hydrostatic pressure outside the buoy. The foam material preferably is used in lieu of bulkheads **28**, but it may be used in combination with the bulkheads if desired.

In many instances, it may be desired to provide a spar buoy which cannot move from a desired location in response to ocean currents or the like. Such a buoy normally is desired for use in relatively shallow depths of water, such as depths of water up to 3000 feet. FIG. 3 shows a buoy **40**, in accord with the foregoing description, which has a lower extension **41** disposed in a hole **42** formed in a geological formation **43** underlying body of water **11** and secured in place in the hole by cement **44** or the like.

FIGS. 5–10 are graphs showing the variations in certain characteristics of long spar buoys fabricated of 13.375 inch pipe with variations in buoy length. FIGS. 5, 6 and 7 which show, respectively, the natural vertical oscillatory

period, the heave in various wave trains, and the angular deflection (i.e., heel or list) of long spar buoys as a function of the length of the buoy, expressed in feet, are of particular interest. FIG. 5 shows that as the length of the buoy increases, the natural vertical oscillatory or heave resonance period of the buoy increases non-linearly. It will be apparent that the input to the buoy inducing heave is directly related to the wave trains passing the buoy. The longer the wave train, the greater the period between successive heave-inducing inputs to the buoy.

Curve A in FIG. 6 describes the heave amplitude of a 13.375 inch outer diameter spar buoy in a 10 foot by 12 second wave train, i.e., a wave train in which the trough-to-peak height is 10 feet and a wave crest passes a fixed point every 12 seconds. Curve B describes the heave performance of such a buoy in a 25 foot by 12 second wave train, and curve C relates the performance of such a buoy to a 50 foot by 20 second wave train. Curve C shows that in a 50 foot by 20 second wave train, such a buoy 600 feet long will have a heave amplitude of 4.7 feet, a buoy 1200 feet in length will have a heave amplitude of 3 inches, and a buoy 3200 feet in length will have a heave amplitude of less than $\frac{1}{100}$ of an inch. It is apparent, therefore, that a buoy according to this invention can be provided to have any heave characteristic desired. As a result, such buoys can be made extremely stable regardless of the severity of the sea-states to which they must be subjected. Such buoys are ideal for use as vehicles or platforms for oceanographic instrumentation arrays.

As an alternative to extending the length of the buoy to reduce heave amplitude, the cross-sectional area of the buoy at some point below the water surface may be made a selected amount larger than the diameter of the buoy at the water surface. If such an expedient is to be used, it is preferred that circular anti-heave plates, rather than elongated, extra large cylindrical sections of buoy body, be used. Such plates function in a manner analogous to dash pots to oppose induced heave motions.

FIG. 7 described the angular deflection (heel or list) of the upper end of a 13.375 inch diameter rigid long spar buoy relative to a vertical reference line through the lower end of the buoy in response to the combined action of sea currents, and wind and wave forces applied to the upper end of the buoy as well as lateral components of mooring forces applied to the buoy; it will be understood that bending of the buoy along its length will be superimposed upon the deflection represented by FIG. 7. The sea conditions relating to FIG. 7 are 100 knot winds, 25 foot waves, and ocean currents like those found in the "*Thresher* Search Area." In the *Thresher* Search Area, ocean currents in the first thousand feet of water below the ocean surface are substantially uniform at .9 feet per second. Below 1000 feet, ocean currents are substantially uniform at about .4 feet per second. The angular deflection of the buoy, as well as the lateral movement of the upper end of the buoy in response to the action of wave trains alone, is of concern where the buoy is to be used as a supporting vehicle for an oceanographic instrumentation array, particularly where the buoy carries an above-surface transmission antenna. Angular deflection and lateral movement of the upper end of the buoy has an effect upon the effectiveness of signal transmission from the antenna. FIG. 7 shows that the angular deflection of the upper end of the buoy decreases with increasing buoy length.

As shown in FIG. 8, the payload capacity of a long spar buoy (considered as a function of buoyancy before ballasting the buoy) does not increase linearly with buoy length since heavier pipe sections must be used in the lower portions of longer buoys to resist hydrostatic collapse pressures. The buoyancy, and thus the payload capacity of a long spar buoy is dependent upon the submerged length of the buoy and its diameter. For example, a 3200 foot buoy 16.00 inches in diameter has a payload capacity of 14,500 pounds, whereas the same length buoy 13.375 inches in diameter has a payload capacity of about 8000 pounds. Because ballast usually is required to impart stability to a long spar buoy, it is preferred that concrete ballast be used since it is more dense than water and a smaller mass of concrete, producing a smaller offset against payload capacity than water, produces the desired gravity correction more effectively, in terms of buoy payload capacity, than water ballast.

