

United States Patent

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3,159,130 12/1964 Vos 114/0.5(T)
3,335,685 8/1967 Gimbel 114/16

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[54] BUOYANCY CONTROL SYSTEM WITH CHOKE

6 Claims, 5 Drawing Figs.

[52] U.S. Cl. 114/16
[51] Int. Cl. B63g 8/22
[50] Field of Search 114/16,
16.3, 122, 125; 73/427; 137/392, 426

[56] **References Cited**
UNITED STATES PATENTS
2,031,230 2/1936 Seraphin 73/427

ABSTRACT: In a buoyancy control system including a buoyancy control chamber adapted to allow fluid communication with the surrounding water environment and to receive air introduced to form an air bubble within the chamber, a vertically movable fluid conduit for providing such fluid communication, a water level sensing device associated with the fluid conduit, and means for causing quantities of air and water to be supplied to the control chamber, there is provided a rigid cylindrical choke disposed within the control chamber to improve the sensitivity of the control system. The system is particularly adaptable for use with a protective cage, such as an antishark cage.

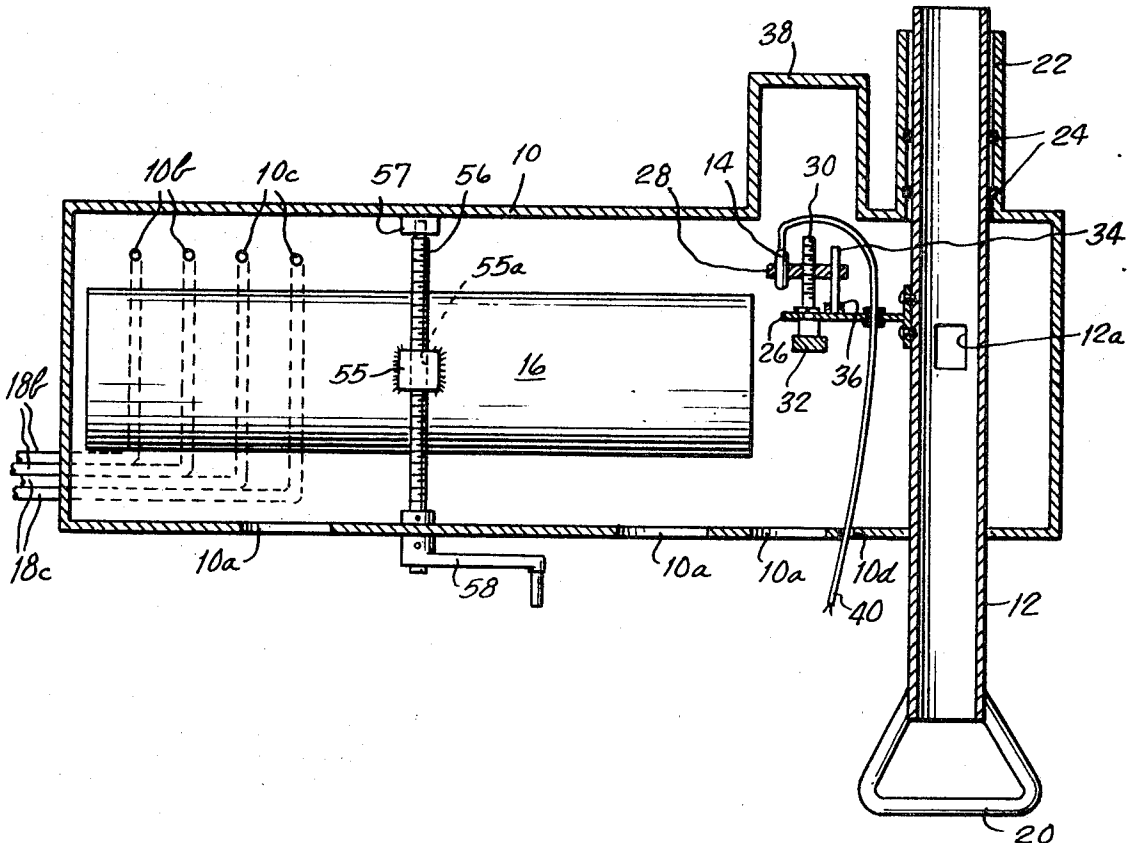


Fig. 1.

