United States Patent [19]

Dolengowski

[11] **Patent Number: 4,890,568**

[45] **Date of Patent: Jan. 2, 1990**

[54] **STEERABLE TAIL BUOY**

[75] Inventor: **George A. Dolengowski,** Bellaire, Tex.

[73] Assignee: **Exxon Production Research Company,** Houston, Tex.

[21] Appl. No.: **236,107**

[22] Filed: **Aug. 24, 1988**

[51] **Int. Cl.**[4] **B63B 21/00**

[52] **U.S. Cl.** **114/246;** 114/253; 114/163

[58] **Field of Search** 114/162, 163, 242, 244, 114/246, 253

[56] **References Cited**

U.S. PATENT DOCUMENTS

1,717,286	6/1929	Ward	114/163
3,125,980	3/1964	Anderson	114/235
3,469,552	9/1969	Patrick	114/246
3,560,912	2/1971	Spink et al.	340/
3,605,674	9/1971	Weese	114/235 B
3,710,749	1/1973	Duryea	114/163
3,774,570	11/1973	Pearson	114/235
3,896,756	7/1975	Pearson et al.	114/235 B
4,033,278	7/1977	Waters	114/245
4,063,213	12/1977	Itria et al.	340/
4,087,780	5/1978	Itria et al.	340/7 R
4,130,078	12/1978	Cholet	114/244
4,290,124	9/1981	Cole	367/18
4,323,989	4/1982	Huckabee et al.	367/181
4,350,111	9/1982	Boyce, II	114/245
4,404,664	9/1983	Zachariadis	367/19
4,463,701	8/1984	Pickett et al.	114/245
4,506,352	3/1985	Brandsaeter et al.	367/21
4,574,723	3/1986	Chiles et al.	114/253
4,729,333	3/1988	Kirby et al.	114/244
4,763,126	8/1988	Jawetz	441/16

FOREIGN PATENT DOCUMENTS

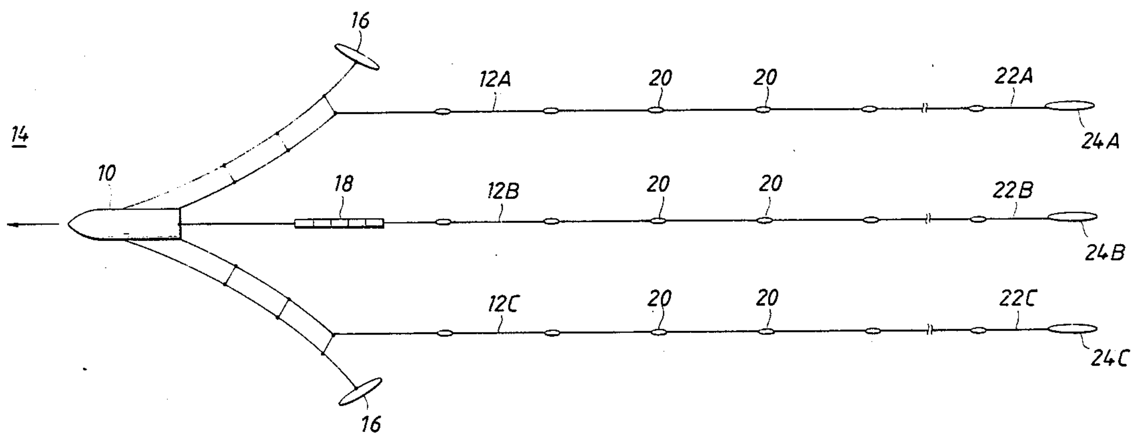
2047406B 9/1983 United Kingdom .

Primary Examiner—Sherman D. Basinger
Assistant Examiner—Stephen P. Avila
Attorney, Agent, or Firm—Sheila M. Luck

