

- [54] STEERABLE TAIL BUOY
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- [73] Assignee: Exxon Production Research Company, Houston, Tex.
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- [52] U.S. Cl. 114/246; 114/253; 114/163
- [58] Field of Search 114/162, 163, 242, 244, 114/246, 253

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[57] ABSTRACT

A remotely controllable tail buoy for use in marine geophysical prospecting operations is disclosed. The tail buoy is attached to the trailing end of one or more seismic streamers towed by the vessel. The tail buoy is provided with rudders that are controlled by a steering mechanism and communication system. The communication system collects and processes radio signals emitted from a radio transmitter located on the towing vessel. The processed signals control the steering mechanism which includes a hydraulic pump for directing fluid into a hydraulic cylinder. The fluid flow rotates the rudders. The tail buoy will travel toward the direction that the rudders are turned and thus avoid hooking or entangling of the tail buoy on other like tail buoys or structures.

15 Claims, 2 Drawing Sheets

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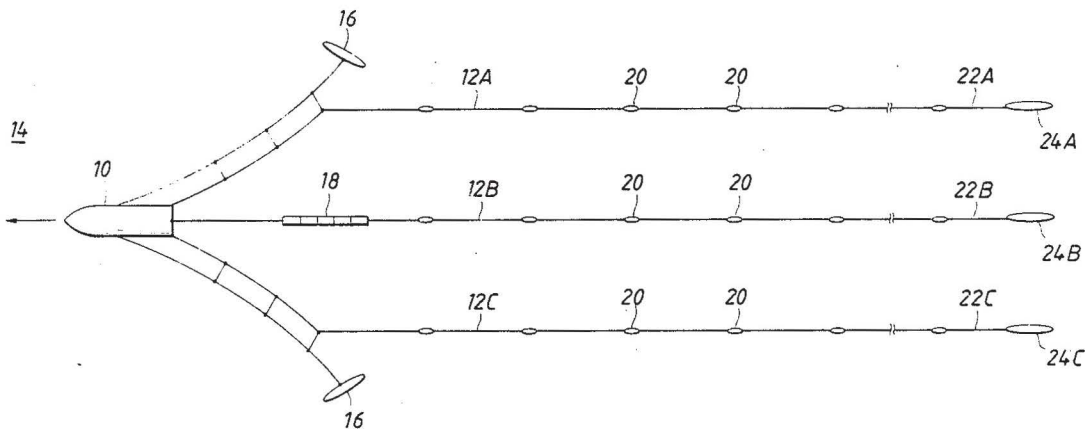