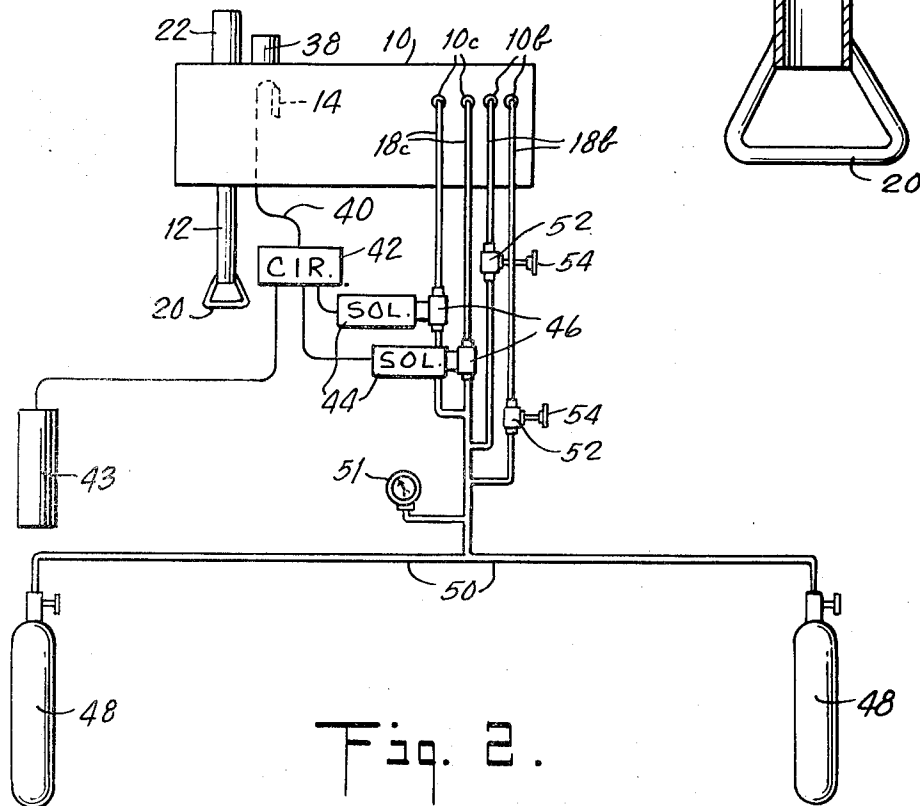
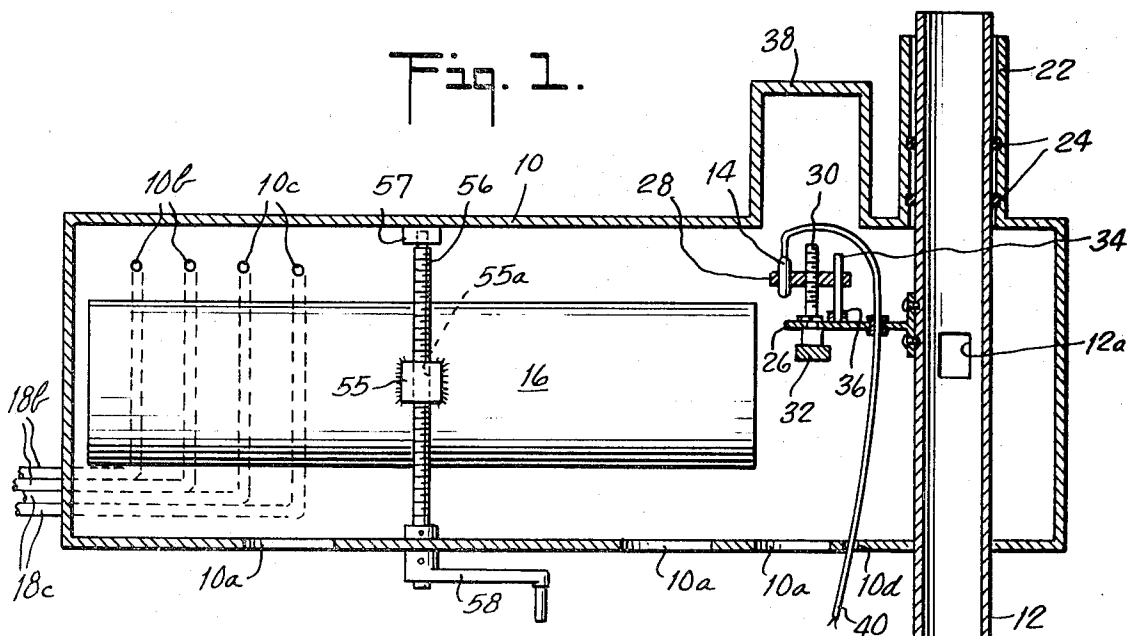
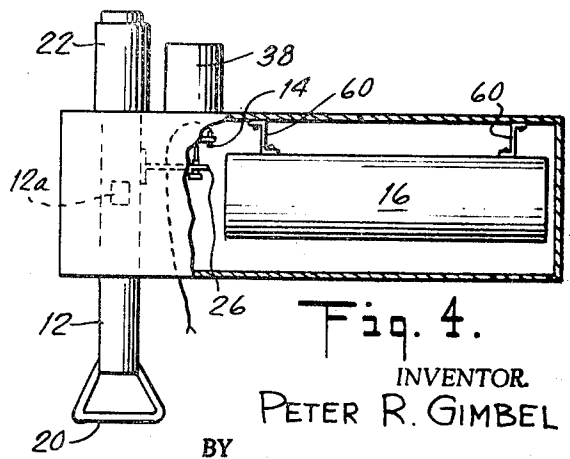