[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



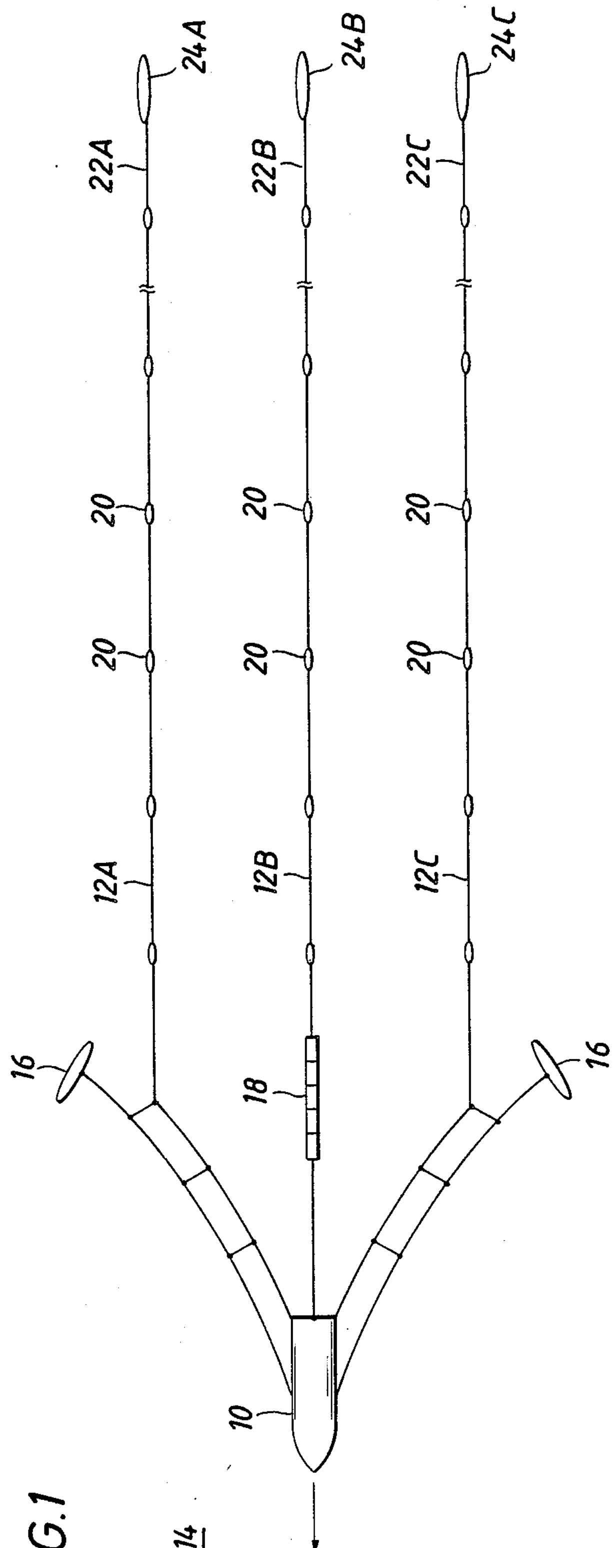

24A
24B
24C
22A
22B
22C
20
12A
12B
12C
16
18
10
14

FIG.1

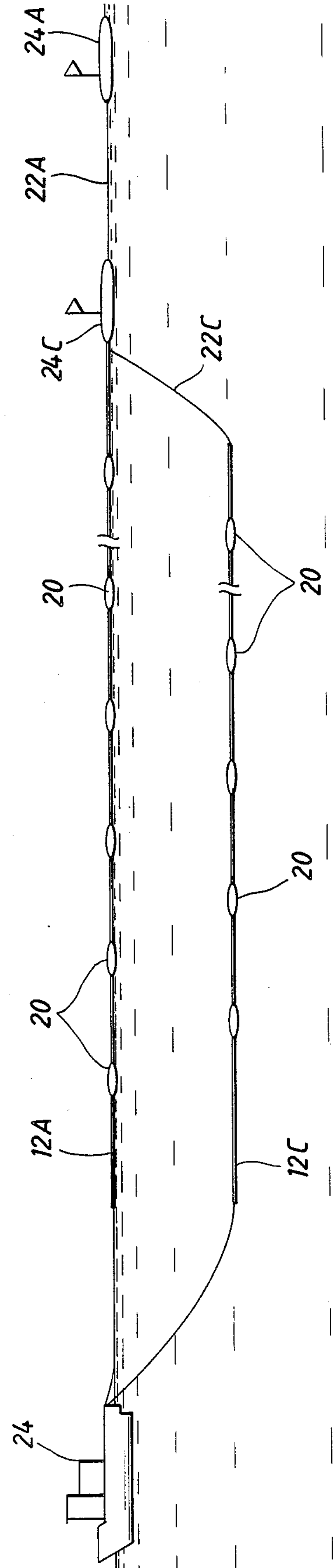

24A
22A
24C
22C
20
12A
12C
24

FIG.2

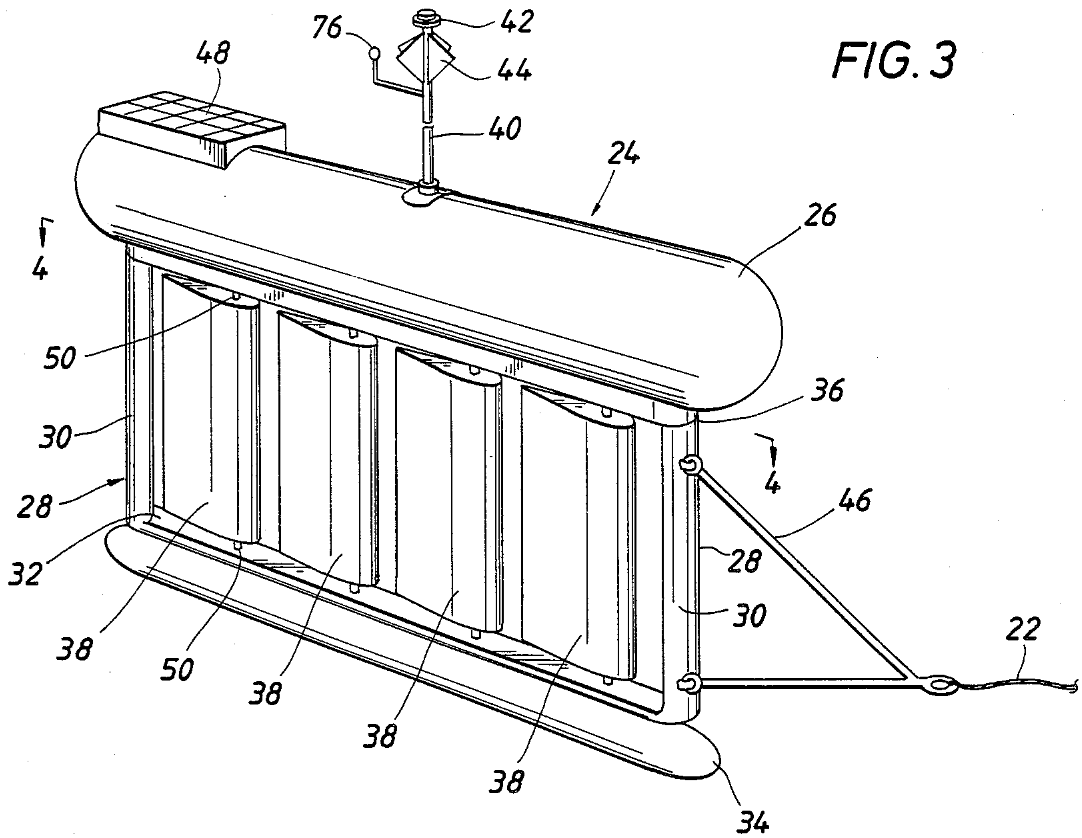
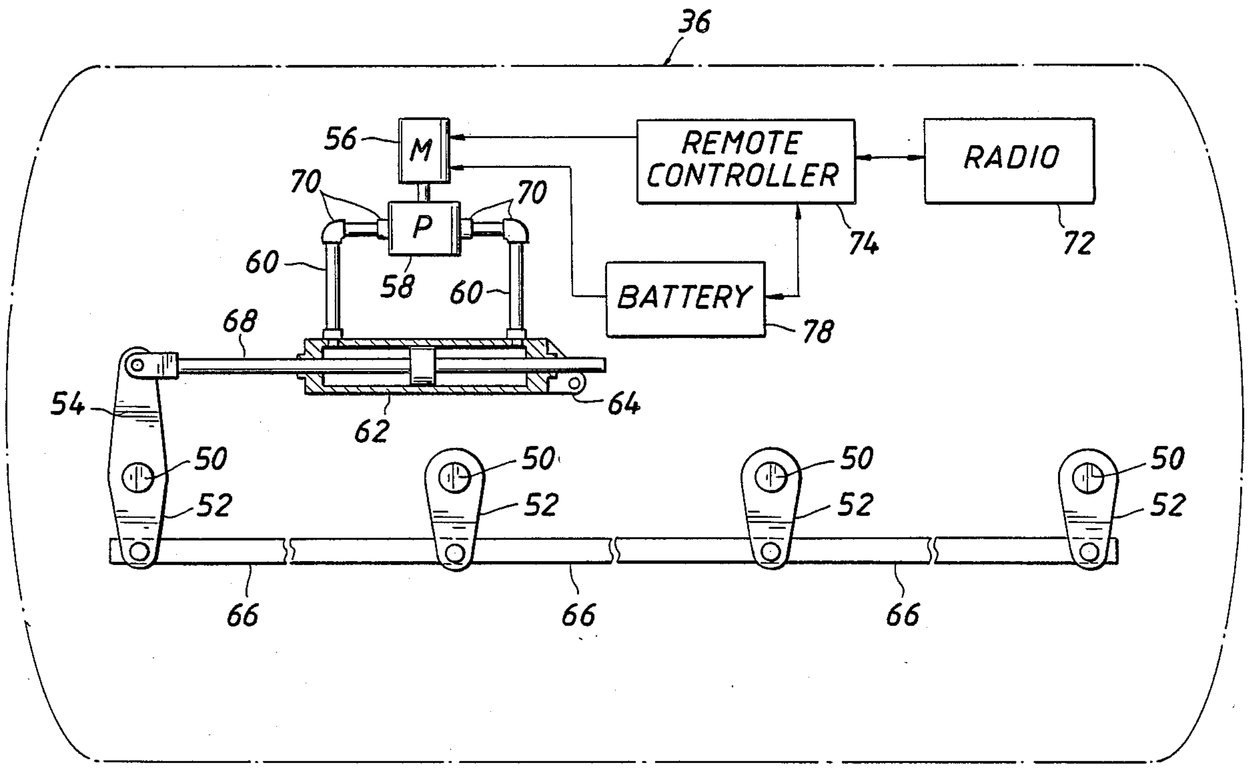

76
42
44
48
40
24
26
4
50
36
30
4
46
28
28
32
30
22
38
50
38
38
38
34

FIG. 3

FIG. 4


36
56
M
REMOTE
CONTROLLER
RADIO
70
70
P
74
72
60
58
60
BATTERY
68
78
54
64
62
50
50
50
50
52
52
52
52
66
66
66

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 seperate 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

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming inter-face) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.

WHAT WILL YOU BUILD? | sales@docketalarm.com | 1-866-77-FASTCASE