The resistance of a long spar buoy to drift through the ocean in response to ocean currents is greater than for buoys which are located essentially entirely at the water surface. For example, if a 3200 foot, 13.375 inch long spar buoy were placed in the ocean in the area where the SSN 593 *Thresher* sank, it would drift only .4 mile per hour, whereas a conventional surface buoy would drift .9 mile in the same time. The lower drift rate of a long spar buoy is attributable to the presence of a significant portion of the length of the buoy in the lower reaches of the ocean where currents are not as strong as near the surface. In mid-ocean, rather than adjacent a continent, where currents generally are strongest, an unmoored long spar buoy would remain within a relatively small area of the ocean for several months. The research vessel FLIP, which has a length of only 300 feet, had a mid-ocean drift of only 60 miles in 30 days.

FIG. 9 shows the effect of buoy length, again for a 13.375 inch diameter buoy, upon drift for a buoy subjected to ocean currents like those in the *Thresher* Search Area.

Because a long spar buoy has a cross-sectional area which is very small relative to its submerged volume, and because such a buoy has vertical walls, it has a very low figure of increased buoyancy per increased foot of draft and a very high figure of increased draft (in feet) per pound of increased load. For this reason, long spar buoys show a pronounced increase in draft as vertical loads on the buoy are increased. As a result, because of their sensitivity to vertical loads, long spar buoys present unique mooring problems. For example, a 13.375 inch diameter buoy will sink about one foot for every 60 pounds additional vertical load. Conventional mooring systems, which impart large vertical loads on the moored object in proportion to the lateral constraining force applied to the object, cannot be used with long spar buoys such as buoy **10** which carries a radio transmission antenna at its upper end.

On the other hand, long spar buoys, as shown in FIG. 10, permit the use of mooring systems which exert little force in a horizontal direction, as compared with conventional surface buoys. FIG. 10, relating to a long spar buoy 13.375 inches in diameter, shows the variation with buoy length in the force which must be applied horizontally to the buoy to keep the buoy in a selected position in the ocean when the buoy is subjected to 100 knot winds, 35 foot waves and ocean currents like those encountered in the *Thresher* Search Area. While such is not apparent from the graph of FIG. 10, a 3200 foot, 13.375 inch buoy moored in 100 knot winds, 35 foot by 8 second waves, and *Thresher* Search Area currents, would experience average static horizontal mooring loads of about only 1480 pounds; a conventional surface buoy of like capacity would require a mooring system capable of withstanding an average static horizontal load of about 40,000 pounds. Vertical mooring loads for long spar buoys are essentially negligible because of the negligible heave of such buoys.

The curve shown in FIG. 10 was obtained by assuming that the buoy is flexible and follows, by a factor of from one-third to one-half, the horizontal displacement of a water particle in a wave train, the actual displacement of a water particle varying with the average depth of the particle below the water surface.

From the foregoing discussion of the mooring characteristics of a long spar buoy, it is apparent that conventional mooring systems cannot be used with such buoys.

Accordingly, this invention provides a novel mooring system and method for use with long spar buoys. FIG. 11 shows a mooring system **50** for a long spar buoy **51** moored in body of water **11**, such as an ocean. The system includes an anchor **52** which rests on the ocean floor and is connected to one end of a length of positively buoyant mooring cable **53**. Cable **53** preferably has a uniform weight per foot. A length of non-buoyant mooring cable **54**, preferably having a substantially uniform weight per foot, is connected between cable **53** and the lower end of the buoy. If the water depth over the anchor is 3000, cable **53** may be provided by a 10,000 foot length of 1½ inch polypropylene cable. Cable **54** may be a 2000 foot length of ½ inch steel cable. Steel cable is preferred over weighted polypropylene cable in the upper portions of the mooring system because sharks have been found to have an appetite for polypropylene. The anchor may be a 5000 pound mushroom anchor. Mooring system **50** has the feature that the vertical component of mooring load, this component being fully imposed upon the buoy, is small over the range of horizontal mooring load components sustained by the system.