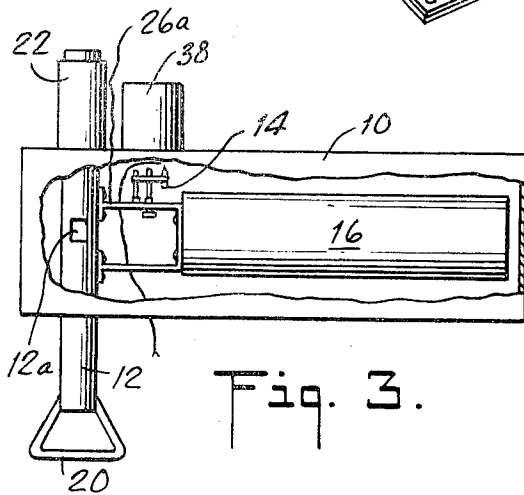
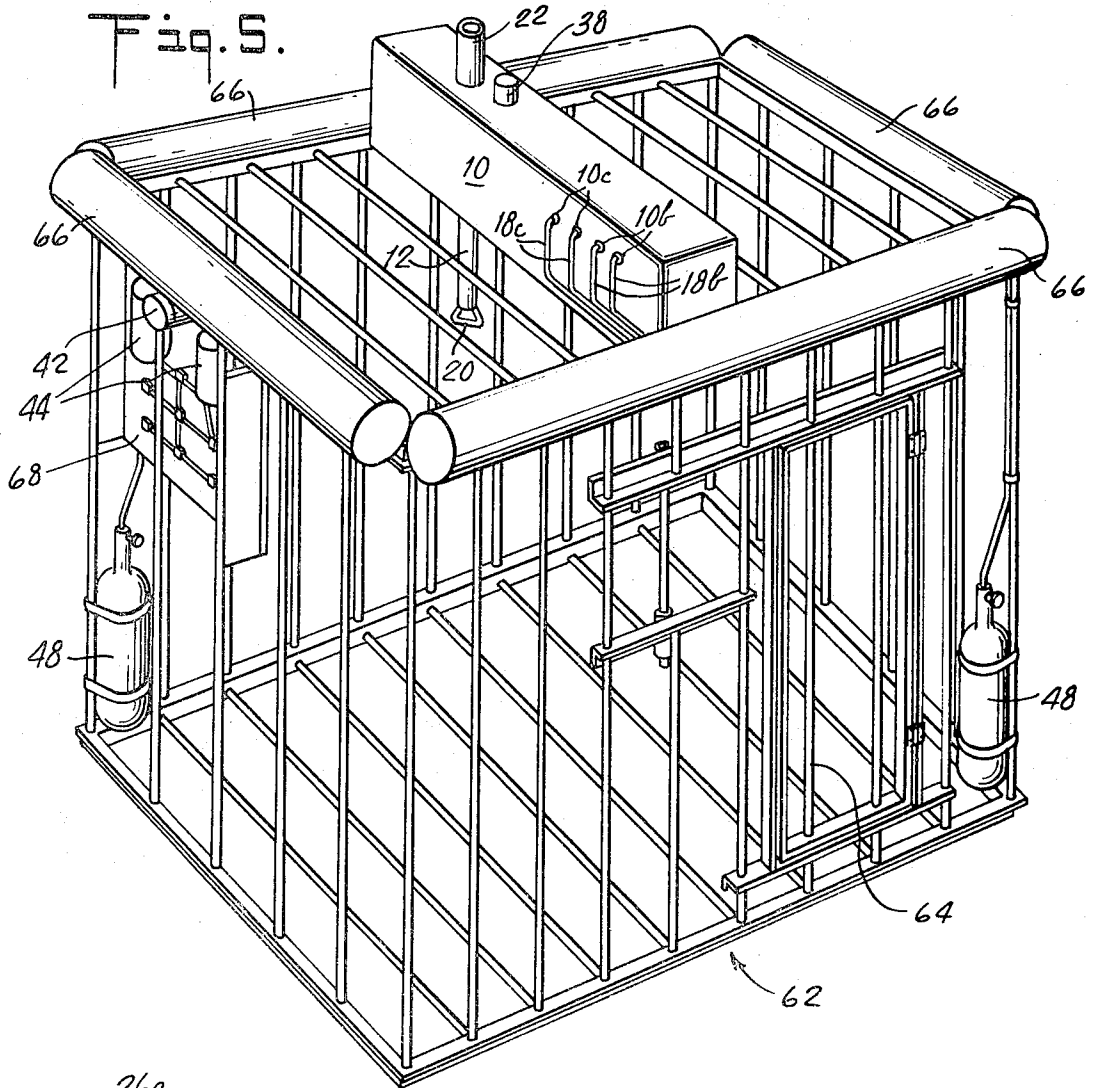


