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Dow

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[54] **NEUTRALLY BUOYANT INSTRUMENT SUSPENSION**

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[52] **U.S. Cl.** ..... **340/8 S**

[51] **Int. Cl.** **H04b 13/00**

[58] **Field of Search** ..... 390/8, 8 S, 10, 11, 390/12, 13; 61/46.5

[56] **References Cited**

UNITED STATES PATENTS

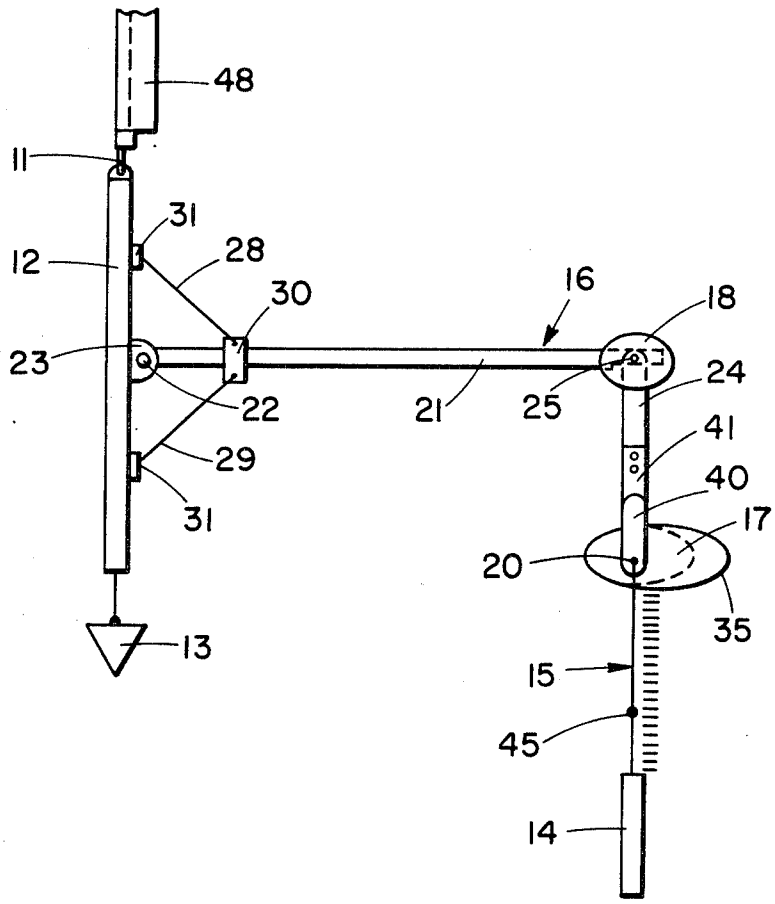
3,027,539	3/1962	Stillman, Jr.	340/8 S
2,895,300	7/1959	Hayward	61/46.5
3,563,335	2/1971	Holmes	340/8 S
2,837,727	6/1958	Mayes	340/8 S
3,471,828	10/1969	Fredenburg	340/8 R
2,646,950	7/1953	Nelson et al.	340/8 S

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Assistant Examiner—H. J. Tudor
Attorney—R. S. Sciascia et al.

[57] **ABSTRACT**

A hydrophone stabilizing device in which the hydrophone is maintained in neutral buoyancy and in a stabilized attitude during low speed tow and while tethered is provided. The hydrophone is suspended about the center of buoyancy of a major flotation member and is maintained in a stabilized attitude by the linkage of supporting arms which are selectively pivotable in the plane of the tow line. A smaller float is positioned at the intersection of the immediate vertical supporting arm and an intermediate arm or boom connecting the supporting arm to a vertical strut to assure that the point of intersection of the arms is always above the hydrophone.

