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[54] VARIABLE BUOYANCY ARRANGEMENT

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[58] Field of Search 61/69, 70; 114/16; 62/52

[56] References Cited

UNITED STATES PATENTS

3,161,028	12/1964	Odum et al.	61/69 R
3,487,647	1/1970	Brecht	61/69 R

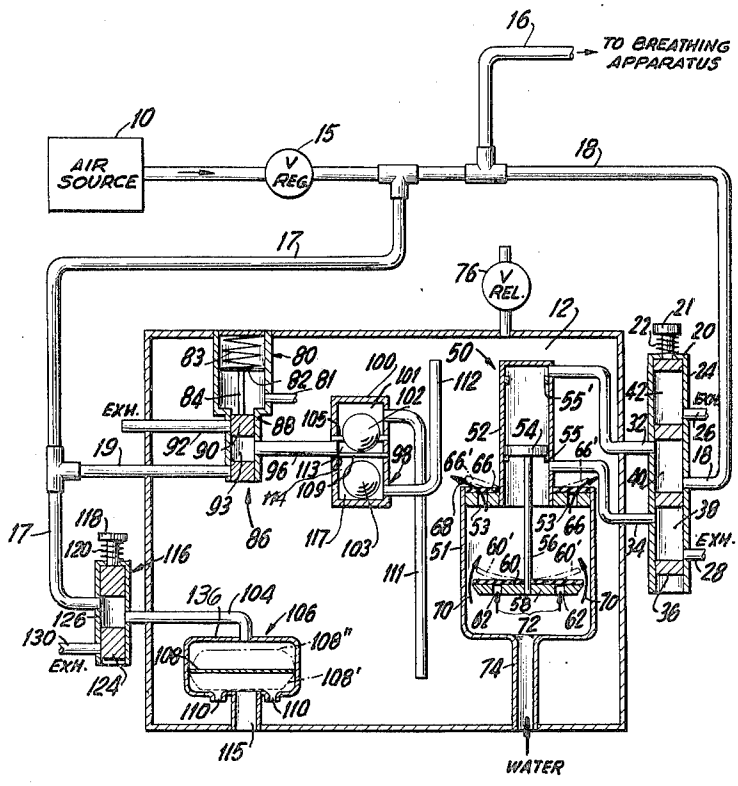
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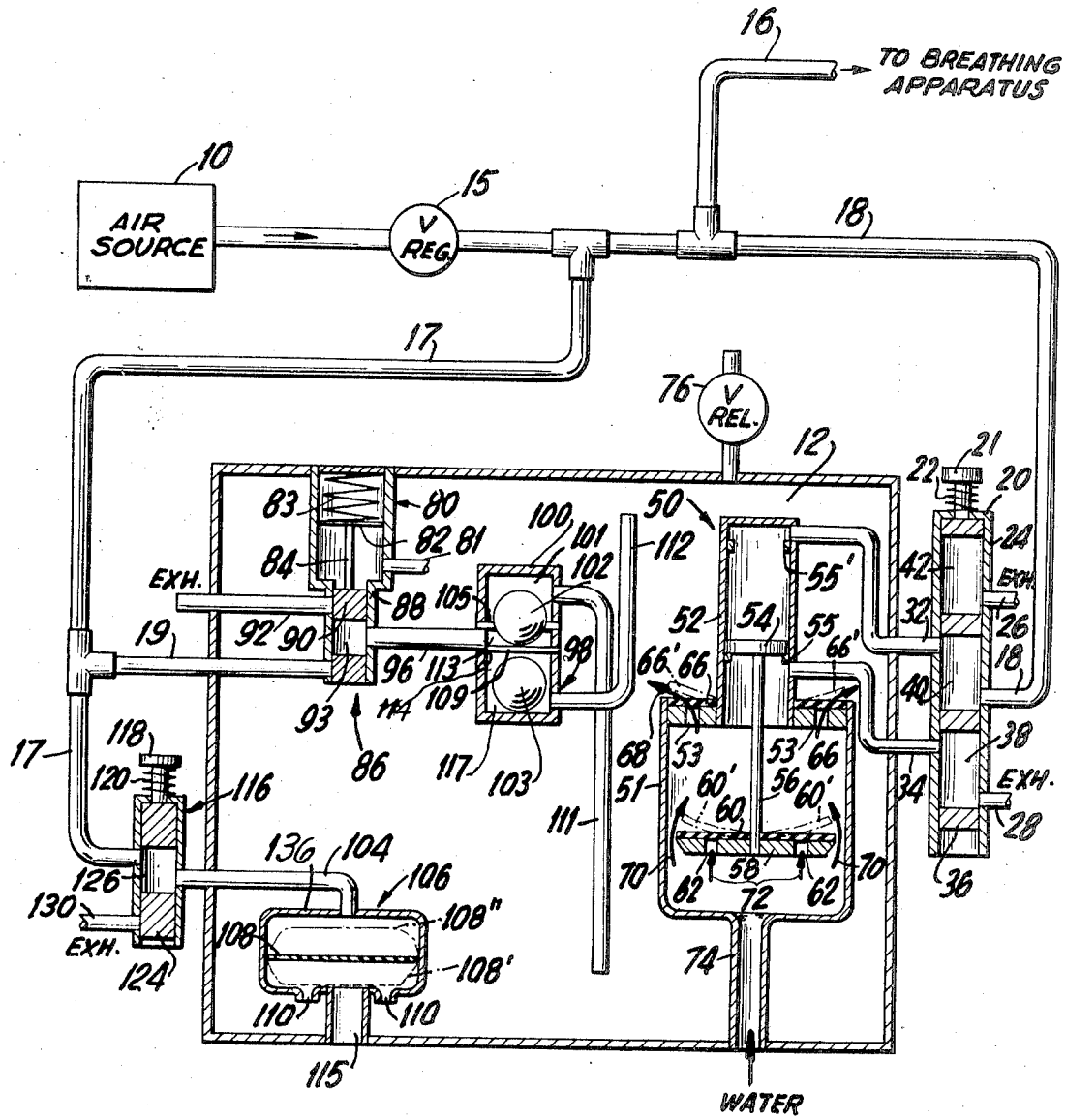
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[57] ABSTRACT