FIG. 1

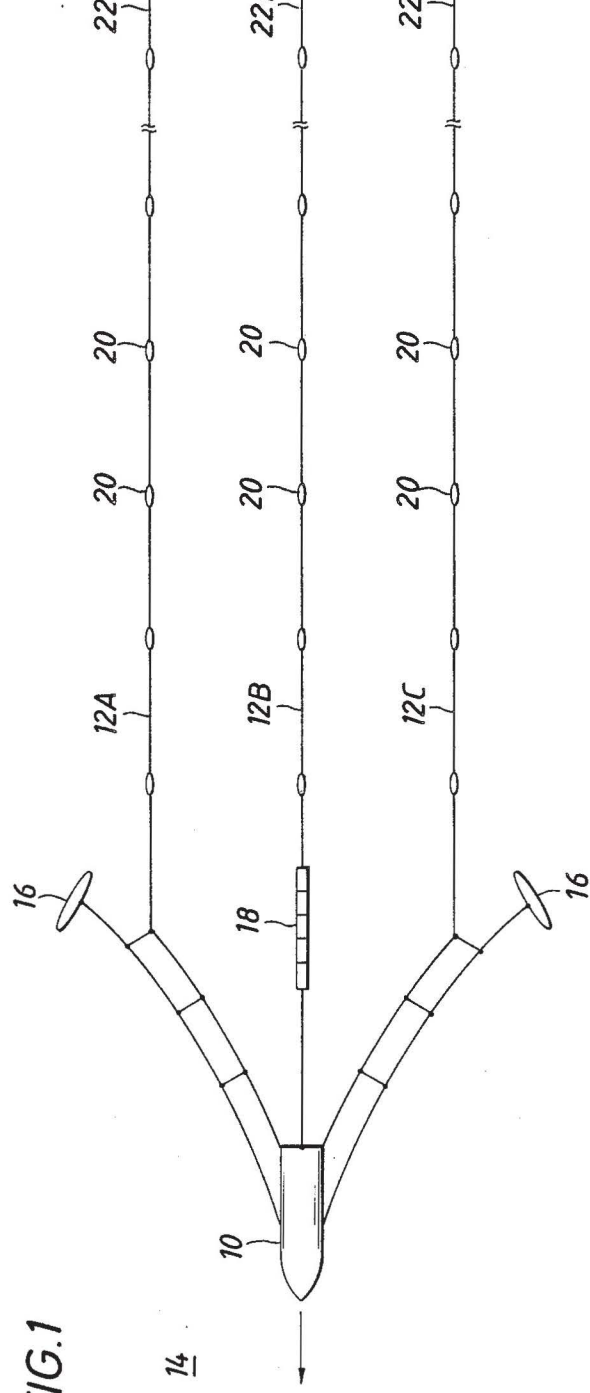
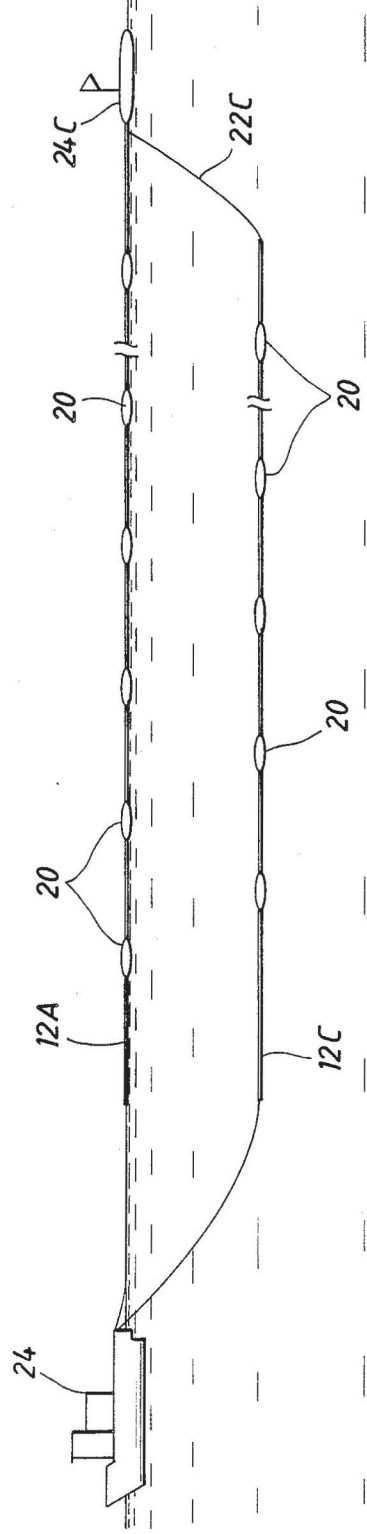