12 Claims, 5 Drawing Figures



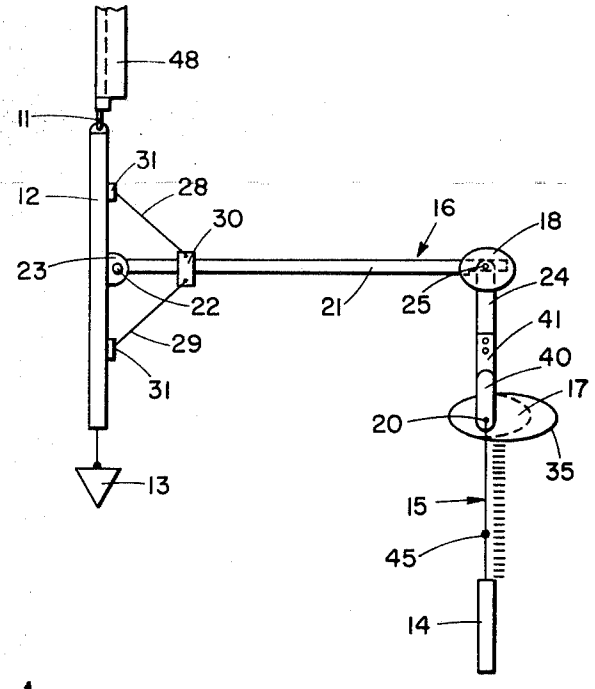

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Fig. 1

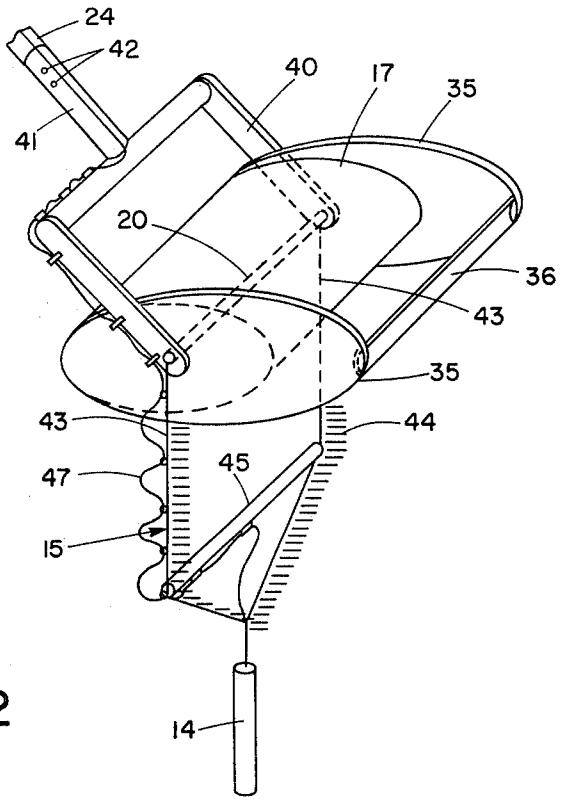

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Fig. 2

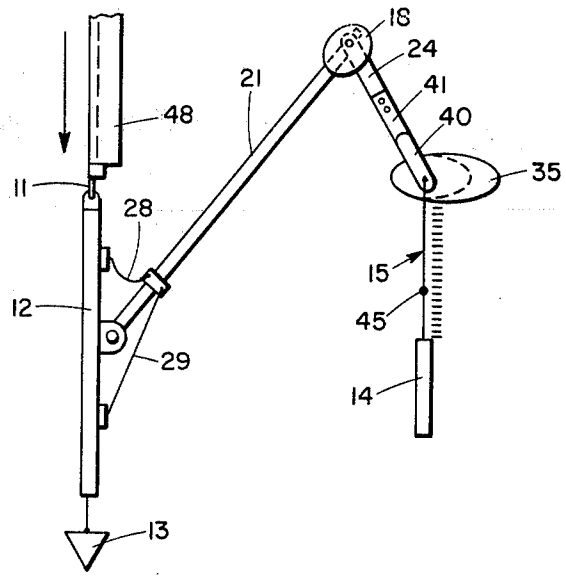

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Fig. 3

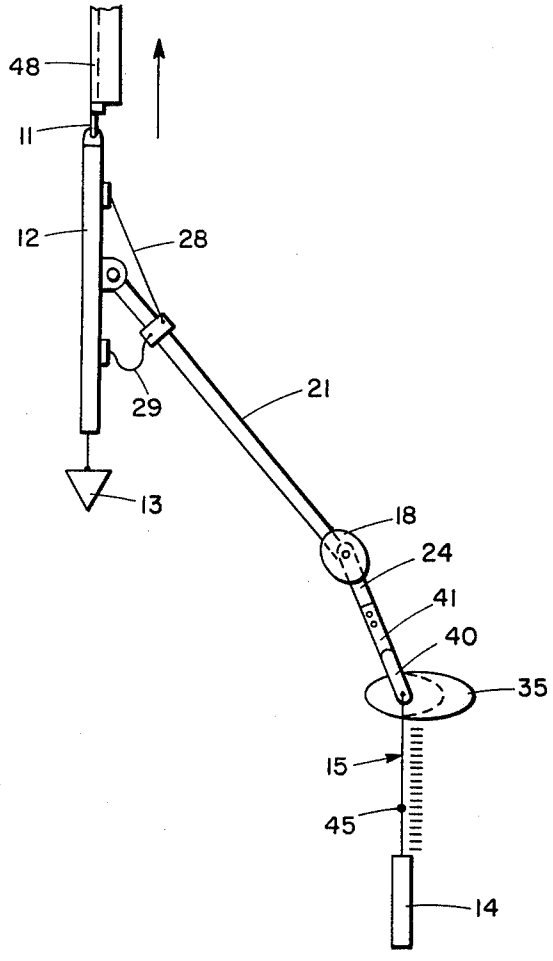