A variable buoyancy arrangement includes a tank of fixed volume and pressure-regulating apparatus for maintaining the interior of the tank within a fixed pressure range above the ambient underwater condition. An air pressure actuated pump is selectively operable under user control for decreasing buoyancy by inserting water into the tank; and buoyancy may be increased by opening a stop valve to expel water from the tank.

13 Claims, 1 Drawing Figure





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VARIABLE BUOYANCY ARRANGEMENT

This application is a continuation-in-part of my pending application Ser. No. 767,373, filed Oct. 14, 1968, patented Mar. 23, 1971 U.S. Pat. No. 3,572,048 and also a continuation-in-part of my joint application Ser. No. 766,932, filed Oct. 11, 1968 patented Nov. 24, 1970 U.S. Pat. No. 3,541,985.

This invention relates to apparatus carried by a person during underwater activities to control the aggregate buoyancy of himself and his equipment. The apparatus enables the diver to effect a desired buoyancy with respect to the depth of his activities and facilitates his ascent or descent in the water.

For underwater activities such as military demolition and hazard fabrication, salvage and treasure recovery, scuba explorations and the like, a diver is equipped with an air source for breathing, and typically loaded with sufficient weight to characterize the system comprising the diver and his equipment as having a neutral, or substantially neutral buoyancy. This permits the diver to move about, and to select his vertical water depth under his own physical power while expending energy only to overcome inertia and develop motion, and not to maintain a desired depth once it has been attained.

However, this weight selection process is only approximate at best. Further, when the buoyancy forces acting on the diver change, e.g., by decreasing when the volume of the diver and his equipment decreases under the influence of increased water pressure at greater depths, normally referred to as "suit squeeze," or by increasing when the weight of the diver and his equipment decreases as his air is consumed (typically a change of several pounds), the diver is forced to reduce or add to his weighting (or to change the volume of his equipment) to maintain a neutral buoyancy. This is often accomplished by picking up rocks from the water bottom and carrying the rocks about, clearly a cumbersome and insecure procedure.

Further, a diver must often swim significant distances at water level to go to and from a starting point such as an anchored craft to the desired diving area. Thus he must expend considerable energy swimming on the surface in a buoyancy condition much better suited to underwater swimming.