FIG. 2



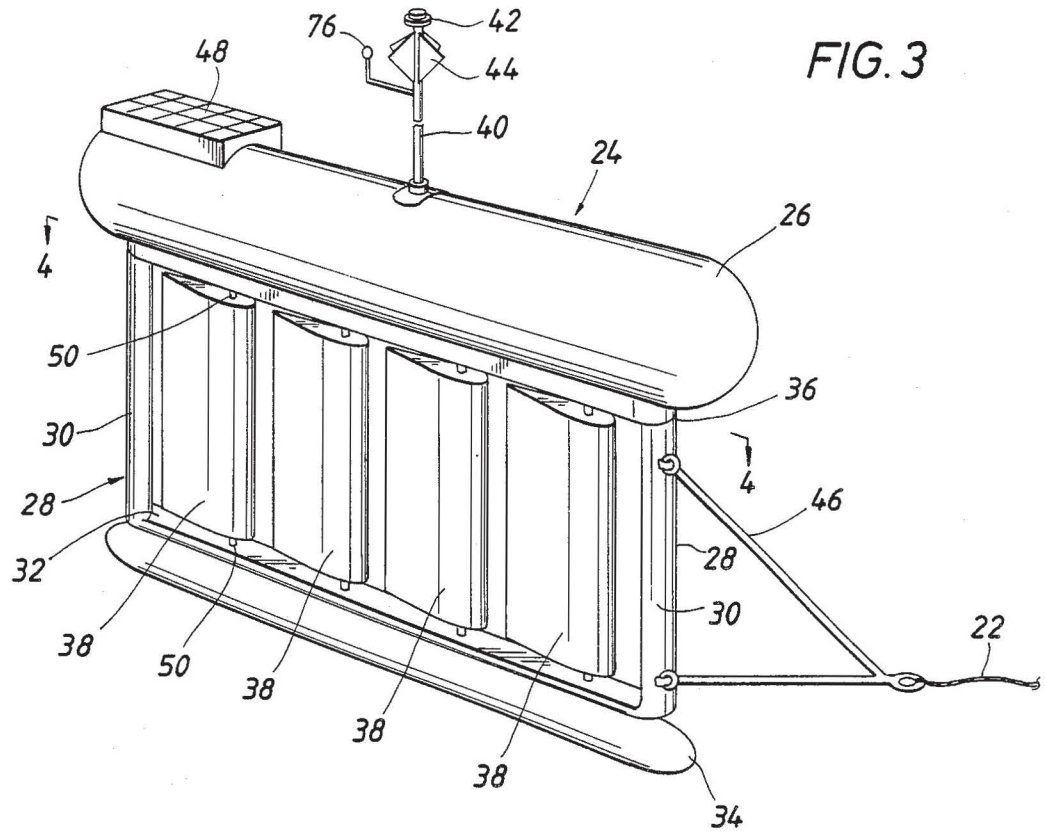
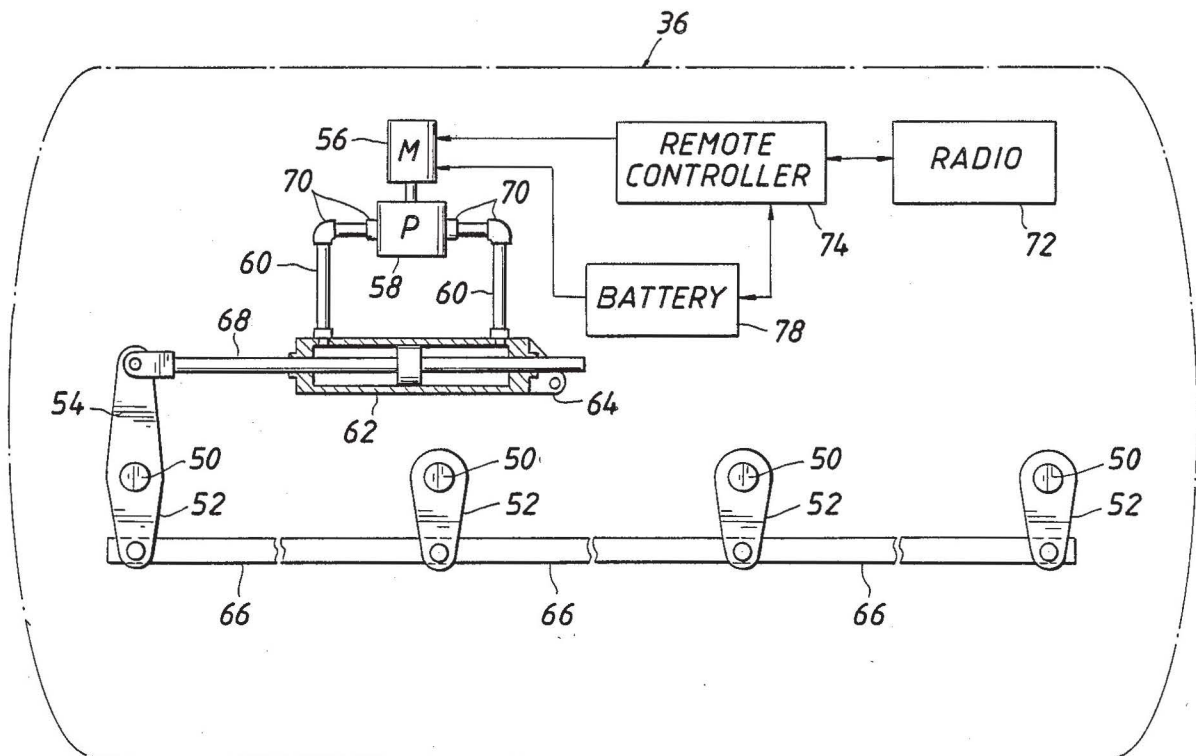