FIG. 12 shows a presently preferred mooring system **60** for use with buoy **61**. The system comprises an anchor **62**, a length of buoyant mooring cable **63** connected to the anchor, and a length of non-buoyant mooring cable **64** connected between the anchor and the buoy. The cables preferably have substantially uniform weights per foot of length and are substantially equal in length. Also, the total length of the cables is substantially greater than the depth of water over the anchor, although neither length is as long as the water is deep over the anchor. A metallic cable is preferred for cable **64**. When system **60** is subjected to a horizontal load of 1000 pounds, the vertical load imposed upon the buoy is only 630 pounds. The positive buoyancy of cable **63** should be equal to the negative buoyancy of cable **64**. The natural catenaries of the cables in the system result in minimal increase in vertical load upon the buoy for an increase in the horizontal load imposed upon the mooring system.

Mooring system **60** has several beneficial features. When used with a long spar buoy, none of the cables of the system is in the portion of the ocean closely adjacent the water surface. The mooring system, therefore, is safe from shark bite hazards. Sharks readily bite through mooring cables of surface buoys, and such action by sharks poses a serious problem in the mooring of surface buoys and the like. System **60** provides a spring action on buoy **61** which acts to return the buoy to over the anchor after the buoy has been moved laterally by a storm or the like. The non-buoyant cable keeps the buoyant cable from the water surface, and the buoyancy of cable **63** prevents bottom fouling of this cable. All these features are provided in a mooring system which effectively restricts movement of the buoy from a desired location in the ocean.

Both mooring systems described benefit from the low heave characteristics of long spar buoys. Because the buoys do not heave appreciably, the loading upon the associated mooring system is essentially constant and any cyclic loads are of low magnitude relative to the average static loading of the system. As a result, the components of the mooring systems do not fatigue.

The invention has been described above by reference to certain structural arrangements which have been presented merely by way of example in furtherance of a complete and comprehensive explanation of the invention. It will be realized that these examples do not encompass all forms which the invention may take, and that the structures described may be altered or modified without departing from the scope of the invention. Accordingly, the foregoing description is not to be regarded as limiting the scope of the invention.

What is claimed is:

1. A long spar buoy comprising an elongate substantially hollow and positively buoyant body having a length many times greater than the maximum transverse dimension thereof, the body being comprised of a plurality of substantially identical tubular members having a maximum diameter of about thirty-six inches, the body having a length greater than about one hundred feet, means connecting the members together in end-to-end relation, watertight bulkhead means transversely of the interior of each member adjacent each end thereof for preventing flooding of the member in the event of leakage of the adjacent connecting means, and ballast means carried by the body adjacent one end thereof for causing the buoy to have a center of gravity closer to the one end thereof than the center of volume of the portion of the buoy lying within a body of water in which the buoy may be disposed.

2. A long spar buoy according to claim **1** wherein said tubular members are lengths of pipe and all of the lengths of pipe in said plurality have an outer diameter in the range of from about four inches to about thirty-six inches.

3. In combination with a long spar buoy adapted to float vertically in a body of water with its upper end disposed above the surface of the water and having substantially no vertical heave in response to passing waves and a low factor of increase in displacement per foot of increased draft, a buoy mooring structure comprising an anchor for engaging the bottom of the body of water at a selected location on the bottom, a length of buoyant mooring cable secured at one end thereof to the anchor, and a length of non-buoyant mooring cable of substantially uniform weight per foot of length secured at one end to the other end of the buoyant cable and secured at its other end to the lower end of the buoy, the buoyant and non-buoyant cables being substantially equal in length and having a combined length which is substantially greater than the depth of water over said location.

4. The combination of claim **3** wherein the positive buoyancy of the buoyant cable is substantially equal to the negative buoyancy of the non-buoyant cable.

5. In combination with a long spar buoy having sufficient length and sufficiently high ratio of length-to-diameter that the buoy floats vertically in a body of water with its upper end disposed above the surface of the water, the buoy manifests substantially no vertical motion in response to waves moving past the buoy across the water surface, and the buoy has a low factor of increase in displacement per foot of increased draft, a buoy mooring structure consisting of an anchor for engaging the bottom of the body of water at a selected location on the bottom, a length of buoyant mooring cable secured at one end thereof to the anchor, and a length of non-buoyant mooring cable of substantially uniform weight per foot of length secured at one end to the other end of the buoyant cable and secured at its other end to the lower end of the buoy, the buoyant and non-buoyant cables being substantially equal in length and having a combined length which is substantially greater than the depth of water over said location.

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