It is thus an object of the present invention to provide improved underwater maneuvering apparatus.

More specifically, an object of the present invention is the provision of apparatus for selectively varying the buoyancy of the diver and his apparatus without employing cumbersome weighting elements.

These and other objects of the present invention are realized in an illustrative variable buoyancy-control apparatus adapted to be physically carried by the diver during his underwater activities. The apparatus includes a tank of fixed volume having as one input thereto a valve configuration for maintaining the interior of the tank at an air pressure within a fixed narrow range above that of the ambient environment. A pushbutton actuated valve is employed to selectively actuate a water pump, with the pump being responsive to each depression of the valve button for inserting a fixed quantity of water into the tank chamber. The tank includes an operator-controlled stop valve for selectively expelling water from the tank, the water being discharged under the action of the above-ambient internal tank pressure when the stop valve is opened.

The user of the above apparatus may decrease its buoyancy as changing conditions from time to time dictate by depressing the valve actuating button, thereby causing the pump to force additional water into the tank chamber. Since the chamber is of fixed volume, the weight of the additional water displacing an equal volume of much lighter air in the tank supplies an incremental downward force in absence of additional water displacement. The added water alters the ration of water volume to air volume in the tank. But, since the chamber is of fixed volume, the amount of water displaced by the tank and not counteracted by water within the tank is lessened, thereby decreasing the buoyancy. Correspondingly, to increase the system buoyancy by a desired amount, the stop valve is opened and water is forced out of the pressurized chamber, thus reducing the system weight, while its volume remains

constant. Swimming along the water surface is facilitated since the chamber can be purged of water and thus act as a flotation aid.

A complete understanding of the present invention, and of the above and other features and advantages thereof may be gained from a consideration of the detailed description of an illustrative embodiment thereof presented hereinbelow, in conjunction with the accompanying drawing which depicts in schematic form a variable underwater buoyancy arrangement.

Referring now to the drawing, a variable buoyancy arrangement there shown includes a tank 12 which is adapted to exhibit a constant volume when the inside thereof is pressured. The tank 12 may thus be fabricated either of a rigid material such as metal or a hard synthetic plastic, or of an air-inflatable material such as canvas which will not stretch beyond a fully expanded volume. Any desired shape will suffice for the tank 12, although a form contoured for comfortable mounting on the back of the user about the user's air supply cylinder is most convenient.

To supply air under higher than ambient underwater environmental pressure, an air source 10 is provided. In the preferred form illustrated, this is the main air cylinder carried for underwater breathing purposes which commonly contains air under a pressure of several hundred pounds per square inch. Before reaching the tank 12 in the manner discussed below, the high-pressure air is supplied to a pressure regulating valve 15 which reduces the air pressure to a relatively low level, e.g., to about 100 pounds per square inch above the ambient underwater pressure for delivery to four branch conduits 16, 17, 18 and 19. One air conduit 16 leads to the user's breathing apparatus, a second conduit 17 conveys air to a stop valve 106 via a valve 116 for selectively expelling water from the tank 12; the third conduit 18 leads to a valve 20 which, when actuated, operates a pump 50 for inserting a fixed charge of water into the tank 12; and the fourth conduit 19 conveys pressurized air to valve apparatus 80–86–98 for maintaining the interior of the tank 12 within a fixed pressure range (e.g., 3–5 p.s.i.) above the ambient underwater pressure.

To insert water into the tank chamber 12, thereby decreasing diver buoyancy, a pump 50 is adapted to insert a fixed quantity of water into the tank 12 each time it is operated by the valve 20. The pump 50 is advantageously located within the tank, although it may be externally mounted and coupled to the tank by suitable conduits. The pump 50 includes a cylinder 52 having a drive piston 54 which slides therein. A connecting rod 56 connects the drive piston 54 with a follower piston 58 having a plurality of ports 62 therein. The ports 62 are sealed by a flapper (check) valve member 60 during the active pumping stroke. A pump housing 51 includes a plurality of ports 53 therein through which water passes into the tank 12 during an active pump stroke. The ports 53 are sealed by a flapper (check) valve member 66 which seals these ports under urging of the internal tank pressure at all other times.