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Fig. 4

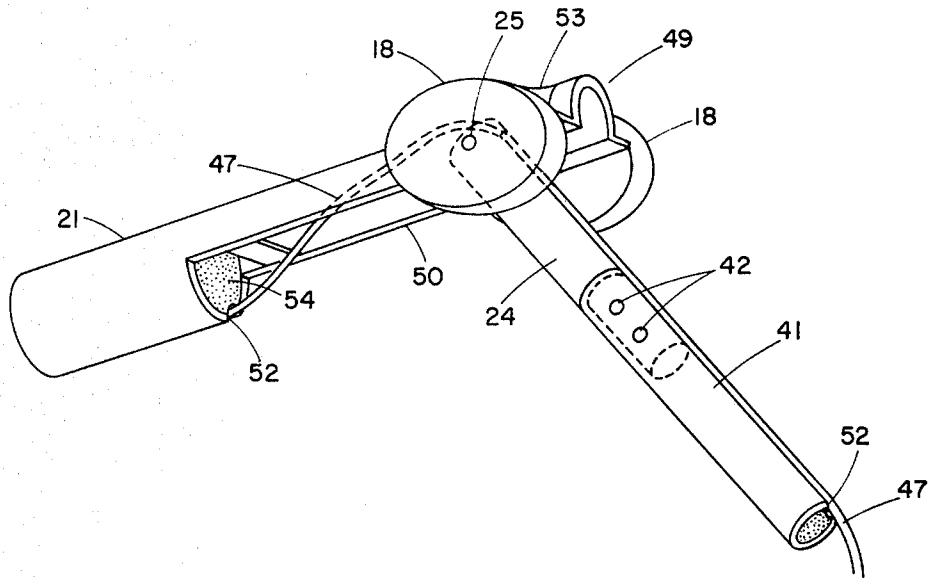


Fig. 5

NEUTRALLY BUOYANT INSTRUMENT SUSPENSION

This invention relates to oceanographic instrumentation and, more particularly, to a system for stabilizing a hydrophone in a fluid environment while suspended in a stationary fluid or a current, or under tow at low speed.