Fig. 2.

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BUOYANCY CONTROL SYSTEM WITH CHOKE

BACKGROUND OF THE INVENTION

This invention relates to submarine structures and the like and to buoyancy control systems for same. More particularly, the present invention concerns a choke for a buoyancy control system for increasing the sensitivity of such a system so that it may readily maintain a submersible structure at a given depth beneath the surface of a body of water.

Buoyancy control systems are known and have been previously employed in submarines and other underwater structures. However, many of the existing systems are quite complicated and difficult to operate, and those that are simple generally require the full-time attention of the operator to continuously maintain the system at the desired depth. Moreover, some buoyancy control systems include the operator as a functional part of the system in that if the operator does not actively control the system, the system tends to fail.

These problems were basically overcome by the mechanism disclosed in applicant's U.S. Pat. No. 3,335,685, of which the present invention is an improvement. It is there disclosed that as the buoyancy of such a system is dependent upon the size of an air bubble in a free-flooding buoyancy chamber, the buoyancy may be controlled by manipulating the dimensions of the air bubble, a larger size air bubble within the buoyancy chamber imparting greater buoyancy to the system and a smaller size air bubble imparting relatively less buoyancy.

In the system disclosed in U.S. Pat. No. 3,335,685 the size of the air bubble within the buoyancy chamber is controlled by an adjustable water level sensing device located within the buoyancy chamber. This sensing device is operatively connected to an air supply in order to introduce air into the buoyancy chamber when the water at the air-water interface within the chamber contacts the sensing device, the incoming air resulting in an increase in the buoyancy of the system.

Whenever it is desired to reduce the buoyancy of the system, air is discharged from the bubble in the buoyancy chamber to the surrounding environment through a fluid conduit communicating between the interior of the buoyancy chamber and the water environment. The fluid conduit is provided with an aperture which, when exposed to the air at or above the air-water interface within the buoyancy chamber, allows air to be discharged from the air bubble via the aperture and the fluid conduit into the water environment, thereby reducing the size of the air bubble and hence the buoyancy of the system.

The water level sensing device is fixed to the fluid conduit, spaced above the upper edge of the aperture therein, such that when the fluid conduit is displaced vertically within the chamber, the size of the air bubble may be altered. Thus if the fluid conduit is moved upwardly within the buoyancy chamber, to expose the aperture in the fluid conduit to the air within the air bubble, air will be discharged via the fluid conduit into the surrounding environment with a corresponding reduction in the buoyancy of the system. On the other hand, if the fluid conduit is moved downwardly within the buoyancy chamber, the water level sensing device will contact the water at or below the air-water interface and thus cause air to be introduced into the buoyancy chamber, increasing the size of the air bubble and hence increasing the buoyancy of the system.

Control of the sensitivity of the system is accomplished to some degree by adjusting the vertical distance separating the water level sensing device and the upper edge of the aperture in the fluid conduit, a separation of one-fourth—three-fourths inch having been found satisfactory under normal conditions.

The aforementioned patent further teaches the employment of a buoyancy control device in conjunction with an antishark cage or similar protective submarine observation platform.

Despite the many advantages of the aforementioned patented buoyancy control system over prior art devices, it would be desirable to have a more sensitive system, one which

would rapidly respond to the passage of even a relatively small wave over the device or to the movement of the operator or an occupant from or within an associated protective cage. It is further desirable to provide means for conserving the air supply of such a system.

SUMMARY OF THE INVENTION

An object of the invention is to provide means for improving the responsiveness, and thereby the stability, of a buoyancy control system. Another object is to provide in a buoyancy control system means for decreasing the response time of the system, thereby conserving the air supply.

To these and other ends, the instant invention contemplates the disposition of a choke within a buoyancy control chamber adapted to contain quantities of air and water, the air and water within the chamber providing an air-water interface, and supply means for providing quantities of air and water to the control chamber upon sensing of a variation in those quantities.