A passageway 74 connects the pump to the underwater medium. Two conduits 32 and 34 are connected to the pump cylinder 52 on either side of the piston 54, and connect the piston cylinder to a slide valve 20 which is selectively operated by a pushbutton 21 biased by a spring 22 to a rest position.

The valve 20 includes a slide member 36, having three apertures 38, 40 and 42 thereon, for selectively connecting one of the conduits 32 or 34 to the relatively high air pressure output of the regulator valve 15 via the conduit 18, and for venting the other conduit 32 or 34 to the underwater medium through one of two exhaust orifices 26 or 28 which are open to the ocean. In particular, with the valve 20 in its normal inactive state as shown in the drawing, the slide aperture 40 connects the conduit 32 to the pressurized tube 18, and the aperture 38 connects the conduit 34 to the exhaust port 28. Correspondingly, when the valve 20 is operated by depressing the button 21, aperture 42 vents conduit 32 via port 26, and the valve 15 supplies air pressure to the conduit 34.

With the valve 20 in its rest position, the pressure above the piston 54 (that generated by the regulating valve 15) exceeds

the ambient pressure beneath the piston, and the piston **54** resides at the bottom of the cylinder **52** against a stop **55**. Water flows through the passageway **74** and around the follower piston (indicated by vector **70**) into the pump housing **51**. The water is prevented from flowing through the pump exit ports **53** by the flapper **66** which is maintained against the ports **53** by the internal tank pressure.

To insert the water residing in the pump housing **51** into the tank **12**, the valve **20** operating button **21** is depressed. As discussed above, this couples a relatively high pressure to the bottom of the drive piston **54** via conduit **34**, while venting the cylinder **52** above the piston **54**. Accordingly, the piston **54**, along with the connecting rod **56** and the follower piston **58**, are forced upward toward a stop **55'**.

During this active pumping stroke, the follower piston **58** and its covering flapper member **60** create a pressure which forces water through the ports **53** and into a tank chamber, while forcing the flapper member **66** away from the exit side of the ports **53**, as to the dashed position **66'** shown in the drawing. The volume of water inserted in the tank is essentially given by the cross-sectional area of the tank housing **51** multiplied by the length of the active piston stroke, i.e., the height of the cylinder between the stops **55** and **55'**. At the end of the active stroke, the pump no longer exerts a pressure on the flapper **66** which is returned to a position sealing the ports **53** by the internal tank pressure.

When the valve **20** operating button **21** is released, and thereby reset to its normal position by the spring **22**, the pressure gradient between the conduits **32** and **34** is reversed, and an excess of pressure above the driving piston **54** resets it to its normal, or rest position against the stop **55**. The connecting rod **56** forces the follower piston **58** along with its flexible flapper member **60** to their downward normal position.

Water is drawn into the pump housing **51** beneath the piston **58** during the active stroke when the tank **12** is being charged. On the return stroke for the follower piston **58**, water flows through the ports **72** in the piston and around the flapper member **60** which is forced away from the piston to the dashed position **60'** shown in the drawing. In addition, water flows around the follower piston **58**. Thus, following the return stroke, water is again disposed into the pump housing **51** between the follower elements **58–60** and the pump exit ports **53** to discharge into the tank **12** during the next actuation of the valve **20**.

A three-way slide valve **116** is employed to operate a stop valve **106** for selectively expelling water from the tank **12**. The valve **106** includes a valve housing **136** and pressure-sensitive diaphragm **108**. The stop valve housing **136** includes ports **110** through which water may selectively enter from the tank **12**, and a discharge passageway **115** leading to the underwater medium. A conduit **104** is normally Thus, by the valve **116** to the relatively high-pressure output of the regulator valve **15** to bias the diaphragm **108** downward over the ports **110** (dashed position **108'** in the drawing) hence preventing water from flowing from the tank **12** into the interior of the valve **106**. When the valve **116** is operated, the conduit **104** is vented to the ambient medium and the diaphragm **108** is raised to the dash-dotted position **108''** by the internal pressure of the tank **12**, whereupon water flows from the tank through the ports **110** and is discharged through the passageway **115**. Thus, water is continuously expelled from the tank **12** as long as the conduit **104** is vented.