FIG. 4



STEERABLE TAIL BUOY

FIELD OF THE INVENTION

This invention relates generally to marine towing operations. More specifically, but not by way of limitation, it relates to a steerable tail buoy for use while gathering marine seismic data using one or more seismic streamers.

BACKGROUND OF THE INVENTION

In recent years the search for oil and gas has moved offshore. In order to locate potential offshore oil and gas reservoirs, it has been necessary to develop new devices and techniques for conducting marine geophysical prospecting operations. Due to the hostile environment in which they are conducted, such operations are typically quite difficult and costly to perform.

The primary method for conducting marine geophysical prospecting operations involves the use of towable marine seismic sources and seismic receiver cables. The basic principles of this prospecting method are well known to those skilled in the art. The seismic source(s) introduce seismic signals into the body of water. The signals travel downwardly through the water, across the water-floor interface, and into the subterranean geological formations, and are, to some extent, reflected by the interfaces between adjacent formations. The reflected signals travel upwardly through the geological formations and the body of water to a seismic receiver cable located near the surface of the body of water. The seismic receiver cable typically contains a number of hydrophones spaced along its length which record the reflected signals. Analysis of the signals recorded by the hydrophones can provide valuable information concerning the structure of the subterranean geological formations and possible oil and gas accumulation therein.

Seismic receiver cables, commonly known as "streamers", are usually towed below the water surface. The streamers are preferably of neutral buoyancy and can be balanced by filling them with a liquid having a specific gravity less than 1 to add flotation, or by removing excess liquid or taping lead strips to the outer surfaces of the streamers to reduce flotation. As is well known to those skilled in the art, a properly balanced streamer should maintain approximately the same depth along its entire length while it is being towed. Balancing the streamer is often a difficult process as it is possible for the streamers to be 6 kilometers (3.7 miles) long or more.

The depth of the streamers during tow is usually controlled by winged devices known as "birds" which are attached to the streamers typically every 300 to 500 meters (about 1000 to 1600 feet). The birds are provided with remote depth controls which enable them to maintain the streamer at a uniform running depth or to raise or lower the streamer. A typical bird looks like a torpedo, being about 0.6 meters (2 feet) long, with two short winglike fins. It usually separates into halves, along its length, and is hinged on one side so that it can be opened and clamped onto the cable. One example of a bird is described in U.S. Pat. No. 3,605,674 which issued on Sept. 20, 1971 to Weese.

At the trailing end of the streamer, away from the vessel, a tail buoy is attached to the streamer, typically by a rope. The tail buoy enables the vessel operators to determine and mark the approximate location of the end

of the streamer. It also serves as a warning device for other vessel operators to indicate that a streamer is being towed. The tail buoy is usually a catamaran raft provided with tubular floats, lights and radar reflectors. The rope, which may range in length from 30 to 300 meters (about 100 to 1000 feet), allows the tail buoy to float on the surface of the water without raising the trailing end of the streamer.