In the system of the invention, the buoyancy control chamber is a free-flooding housing adapted to contain an air bubble in its upper portion. The chamber is further adapted to allow access of water to its interior, the air and water contained within the chamber providing an air-water interface.

In order to provide fluid communication between the buoyancy control chamber and the water environment surrounding the structure, a fluid conduit is employed, the fluid conduit comprising a pipe vertically movable within the chamber with an aperture therein for actually providing the path of communication.

A water level sensing device is associated with the fluid conduit and vertically movable with it within the chamber. As the water level sensing device is spaced slightly above the upper edge of the aperture in the fluid conduit, the sensing device determines when the water level has risen to a point which warrants introduction of air to the buoyancy control chamber in order to maintain the structure in a stable position.

An air supply must be provided for the system in order to introduce air into the buoyancy control chamber whenever the sensing device contacts water at the air-water interface within the chamber.

The choke of the present invention is a rigid body of substantially any suitable shape, preferably a cylindrical body, located within the buoyancy control chamber and positioned so as to displace a quantity of air and/or water within the buoyancy chamber, preferably in the vicinity of the air-water interface. Preferably, the overall density of the choke is substantially that of water, although the choke might be a hollow cylinder. The choke may be either fixed relative to the control chamber, independently vertically adjustable within the chamber relative to the chamber and the water level sensing device, or vertically adjustable within the chamber relative to the chamber but fixed relative to the sensing device.

A potential use for the buoyancy control device is in cooperation with a submersible protective structure, for example, an antishark cage, to which the system is operatively connected.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of the buoyancy control chamber of the buoyancy control system showing one form of choke in accordance with the invention;

FIG. 2 is a schematic view of the entire buoyancy control system of the invention;

FIG. 3 is a view, partially broken away, of the buoyancy control chamber similar to FIG. 1 but showing another form of choke of the present invention;

FIG. 4 is a view, partially broken away, of the buoyancy control chamber similar to FIG. 1 but illustrating still another form of choke of the invention; and

FIG. 5 is a top perspective view of an antishark cage having associated therewith an embodied therein the buoyancy control system of the invention.

DETAILED DESCRIPTION

Referring to FIG. 1 of the drawings, there is shown a free-flooding buoyancy control chamber 10 adapted to receive and to contain an air bubble in the upper portion thereof. Fluid conduit or pipe 12 is provided within the control chamber 10 for allowing fluid communication between the control chamber 10 and water constituting a surrounding environment. Associated with the fluid conduit 12 is a water level sensing device 14 useful for activating an associated air supply system for the introduction of air into the control chamber 10 to increase the buoyancy of the system. Rigid cylindrical choke 16 is disposed within the control chamber 10 to increase the sensitivity of the buoyancy control system to changes in hydrostatic pressure by increasing the rate and/or amount of rise or fall of the air-water interface within the chamber 10 upon change in hydrostatic pressure.

The free-flooding buoyancy control chamber is adapted to contain both air and water, the air and water providing the air-water interface within chamber 10. Ports 10a are provided in the bottom of control chamber 10 to permit water from the surrounding environment to enter into and to flood the interior of chamber 10, as well as to permit access into the interior of chamber 10 for adjustment or repair of the mechanisms contained therein. Air inlet ports 10b and 10c are provided in the upper portion of the control chamber 10 and are connected by air lines 18b and 18c, respectively, to an air supply. It should be noted that although air is the preferred gaseous medium for providing buoyancy for the control system, any suitable gas might be employed, e.g., oxygen, an oxygen containing gas, helium, or nitrogen, so long as the gas is not greatly soluble in water and is substantially nonreactive therewith. Furthermore, although the described system is primarily applicable for use in bodies of water, it should be apparent that the system may also be employed in bodies of other fluids.

Fluid conduit or pipe 12 is disposed vertically within the control chamber 10 and provides fluid communication with the surrounding environment via an aperture 12a. Handle 20 permits fluid conduit 12 to be vertically adjusted within control chamber 10, the upper portion of the conduit 12 moving within open cylindrical housing 22 disposed on the upper portion of the control chamber 10. O-rings 24 are provided between the internal surface of housing 22 and the external surface of fluid conduit 12 to create a substantially fluid-tight seal between the housing 22 and fluid conduit 12.

Bar 26 extends horizontally from fluid conduit 12 into control chamber 10, bar 26 being fixed to fluid conduit 12 by any suitable fastening means. Bar 26 serves, in part, to prevent the complete withdrawal of fluid conduit 12 from the control chamber 10.