In oceanographic operations, much information is obtained through the use of hydrophones which are either deployed statically in the fluid environment or which may be moved through the water at low speed to monitor various signals and echos. When hydrophones are either moved through the water or suspended in a listening mode from a means of support which is in motion such as a rolling or pitching surface vessel, turbulence is encountered which produces noise and thus limits hydrophone sensitivity and also interferes considerably and sometimes completely with the reception of even strong signals.

To decrease the motion of hydrophones and attempt a stabilized hydrophone attitude, compliant suspension systems of many varieties have been devised. Some are effective only in certain sea states or provide isolation only against restricted ranges of amplitudes and periods of motion in the passive mode, but even those which are effective in the passive mode may become ineffective or serve to increase turbulence when they are towed. This device is streamlined not so much to reduce turbulence due to horizontal tow but to make sure that isolation from vertical motion of the suspending cable is still effective when the device is being towed at low speeds. More effective but also more cumbersome and complex systems involving suspension from subsurface floats or spar buoys have been attempted, while in other applications hydrophones have been floated up from heavy, deep moorings or anchors. All of the more effective systems are relatively expensive and, in addition, require heavy handling equipment. The considerable time required to deploy and recover such systems makes it difficult or impossible to retrieve them and move quickly from one area to another to take advantage of changing acoustic or weather conditions. Further, changing the depth at which the hydrophone is deployed is a major operation with the more cumbersome systems.

Although the foregoing discussion has been directed to hydrophones, it is also applicable to certain other oceanographic instruments which likewise must be stabilized in depth or with respect to the water surrounding them so that in general the same problems are encountered as with the hydrophones. The disadvantages of prior systems and methods of deploying hydrophones are avoided by the present invention.

According to the teachings of the present invention, a hydrophone stabilizing system is provided by means of which a hydrophone may be suspended in virtually the same vertical position and attitude under conditions where the ship is rolling and pitching while anchored, drifting, or in motion towing the system. A damping plane is established in which a major flotation member, to which the hydrophone is attached, is maintained in such a manner that it is substantially insensitive to "angle of attack" when the hydrophone is being towed. Stability in the damping plane is achieved by having the major flotation member pivotable about its center of flotation and steadied for towing by a trailing

crossbar which is disposed parallel to and a selected distance from the flotation member. The hydrophone is suspended from a vertical arm by a compliant bridle which in turn is suspended from a major flotation member. This flotation member is pivotally suspended at its center of flotation from the end of the vertical arm which arm in turn is connected to the ship's cable by a horizontal boom. A minor flotation member at the juncture of the boom and vertical arm maintains this juncture always above the major flotation member, while at its other end the boom is pivotally mounted on a vertical strut. This strut is maintained substantially vertical by a weight suspended from its lower end. A cable suspending the entire system is covered in the region of the flotation member by a suitable rubber fairing.

Accordingly, it is an object of the present invention to provide a neutrally buoyant suspension system for isolating hydrophones or other instruments from the oscillatory excursions of the cable by which they are lowered into the water.

Another object of the invention is to provide a neutrally buoyant suspension system for isolating hydrophones or other instruments which is effective over the full range of periodic motion of the suspending cable notwithstanding the amplitude of cable oscillations.

A further object of this invention is to provide a neutrally buoyant suspension system which remains effective when the vessel deploying the hydrophones or other instruments is at anchor, drifting or underway at low speed, or when the system is subject to deep currents which may not affect the surface vessel.