In recent years, it has become feasible to tow a plurality of streamers, laterally spaced apart, behind a single vessel. As a result, a greater survey area may be covered in a shorter period of time, resulting in a lower overall survey cost. When a plurality of streamers are towed behind a single vessel, paravanes, being attached to the lead end of each streamer, are often used to laterally separate the lead end of each streamer. One example of a paravane is described in U.S. Pat. No. 4,463,701 which issued Aug. 7, 1984 to Pickett, et al. A remotely controlled paravane is disclosed in U.S. Pat. No. 4,729,333 which issued Mar. 8, 1988 to Kirby, et al.

A particular difficulty has arisen when towing a plurality of streamers. In routine turns, all streamers normally tow in concentric circles. However during deployment or repair of the streamers or in non-routine turns such as slow speed turns or sharp turns, it is common for the streamers to cross and become tangled. It is possible to prevent entanglement of the streamers by diving one streamer while surfacing the other with the aid of the remotely controllable birds. Although this keeps the streamers from tangling, the tail buoys, which at all times remain on the water's surface, are likely to cross and become hooked, or the ropes that connect the buoys to the streamers may become tangled. Unhooking the tail buoys or untangling the ropes requires the use of a small auxiliary boat, if available. Otherwise, the streamers and ropes must be reeled toward the vessel to be untangled by the vessel operators.

Another difficulty arises when data is being collected near an offshore structure. As one or more streamers are towed behind a vessel, the wind and water current may cause the trailing end of the streamer to feather outwardly from the vessel's path. If data is being collected along a path near an offshore structure, the wind and current may push the streamer and tail buoy into the structure. As a result the buoy or the streamer may become damaged or they may become hooked to the structure.

Accordingly, in marine seismic exploration the need exists for a remotely controllable tail buoy which can be attached to a seismic streamer so as to indicate the approximate location of the trailing end of the streamer, and which can be remotely steered away from other tail buoys attached to other streamers or from offshore structures and other obstructions in order to prevent tangling of the tail buoys or damage to the tail buoys or streamers.

SUMMARY OF THE INVENTION

The present invention is a remotely controllable tail buoy that may be directed from a remote location such as from a towing vessel to prevent damage to the tail buoys, hooking of the tail buoys or tangling of the ropes when one or more streamers are being towed by the towing vessel. Additionally, the inventive tail buoy may be used when towing one or more streamers to direct the trailing ends of the streamers away from offshore

structures or other obstructions which could damage the streamers.

In a preferred embodiment, the tail buoy is provided with two or more rudders, a steering mechanism and a communication system. The rudders are adapted to rotate substantially simultaneously about generally vertical axes to control the course of the tail buoy. The rotation of the rudders are controlled by the steering mechanism and the communication system. The steering mechanism controls the rudder position based on signals received by the communication system from a remote transmitter on the vessel. The communication system includes a two-way radio receiver tuned to the same frequency as the remote transmitter for receiving radio signals emitted from the remote transmitter. The signals are processed by a remote controller which is preferably a microprocessor-based controller and data acquisition system. The processed signals control the steering mechanism which includes a hydraulic pump. The pump directs flow to a hydraulic cylinder causing the rudders to turn. Then, as the vessel continues to move, the tail buoy will travel toward the direction that the rudders are turned thereby avoiding other tail buoys or offshore structures.

The tail buoy design preferably includes a single tubular float and an anti-roll weight. The tubular float provides all necessary buoyancy for the tail buoy while the anti-roll weight keeps the buoy in an upright or vertical position. This design lessens the probability that the tail buoys will hook if one buoy floats into another's path.

The steerable tail buoy of the present invention may include additional peripheral equipment such as rudder position sensors, relative positioning instrumentation and navigational instrumentation. The navigational instrumentation may be acoustic based, radio based or optical based instrumentation. Data from these sensors and instruments may be continuously transmitted to the vessel and fed into a computer located on board the vessel. The computer would continuously monitor the precise location of the tail buoy and initiate any necessary actions to adjust the course of the tail buoy.