The slide valve **116** includes an operating button **118** which is biased to an external rest position by a spring **120**. The valve includes a slide member **124** with an aperture **126** thereon. When the button **118** is not activated, the aperture **126** connects the conduits **17** and **104** thus forcing the stop valve diaphragm **108** downward and sealing the valve ports **110**. When the button **118** is depressed, the aperture **126** connects the conduit **104** with a valve venting port **130** thereby opening the water discharge path **110–115** as considered hereinabove.

To maintain the interior of the tank within a fixed pressure range above the ambient medium (e.g., 3–5 p.s.i. as discussed above), a three-way valve **86** includes a slide member **90** which is selectively operated by a differential pressure-responsive regulating valve **80**. The valve **80** includes a diaphragm **82** having one side exposed to the underwater medium, and the other side connected to the interior of the tank **12** by a port **81**. The pressure of the underwater medium is increased by a spring **83** which adds an additional pressure in the range 3–5 p.s.i.

When the interior tank **12** pressure beneath the diaphragm **82** is approximately equal to the pressure on top of the diaphragm **82** (at a level given by the underwater ambient pressure plus the spring pressure), a connecting rod **84** connected to the diaphragm positions the slide member **90** in the three-way valve **86** to a neutral position. In this neutral position a valve **86** output conduit **96** is connected to neither the output of the regulator valve **15** via a conduit **19**, nor to the ambient medium via a conduit **92**.

Should the interior tank pressure become less than the desired pressure, the diaphragm **82** is forced downward by the spring **83** and the underwater medium. This, in turn, forces the valve **86** slide member **90** downward such that an aperture **93** in the slide member **90** connects the output conduit **96** with the pressurized conduit **19**. When this condition obtains, air flows through the conduit **96**, through a valve **98** and into the tank via two tubes **111** and **112**. After sufficient air is inserted in the tank, the pressure coupled to the bottom of the diaphragm **82** via the valve port **81** returns the diaphragm **82** to its normal position, thereby resetting the slide member **90** to its neutral rest position hence disconnecting the conduit **96** from the pressurized conduit **19**.

If the interior pressure of the tank increases above the desired pressure (e.g., when the diver is rising such that the ambient pressure decreases, or when the pump **50** is actuated decreasing the residual air volume thus increasing its pressure) the port **81** couples a net positive pressure to the bottom of the diaphragm **82** thereby raising this member, along with the connecting rod **84** and the valve slide member **90**. The slide aperture **93** then connects the conduit **96** with the venting conduit **92** such that air flows out of the tank via one of the conduits **111** or **112** (depending upon the orientation of the tank) and through the valve **98**. Air is continuously vented until the pressures on both sides of the diaphragm **82** are equalized to maintain the slide member **90** in its neutral position.

The orientation sensitive three-way valve **98** and the two conduits **111** and **112** having their ends located in opposite portions of the tank **12** are employed to connect the conduit **96** with the vertically raised part of the tank which has air in it, and not to the lower tank portion which contains water. This selection permits the pressure in the tank **12** to be maintained within the desired range by removing air and not water when the internal tank pressure is to be reduced.

The position sensitive three-way valve **98** and the conduits **111** and **112** are described in detail in said application Ser. No. 767,373, filed Oct. 14, 1968, now U.S. Pat. No. 3,572,048, the disclosure of which is made part hereof. In brief, the valve **98** includes a housing **100** having end chambers **101** and **117**, and a central chamber **113** connected to conduit **96**. The chamber **101** comprises the space between the end of the housing **100** and an annular ring **105**, while the chamber **117** is disposed between the other end of the housing **100** and an annular ring **114**. Two balls **102** and **103** are respectively disposed in the compartments **101** and **117** and selectively seal central apertures **107** and **109** in the annular rings **105** and **114**, respectively, depending upon the orientation of the valve **98** as discussed below. The tube **111** connects the valve **98** compartment **101** to the bottom portion of the tank **12**, and the tubing **112** connects the upper portion of the tank **12** to the valve compartment **117**.