Other objects, advantages and novel features of the invention wil become apparent from the following detailed description thereof when considered in conjunction with the accompanying drawings in which like numerals represent like parts throughout and wherein:

FIG. 1 is a schematic drawing of the invention in a position of rest;

FIG. 2 is a perspective view of the major flotation member and components associated therewith of the embodiment of FIG. 1;

FIG. 3 is a schematic illustration showing the position of the components of the invention as the supporting cable descends below the position shown in FIG. 1;

FIG. 4 is a schematic illustration showing the position of the components as the cable ascends above the position shown in FIG. 1; and

FIG. 5 is a perspective view of the juncture of two arms of the device.

Referring to FIG. 1, one embodiment of the invention is presented which includes a towing or suspension cable 11 to which is pivotally secured a vertical strut 12 and a hold-down weight 13. A hydrophone 14 is suspended from strut 12 by a compliant bridle 15 and an assembly of jointed arms 16, the hydrophone being supported in neutral buoyancy by a major flotation member 17 and the arm assembly by a minor flotation means 18. Vertical strut 12 and arm assembly 16 preferably are made of tubular aluminum stock, the arms being filled with syntactic foam or a similar material so as to be uniformly neutrally buoyant, while the flotation means preferably are of syntactic foam which may be cast in molds suitable or any depth to 20,000 ft. The force of buoyancy of flotation member 17 acts through a shaft 20 to which bridle 15 is rotatably connected. Flotation means 18 shown in greater detail in FIG. 5,

is positioned so as to maintain the arm assembly in a positive attitude with respect to the hydrophone.

Jointed arms **16** in this embodiment comprise a boom **21** which is pivotable about a pin **22** in a bracket **23** on strut **12** and an extension arm **24** which, although shown in a vertical attitude in FIG. **1**, is freely pivotable about a pin **25** so that vertical oscillations of cable **11** may be at least partially absorbed by a scissor-like action of arm **24** and boom **21**. A pair of shock cords **28** and **29** extending between a bracket **30** on boom **21** and brackets **31** on strut **12** serve to slowly return the boom to the horizontal or neutral or rest position during quiet periods when there is no vertical motion of the supporting cable.

In FIG. **2**, major flotation member **17** and the components associated therewith are shown in greater detail, flotation member **17** preferably being secured between a pair of hydrodynamically contoured plates **35** on shaft **20**, and a damper fin **36** is also secured between plates **35** to impede rotary movement of major flotation member **17** about its supporting axis when the device is being towed. Shaft **20** may be pivotally mounted in a u-shaped bracket **40** having a rod **41** secured thereto which is adapted to receive a mating extension of arm **24** and to be secured thereto by bolts **42** or similar conventional means. Bridle **15** includes a pair of compliant members **43**, preferably shock cords, which act as shock absorbers and vibration dampers to isolate the hydrophone from the rigid members of the arm assembly. These compliant members are provided with a haired fairing **44** which not only serves to damp out any remaining vibration or strum from support cable **11** that might otherwise be communicated via the rigid arms to the hydrophone but also prevents any strumming of members **43** themselves due to movement of the assembly through the water.

A rigid plastic spreader **45** is inserted between compliant members **43** to prevent the members from interfering with the operation of the damping plane assembly, particularly when the bridle swings aft of pivot **20** as when the system is being towed. Spreader **45** also has haired fairing on it to damp its vibrations.

An electrical cable **47** leading to the hydrophone preferably is "married" to bridle **15** in a series of half loops in order that it may not interfere with the stretching action of the compliant members. Cable **11** is preferably covered in the region of the instrument suspension by a rubber fairing **48** to prevent or substantially prevent the generation of acoustic signals by cable strum in this region.