DESCRIPTION OF THE DRAWINGS

The actual operation and advantages of the present invention will be better understood by referring to the following detailed description and the attached drawings in which:

FIG. 1 is a plan view of a vessel towing three streamers with the inventive tail buoys attached to ends of the streamers.

FIG. 2 is a side view of a vessel towing two streamers, illustrating that one streamer has been lowered to avoid entanglement with the other streamer during a repair operation and the other streamer has been raised to the surface of the water.

FIG. 3 is a perspective view of the inventive tail buoy.

FIG. 4 is an internal diagram along line 4—4 of FIG. 3 which illustrates a preferred embodiment of the tail buoy's steering mechanism, communication system and power source.

While the invention will be described in connection with the preferred embodiments, it will be understood that the invention is not limited thereto. On the contrary, it is intended to cover all alternatives, modifications, and equivalents which may be included within the spirit and scope of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates a plan view of vessel 10 which is moving in the direction of the arrow and is towing three streamers 12A, 12B, and 12C in a body of water 14. In normal operation, streamers 12A, 12B, and 12C are towed at a constant depth of approximately 3 to 15 meters (10–50 feet) below the surface of water 14. Outer streamers 12A and 12C are maintained separated laterally from streamer 12B by paravanes 16. The total distance between streamers 12A, 12B, and 12C can be varied from approximately 50–300 meters (160–1000 feet). For illustration purposes only, seismic source 18 is shown directly behind vessel 10. The most common seismic source used today is an air gun array. Other seismic sources include water guns, explosive gas guns, steam, small explosives and marine vibrators. Spaced along the length of each streamer 12A, 12B, and 12C are remotely controllable birds 20. Birds 20 are typically used to control the depth of streamers 12A, 12B, and 12C. However, as illustrated in U.S. Pat. No. 3,605,675 to Weese, birds 20 also have been designed to control, although to a limited extent, lateral movement of streamers 12A, 12B, and 12C. At the far end of streamers 12A, 12B, and 12C, attached by ropes 22A, 22B, and 22C, are the inventive tail buoys 24A, 24B, and 24C disclosed herein. Tail buoys 24A, 24B, and 24C are used to indicate the approximate location of the ends of streamers 12A, 12B, and 12C and warn boat operators and others that one or more streamers are being towed.

FIG. 2 illustrates the particular problem to be solved by steerable tail buoy 24 of the present invention. For purposes of simplification, streamer 12B and seismic source 18 are not included in FIG. 2. During a repair operation using an auxiliary boat (not shown), to avoid tangling of streamers 12A and 12C, streamer 12A is raised to or near the surface of water 14 and streamer 12C is lowered by about 18 to 30 meters (60–100 feet) by birds 20. As the repairs are being made, streamers 12A and 12C may cross paths due to wind or surface currents but they will not tangle due to vertical separation. However, since tail buoys 24A and 24C remain on the surface of water, they may hit one another, become hooked, or ropes 22A and 22C may tangle.

FIG. 3 illustrates a perspective view of a preferred embodiment of steerable tail buoy 24. The major components shown include tubular float 26, frame 28, anti-roll weight 34, actuator housing 36, rudders 38, mast 40 with light 42 and radar reflector 44, tow bridle 46 and solar panel 48, if desired. Float 26 provides sufficient buoyancy to maintain tail buoy 24 on the surface of body of water 14 during operation. Preferably the buoyancy is provided by one tubular float 26, rather than a plurality of floats in order to reduce the possibility of one tail buoy getting hooked to another by reducing the number of components on the tail buoy. Float 26 should be designed to provide low drag when towed while maintaining adequate hydrodynamic stability. Many designs are feasible, however a cylindrical float with hemispherical ends may be preferred. Frame 28 is attached to the bottom of float 26 by one or more support legs 30. Support legs 30 extend downwardly from float 26 and attach to base plate 32. Attached to base plate 32 is anti-roll weight 34 which reduces rolling of tail buoy 24 due to rudder lift or sea state. Anti-roll weight 34 can be a lead pipe or any other object of sufficient weight to reduce rolling of tail buoy 24. The weight tends to

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