When the tank **12** resides in the vertical orientation shown in the drawing, the ball **102** rests on the annular member **105** sealing the aperture **107** in this annular member. Accordingly, the ball **102** disconnects the conduit **111**, having its free end

disposed in the water-containing lower portion of the tank 12, from the conduit 96. Correspondingly, the ball 103 rests on the bottom of the housing 100, and the conduits 96 and 112 are thereby connected via the valve compartments 117 and 101 and the unblocked center 109 of the annular member 114. Since water resides on the bottom of the tank when it is in the position shown in the drawing, the conduit 96 is connected by the valve 98 and the tube 112 with the air containing upper portion of the tank 12.

When the tank is rotated to reverse the vertical orientation of the drawing (e.g., a diver descending head first), the ball 103 will rest on the ring 114 and seal the aperture 109. This isolates the conduit 96 from the tube 112 having its end now disposed in the water in the tank. Correspondingly, the ball 102 resides against the valve housing 100, and the conduit 96 is thus connected to the conduit 111 which terminates in the air containing portion of the tank.

The balls 102 and 103 are physically proportioned, along with their seats 105 and 114, apertures 107 and 109, and the center chamber 113, so that they cannot both be in a seated position at the same time because of interference.

Thus, the valves 80, 86 and 98, having the several conduits associated therewith, operate to maintain the interior of the tank within the desired pressure range of 3–5 p.s.i. above ambient by selectively increasing or decreasing the air pressure within the tank 12 irrespective of the orientation of the tank.

Finally, the tank contains a relief valve 76 which is adapted to open as a safety measure should the pressure within the tank exceed a predetermined limit for any reason (e.g., 10 p.s.i. above the ambient medium).

With the above arrangement in mind, an illustrative sequence of operation for the buoyancy-controlling apparatus will now be described. A diver just beginning his journey starts with his tank 12 substantially free of water and with an internal pressure between 3–5 pounds per square inch above ambient, as produced by the output of the regulator valve 15 acting through the conduit 19 and the valves 80, 86 and 98. The user swims on the water surface to the diving area with the empty tank being a flotation aid and not an encumbering weight which has to be transported.

At the diving location, the diver repeatedly actuates the button 21 to change his status from positive to neutral or slightly negative buoyancy. With each depression of the button 21, the pump 50 responds in the above-described manner to air pressure from the regulator valve 15 which drives the piston 54 via the valve 20 by forcing a fixed quantity of water through the tank ports 53 and into the tank 12. Since the tank 12 is of a fixed volume it displaces a like fixed volume of water when submerged. Thus, when water is introduced into the tank by the pump 50, the weight of this water directly subtracts from the fixed buoyancy force acting on the user and his submerged equipment, which again is of a fixed volume.

At neutral or slightly negative buoyancy, the diver is free to move about underwater as he desires without expending energy to maintain his underwater depth. As the buoyancy of the diver and his equipment decreases, e.g., because of increased water pressure as he moves to greater depths, he may compensate by releasing some of the water pumped in at the surface to begin his dive. Correspondingly, as his buoyancy increases because the user expends his air supply or moves to shallower water with less pressure and less "suit squeeze," the user simply pushes the button 21 to inject more water into the tank 12.

For any orientation of the diver and the tank 12, the valve 98 connects the conduit 111 or 112 terminating in the air-containing portion of the tank 12 to the conduit 96. The diaphragm 82 and spring 83 normally position the valve 86 slide member 90 to a neutral position, and move the slide member to connect the conduit 96 via the conduit 92 or 19 to reduce or increase the tank pressure, respectively, if it departs from the desired value. Accordingly, the valve arrangement 80, 86 and 98 maintains the interior of the tank within the desired pressure range for any water depth and corresponding ambient pressure, and for any orientation of the diver. Since the internal tank pressure is maintained at a few p.s.i. above ambient, the tank is not crushed at great water depths, even when fabricated of materials which are not normally form retaining or which do not possess sufficient inherent mechanical strength to withstand the ambient underwater pressures which may be extremely large.

When the diver wishes to increase his buoyancy, either as an assistance in rising or to correct for an overweighted condition, he depresses the button 118 to operate the stop valve 106. The internal pressure of the tank forces water in the tank 12 through the valve apertures 110 and out the passageway 115 into the underwater medium while maintaining the diaphragm 108 in a position away from the apertures 110. Water continuously flows out of the tank until the button 118 is released to again apply pressure from the conduit 17 to the conduit 104 to force the diaphragm 108 downward to seal the ports 110. As water is expelled, the downward weight force acting against the buoyancy force is continuously decreased thereby increasing net buoyancy.