FIGS. **3** and **4** illustrate the action of flotation means **18** in maintaining boom **21** and arm **24** in a positive attitude with respect to hydrophone **14** as strut **12** descends or ascends, respectively, in response to movement of cable **11**. Flotation means **18** provides positive buoyancy for the end of boom **21** which is remote from strut **12**, in particular preventing boom **21** and arm **24** from tending to flex to an opposite angle than that shown in FIG. **4** by providing a positive stop **49** which is shown in FIG. **5**. FIG. **5** also illustrates the manner in which boom **21** is cut away as indicated at **50** to permit boom **21** and arm **24** to pivot about pin **25**, the use of sail tracks **52** to accommodate electrical cable **47**, and the positioning of flotation means **18** in sections of equal buoyancy on either side of boom **21**. The sections of flotation means **18** are individually secured to boom **21** by a conventional plastic filler which is indicated at **53**. The syntactic foam filler for boom **21** is indicated at **54**. The tongue and groove fitting of boom **21** and arm **24** at their juncture permits free movement of arm **24** in an arc of substantially 180° within flotation means **18**.

The neutrally buoyant instrumentation described in effect provides a damping plane, which is established by the major flotation member, that is substantially insensitive to angle-of-attack movement particularly when the device is under tow. The plane is positively buoyant under all operating conditions, but is given added stability at high speeds by damper fin **36** which trails the major flotation member. If desired, a small counterweight or transverse keel, not shown, may be embedded in flotation member **17** directly below its pivot axis to increase stability at low towing speeds. The damping plane, being at the point of maximum drag, mass and inertia, is also the waterborne pivot and remains stationary while the independently buoyed boom and arm are completely free to revolve about it. Since hydrophone **14** is also supported from the damping plane's pivot point, it also remains stationary. Flotation means **18** is streamlined into a fin shape to produce a minimum drag and to assure that boom **21** always aligns itself in the direction of current flow here. Only enough flotation is included in flotation means **18** to assure that boom **21** always maintains a position above arm **24**.

The invention has proved to be stable at all reasonably slow towing speeds, i.e., speeds on the order of **2** or **3** knots. In the embodiment constructed, foam weighing 40 lbs/cu. ft. was used for a depth submergence to at least 16,000 ft. The boom and arm are made of streamlined aluminum, hollow spar and mast material manufactured for use in small sailboats. Filling this tubing with syntactic foam makes it neutrally buoyant as well as increasing its strength. The sail track in the spars provides a convenient run for the hydrophone electrical cable. A single 30-ft. section of helicopter fairing was found to be exceedingly satisfactory for the fairing applied to cable **11**.

The present instrument suspension has performed excellently in all respects when towed behind a ship which rolled and pitched in a long swell having roll amplitudes ranging from ±10° to ±15°. Ship drift before the wind resulted in cable angles averaging from 40° to 45°. Frequent spot checks during periods of maximum roll and pitch indicated that no apparent flow noise resulted from the ship's motion, nor was any cable strum received by the hydrophone. The suspension was operated at depths of approximately 500 and then 2400 meters in obtaining the foregoing results. The suspension was also observed to be operating as intended in a seaway 10 ft. below the surface.

The total load capability of the present embodiment of the invention is approximately 35 lbs, however, this can readily be increased to 50 lbs without changing the damping plane. The addition of foam to appropriate areas is expected to permit the device to support an array of hydrophones rather than the single hydrophone described in this embodiment.

The invention isolates hydrophones or other instruments from oscillatory excursions of the cable used to lower them into the water, whether such cable motion is the result of the rolling and pitching motion of a surface vessel, a buoy, or any other means of cable support which is in periodic or aperiodic motion as a result of

wave action, swell or other cause. By appropriate choice of the lengths of the horizontal boom and the vertical arm, the system will operate effectively regardless of the amplitude of the oscillatory excursions of the suspending cable. The suspension system also maintains its effectiveness whether the deploying vessel is at anchor, drifting, underway at low speed, or when the system is subject to deep currents which may not affect the surface vessel. The system automatically deploys itself at any depth when the cable is stopped.

Obviously, many modifications and variations of the present invention are possible in the light of the above teachings. For example, damping fin **36** may be altered somewhat in contour and in its point of attachment between plates **35** to correct for larger ship rolls, and the fin may be made adjustable for either high speed towing or, alternatively, operation in a stationary position in a current.