Water level sensing device 14 for determining when additional air should be introduced into the control chamber 10 is operatively connected to fluid conduit 12 by means of bar 26 and is vertically movable with fluid conduit 12 within control chamber 10. In more detail, sensing device 14 is supported on a platform 28 which in turn is secured to bar 26 by means of a threaded screw 30, engageable with both platform 28 and bar 26 and adjustable by means of a rotatable knurled knob 32. In addition, guide post 34 is secured to bar 26 to guide platform 28 upon vertical movement thereof, a collar 36 loosely disposed about guide post 34 serving as a stop means to prevent the lower end of sensing device 14 from being moved below the upper edge of aperture 12a provided in fluid conduit 12. The sensitivity of the system may to some degree be controlled by adjusting the vertical distance which separates sensing device 14 and the upper edge of aperture 12a within fluid conduit 12. Preferably, a separation of one-fourth—three-fourths inch should be provided between sensing device 14 and aperture 12a.

Closed housing 38 is provided on the top surface of control chamber 10 to allow vertical movement of sensing device 14 and its associated elements within the chamber when sensing device 14 is moved upwardly by fluid conduit 12. Electrical

cable 40 connects sensing device 14 with a suitable electrical power source, e.g., a battery, via an aperture 10d in the bottom of the control chamber 10.

Means for supplying air to the buoyancy control system is schematically illustrated in FIG. 2. Thus electrical cable 40 is connected to electrical circuit 42 and a suitable source of electric power, e.g., a battery 43. Electrical circuit 42 serves to operate and control solenoids 44 which manipulate air valves 46 which in turn control the flow of air through air lines 18c to control chamber 10 via air inlet ports 10c. An air supply, such as a pair of air tanks 48, only one of which is preferably in use at a time, the other being held in reserve, communicates via conduits 50 to air lines 18b and 18c, pressure gage 51 providing the operator with a means for determining the length of time which he may remain underwater. Additional valves 52 may be manually operated by means of handles 54 to supply air via air lines 18b and air inlet ports 10b to the control chamber 10 in order to purge the chamber of water in the event of an emergency.

In accordance with the present invention, choke 16 is provided within buoyancy control chamber 10, displacing a quantity of air and water within the chamber 10, displacing a buoyancy control system more responsive to variations in hydrostatic pressure. Choke 16 is a rigid cylindrical body preferably having a density substantially that of water but, if desired, may possess an overall density less than or greater than that of water. Choke 16 may also have either a hollow center or a solid center; in the former case, the interior of the choke may be filled with some or all of the components of the control mechanism shown in FIG. 2, such as the electrical circuit 42 and/or the solenoids 44 and/or battery 43 and/or a pressure regulating device connected to the air supply. Employing choke 16 within the control chamber 10 for displacing a portion of the air and water within the chamber is preferable to reducing the volume of the chamber, as in the latter case adequate buoyancy might not readily be maintained.

Various means for disposing and/or positioning choke 16 within control chamber 10 are shown in FIGS. 1, 3 and 4. In FIG. 1, choke 16 is illustrated as independently vertically adjustable within control chamber 10 both with respect to chamber 10 and to water level sensing device 14. Guide 55 is provided on a vertical portion of choke 16 and fastened thereto by suitable means, e.g., by welding; guide 55 contains internally threaded socket 55a. Externally threaded screw 56 is vertically disposed with socket 55a and is journaled at its ends by bearings 57 located on the upper and lower portions of control chamber 10. Handle 58 is operatively connected to threaded screw 56 and disposed on the outer lower portion of control chamber 10, such that upon rotation of handle 58, threaded screw 56 engagably drives threaded socket 55a and hence vertically displaces choke 16. Thus choke 16 may be adjustably disposed within control chamber 10 such that a portion of the air and water contained therein may be reduced in the vicinity of the air-water interface.

In FIG. 3, choke 16 is rigidly secured to horizontal bar 26a, similar to bar 26 of FIG. 1, but of such shape and strength as to maintain the choke 16 in a substantially horizontal position, which in turn is affixed to fluid conduit 12 by suitable fastening means. Water level sensing device 14 is secured to the upper portion of bar 26a in the manner discussed above with regards to FIG. 1. Thus choke 16 may be vertically adjustable within the chamber 10 with respect to the chamber but fixed with respect to sensing device 14.

In the embodiment shown in FIG. 4, choke 16 is rigidly secured to the upper portion of control chamber 10 by means of a plurality of brackets 60 attached to choke 16 and to control chamber 10 in a suitable manner. In this form of the invention, choke 16 is stationary relative to the chamber 10 but is not fixed relative to the water level sensing device 14, so that choke 16 does not always occupy the same relative position in the vicinity of the air-water interface within chamber 10.