If at any time the interior of the tank becomes overly pressurized, the relief valve 76 opens to vent the excessive air pressure.

Thus, the variable buoyancy arrangement depicted in the drawing and disclosed in detail above is readily operable under control of the user to generate any desired buoyancy condition for the user and his equipment vis-a-vis the surrounding underwater environment.

The arrangement described above is only illustrative of the principles of the present invention. Numerous modifications and adaptations thereof will be readily apparent to those skilled in the art without departing from the spirit and scope of the present invention. For example, the variable buoyancy apparatus may be used to help a diver carry heavy objects picked up on the bottom, or it may be attached to heavy objects to be transported for maintaining their buoyancy regardless of changing depths without the instability inherent in buoyancy tanks open to the sea.

What is claimed is:

1. In combination in a variable buoyancy arrangement adapted for underwater activity, a tank of substantially fixed volume for selectively storing water, means for maintaining the interior of said tank at a pressure which exceeds the underwater ambient pressure, means for selectively introducing water into said tank, and means for selectively discharging water from said tank, wherein said selective water-introducing means comprises a pump having a discharge port connected to said tank, said pump including a cylinder, a drive piston having first and second surfaces, said drive piston being mounted for sliding translation within said cylinder, a pump chamber, a follower piston connected to said drive piston and located in said pump chamber, and means for selectively impressing a pressure gradient in said pump cylinder about said first and second driving piston surfaces.

2. A combination as in claim 1 further comprising check valve means connected to said pump discharge port.

3. A combination as in claim 2 wherein said check valve means includes flexible flapper-sealing means located over said pump discharge port.

4. A combination as in claim 3 further comprising check valve means included on said follower piston.

5. A combination as in claim 4 wherein said follower piston check valve means includes apertures in said follower piston, and a flexible flapper-sealing means disposed over said apertures.

6. A combination as in claim 2 wherein said pressure gradient impressing means includes first and second conduits connected to said pump cylinder on opposite sides of said drive piston; a valve including an input port to be energized with pressurized air; at least one venting port, and means for alternately connecting one of said conduits connected to said pump cylinder to said pressurized valve port and for connecting the other of said conduits to said venting port.

7. In combination in a variable buoyancy arrangement adapted for underwater activity, a tank of substantially fixed volume for selectively storing water, means for maintaining the interior of said tank within a predetermined pressure range above the underwater ambient pressure, means for selectively introducing water into said tank, and means for selectively discharging water from said tank, wherein said tank interior pressure-maintaining means includes input means adapted for connection to a source of compressed air, venting means, first valve means for selectively connecting said tank to one of said air supplying input means or to said venting means, and differential pressure valve means responsive to the pressure differential between the interior and exterior of said tank means for selectively operating said first valve means.

8. A combination as in claim 7 further comprising orientation-responsive valve means for connecting said first valve means to the upper portion of said tank.

9. A combination as in claim 7 wherein said first valve means includes a slide member for selectively connecting said tank to said air input means, and wherein said differential pressure valve means includes a diaphragm having two surfaces respectively exposed to the environment outside said tank and to the interior of said tank, and means connecting said diaphragm with said slide member of said first valve means.

10. A combination as in claim 9 further comprising spring means for biasing said diaphragm.

11. A combination as in claim 7 wherein said water-discharging means including stop valve means comprising at least one input port and at least one exit port, a diaphragm for selectively sealing said input port, and additional valve means for selectively operating said diaphragm.

12. A combination as in claim 11 wherein said additional valve means includes a vent port, an air input port, a transferred port connected to said stop valve means, and slide means for selectively connecting said transferred port to said vent port or to said air input port.

13. A combination as in claim 8 wherein said orientation-responsive valve means includes three aligned compartments separated by two annular members each having a central orifice therein, ball means in the two end compartments for selectively sealing the central aperture in at most one of said annular members depending upon the orientation of said valve means, first conduit means connecting the central valve compartment with said first valve means, and additional conduit means connecting the end valve compartments with differing portions of said tank such that the portion of said tank oriented vertically upward is operatively connected by said additional conduit means and said orientation responsive valve means to said first conduit means.

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