What is claimed is:

1. A hydrophone stabilizing device for supporting a hydrophone in neutral buoyancy while under tow or restrained in a current or stationary comprising:

a supporting cable having a strut secured at one end of the cable for attaching said device;

a weight secured at the other end of said strut to maintain said strut in a substantially vertical attitude during operation of said device;

a jointed arm assembly pivotally connected to said strut and pivoted so as to stream therebehind in a current and when the cable is being towed;

a hydrophone suspended from said arm assembly at a point remote from said strut; and

flotation means connected to said arm assembly to suspend said hydrophone therefrom in neutral buoyancy.

2. The device as defined in claim **1** wherein said flotation means is connected to said arm assembly adjacent to the point of suspension of said hydrophone.

3. The device as defined in claim **1** wherein said flotation means include a major flotation part and a minor flotation part,

the major part of said flotation means connected to said arm assembly substantially at the point of suspension of said hydrophone;

the minor part of said flotation means connected to said arm assembly intermediate the major part and said strut to maintain said arm assembly in a positive attitude above said hydrophone.

4. An oceanographic instrument suspension system comprising:

an oceanographic instrument and means for suspending said instrument in a fluid environment;

said suspending means including flotation means hydrodynamically contoured to provide a minimum resistance to horizontal motion and maximum resistance to vertical motion with respect to the fluid environment;

a yoke and a bridle connected to said yoke for suspending said instrument from said flotation means;

said bridle connected to opposite ends of said flotation means at a transverse axis through the center of buoyancy thereof;

a vessel having a tow cable connected to it for towing said instrument; and

a jointed arm assembly for coupling said yoke to said cable;

said yoke and said bridle both pivotally connected to said flotation means at said transverse axis.

5. The system as defined in claim **4** and further including a damper fin disposed astern of said flotation means with respect to flow therepast and connected to said transverse axis to maintain said flotation means substantially horizontal during vertical movement of or during application of vertical forces to said flotation member, when said suspension system is subject to horizontal tow.

6. The system as defined in claim **5** wherein said flotation means includes a positively buoyant major flotation member rotatably mounted on said yoke and a positively buoyant minor flotation member mounted on said jointed arm assembly to maintain said assembly in a positive attitude with respect to said major flotation member.

7. The system as defined in claim **6** wherein said major flotation member is in the form of a cylinder which is elliptical in cross section and said transverse axis extends between the planar ends of the cylinder.

8. The system as defined in claim **7** and further including a vertical strut pivotally connected at one end to the end of said cable; and

a weight suspended from the other end of said strut to maintain said strut and the end of said cable in a substantially vertical attitude during operation of said system,

said arm assembly pivotally connected to said strut intermediate the ends thereof.

9. The system as defined in claim **8** wherein said jointed arm assembly includes resilient means connecting points of said strut above and below the point of connection of said jointed arm assembly and said arm assembly to return said arm assembly to a horizontal position in the absence of vertical oscillations of said strut.

10. The system as defined in claim **9** and further including fairing on said cable in the region of said jointed arm assembly to reduce noise caused by cable strum; and

fairing on said bridle to reduce strumming of the bridle caused by flow of water by it as produced by deep currents or towing.

11. The system as defined in claim **10** and further including a spreader inserted across said bridle to form an opening therein through which said suspending means may rotate without coming into contact with said bridle.

12. The method of suspending an oceanographic instrument in water comprising:

providing a vertical reference by suspending a weighted rigid member from the end of a cable;

establishing a horizontal plane from which the instrument is suspended by pivotally deploying a positively buoyant flotation member about its center of flotation from means connected to the rigid member;

articulately connecting the flotation member to the rigid member so that vertical oscillations are automatically damped while the horizontal attitude of the flotation member is maintained; and

adding flotation means to the articulately connecting components to render the suspension system neutrally buoyant.

* * * * *