Turning now to the operation of the buoyancy control system of the present invention and in particular to FIGS. 1 and 2, the buoyancy control system, as for example affixed to a protective cage, is placed in the water at the desired location with fluid conduit 12 at its lowest possible position within control chamber 10 so as to provide the largest possible air bubble within chamber 10. The system should then have its maximum buoyancy. Fluid conduit 12 may then be translated upwardly within control chamber 10 to reduce the size of the air bubble and thereby the buoyancy of the system and to place the system in a sinking or descending condition and to cause the system to sink to the desired depth.

When fluid conduit 12 is moved upwardly within control chamber 10 aperture 12a penetrates the air bubble located within the upper portion of control chamber 10. Air from the air bubble will then be discharged via aperture 12a and fluid conduit 12 into the surrounding water environment. The water level within control chamber 10 will rise as air is discharged from the air bubble until the air-water interface rises to the upper edge of aperture 12a of fluid conduit 12 where air will automatically cease to be discharged. When the desired depth is reached fluid conduit 12 can be moved downwardly within the control chamber to equilibrium or neutral buoyancy position.

When fluid conduit 12 is moved downwardly to the equilibrium position within control chamber 10 water level sensing device 14, which may be either float actuated or actuated by the electrical conductivity of the water, activates electrical control circuit 42 so that solenoids 44 open air valves 46 to permit the flow of air from one of air taps 48 via conduit 50, air lines 18c and air inlet ports 10c into the upper portion of control chamber 10. As the expanding air bubble forces the air-water interface beneath the lower edge of water level sensing device 14 the supply of air is terminated by the closing of air valves 46, the air-water interface maintaining a stable position intermediate the upper edge of aperture 12a of fluid conduit 12 and the lower edge of water level sensing device 14. Thus the buoyancy control system by maintaining the size of the air bubble within buoyancy chamber 10 substantially constant and at its equilibrium or neutral buoyancy position is maintained at a given depth beneath the surface of a body of water.

In operation, the volume of air or the size of the air bubble within buoyancy chamber 10 is determined by the position of fluid conduit 12 and aperture 12a within buoyancy chamber 10. The size of the air bubble or the volume of the air trapped within buoyancy chamber 10 is fixed between two limits, a lower limit determined by the position of the lower edge of the water level sensing device 14 and the higher or greater limit or volume determined by the position of the upper edge of aperture 12a. In effect, the volume of the air bubble within buoyancy chamber 10 is maintained constant for any given position or setting of fluid conduit 10 whether the buoyancy control system is set in a neutral or equilibrium position or in a positive buoyancy condition or a negative buoyancy condition. The buoyancy control system of this invention therefore can be adjusted to effect a steady rate of ascent or a steady rate of descent or to maintain a hovering or equilibrium condition.

Choke 16 of the present invention is particularly useful when from time-to-time wave action, movement of the operator within a protective cage, or other external or internal influences upon the buoyancy control system causes air to be discharged from, compressed within, or introduced into the control chamber 10. Thus a wave passing over the control system tends to compress the air bubble within control chamber 10 due to the increased hydrostatic pressure, allowing some water from the surrounding environment to enter into the control chamber through the water inlet ports 10a. As choke 16 occupies a substantial portion of the volume of the control chamber 10 within the vicinity of the air-water interface, only a small amount of entering water will cause the water level within the control chamber to rapidly rise and

hence contact the water level sensing device 14, instigating the flow of air into the control chamber and causing the system to be stabilized at the desired predetermined level. Moreover, as choke 16 allows the position of the air-water interface to rapidly change, only small amounts of air need be introduced at one time in order to stabilize the system; thus air is saved and air tanks 48 may be employed for a longer period of time.

Choke 16 therefore imparts to the buoyancy control system a very rapid response since it serves to bring about a very rapid change in the level of the air-water interface in the vicinity of the choke. Any change in the buoyancy control system or in the surrounding environment tending to increase or decrease the size of the air bubble within the buoyancy control chamber brings about a very rapid downward or upward change in the level of the air-water interface, leading to a very quick discharge of air from the buoyancy control chamber or a very quick discharge of air into the buoyancy control chamber, so as to substantially maintain the size of the air bubble constant all the time for any given position of the discharge conduit 12 within buoyancy control chamber 10. This very rapid response so as to maintain the air bubble within buoyancy control chamber 10 constant for any given fixed position of discharge conduit 12 prevents the buoyancy control system and associated apparatus, such as an antishark cage attached thereto, from attaining any significant momentum or upward or downward velocity, thereby substantially eliminating any subsequent problems of overcontrol together with its usual high level of air consumption to bring the buoyancy control system back into equilibrium or stable condition.

In normal operation of the buoyancy control system, when it is desired to move the apparatus to a greater depth, the fluid conduit 12 is translated upwardly within the control chamber 10 so that air is discharged into the surrounding environment via the aperture 12a, the air bubble losing a portion of its volume and the buoyancy of the system being reduced to a lower degree. When the desired depth is reached, the air bubble may be increased in size to neutral or equilibrium position by translating fluid conduit 12 downwardly. When it is desired to move the system upwardly toward the surface of the body of water, fluid conduit 12 is translated downwardly within control chamber 10, allowing sensing device 14 to cause air to be introduced into the control chamber and thus increasing the buoyancy of the system.

In FIG. 5, there is shown the buoyancy control system affixed to a representative submersible structure, an antishark cage 62. Means may be provided in such an antishark cage 62 for ingress and egress, such as a door 64. Floats 66 are affixed to the upper edges of the antishark cage 62 to provide positive buoyancy. Ballast is employed, in practice, to overcome the positive buoyancy provided by the floats 66, so that the buoyancy provided by the control system is therefore controlling. Air tanks 48 may be located at opposite corners of cage 62 and electrical control circuit 42 and solenoids 44 may be mounted on the back of panel 68 affixed to the inside of the cage. Other devices, e.g., a mine, a warhead, an underwater camera, or an underwater prospecting device, may also employ the buoyancy control system of the present invention.

Thus, the present invention provides a suitable means for improving the responsiveness of a buoyancy control system, and thereby the stability of the apparatus associated therewith. The present invention further contributes to the conservation of the air supply of a buoyancy control system so that an associated submersible structure may be utilized beneath a body of water for a relatively long period of time.

As will be apparent to those skilled in the art in the light of the foregoing disclosure, many modifications, alterations and substitutions are possible in the practice of this invention without departing from the spirit or scope thereof.

I claim:

1. A buoyancy control system, comprising:

a. a buoyancy control chamber adapted to permit fluid communication with the water environment surrounding said

chamber and to contain air introduced thereinto for the formation of an air bubble within said chamber, the air and water within said chamber providing an air-water interface therein;

- b. fluid conduit means associated with said chamber to provide fluid communication between the interior of said chamber and said water environment, said fluid conduit means being vertically movable within said chamber and containing an aperture for providing via said fluid conduit means fluid communication between the interior of said chamber and said water environment; 5
- c. water level sensing means associated with said fluid conduit means and movable therewith within said chamber, said sensing means being spaced above said aperture; 10
- d. air supply means for introducing air into said chamber when said sensing means contacts the water at said air-water interface within said chamber; 15
- e. wherein the improvement comprises: choke means disposed within said control chamber to increase the sensitivity of said control system. 20

2. A buoyancy control system as defined in claim 1, wherein said choke means is vertically adjustable within said control chamber relative to said chamber.

3. A buoyancy control system as defined in claim 2, wherein said choke means is vertically adjustable within said control chamber relative to said water level sensing means. 25

4. A buoyancy control system as defined in claim 1, wherein said choke means is stationary relative to said chamber and is disposed within said chamber in the vicinity of said air-water interface. 30

5. A submersible protective structure, having a buoyancy control system comprising:

- a. a cage provided with means for egress therefrom and ingress thereto; 35
- b. a buoyancy control chamber associated with said cage and adapted to permit fluid communication with the

water environment surrounding said control chamber and said cage and to contain air introduced thereinto for the formation of an air bubble within said chamber, the air and water within said chamber providing an air-water interface therein;

- c. fluid conduit means associated with said chamber to provide fluid communication between the interior of said chamber and said water environment, said fluid conduit means being vertically movable within said chamber and containing an aperture for providing via said fluid conduit means fluid communication between the interior of said chamber and said water environment; 40
- d. water level sensing means associated with said fluid conduit means and movable therewith within said chamber, said sensing means being spaced above said aperture; 45
- e. air supply means for introducing air into said chamber when said sensing means contacts the water at said air-water interface within said chamber; 50
- f. wherein the improvement comprises: choke means disposed within said control chamber to increase the sensitivity of said control system to variations in the position of said cage. 55

6. A buoyancy control system, comprising:

- a. a buoyancy control chamber adapted to contain quantities of air and water, the air and water within said chamber providing an air-water interface therein; 60
- b. means for providing said quantities of air and water to said control chamber upon determination of a variation in said quantities; 65
- c. wherein the improvement comprises: choke means disposed within and occupying a substantial portion of said control chamber at said air-water interface to increase the sensitivity of said means for providing said quantities of air and water in response to a change in level of said air-water interface within said chamber. 70

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,540,398 Dated November 17, 1970

Inventor(s) Peter R. Gimbel

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 4, line 22, "10, displacing a" should correctly read -- so as to make the --

SIGNED AND
SEALED
MAR 2 1971

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER,
Commissioner of Patent