United States Patent

[11] 3,541,985

[72] Inventors Robert H. Murphy
West Hartford, Connecticut;
Julian Gordon, Malden, Massachusetts
[21] Appl. No. 766,932
[22] Filed Oct. 11, 1968
[45] Patented Nov. 24, 1970
[73] Assignee The Wiremold Company
West Hartford, Connecticut
a corporation of Connecticut

[54] **VARIABLE BUOYANCY ARRANGEMENT**
10 Claims, 1 Drawing Fig.

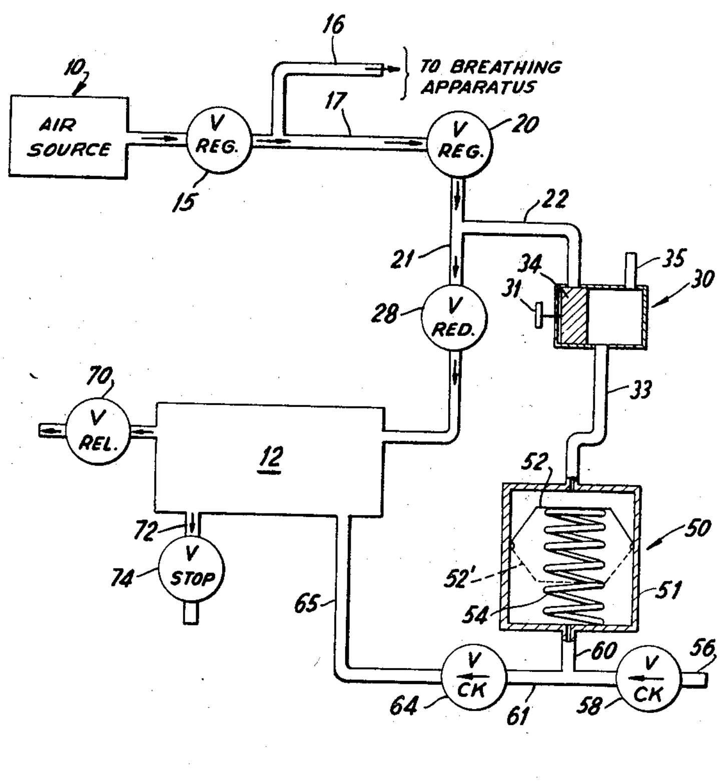
[52] U.S. Cl. 114/16, 61/69
[51] Int. Cl. B63g 8/14, B63g 8/22
[50] Field of Search 114/16, 16.3; 9/8; 61/69

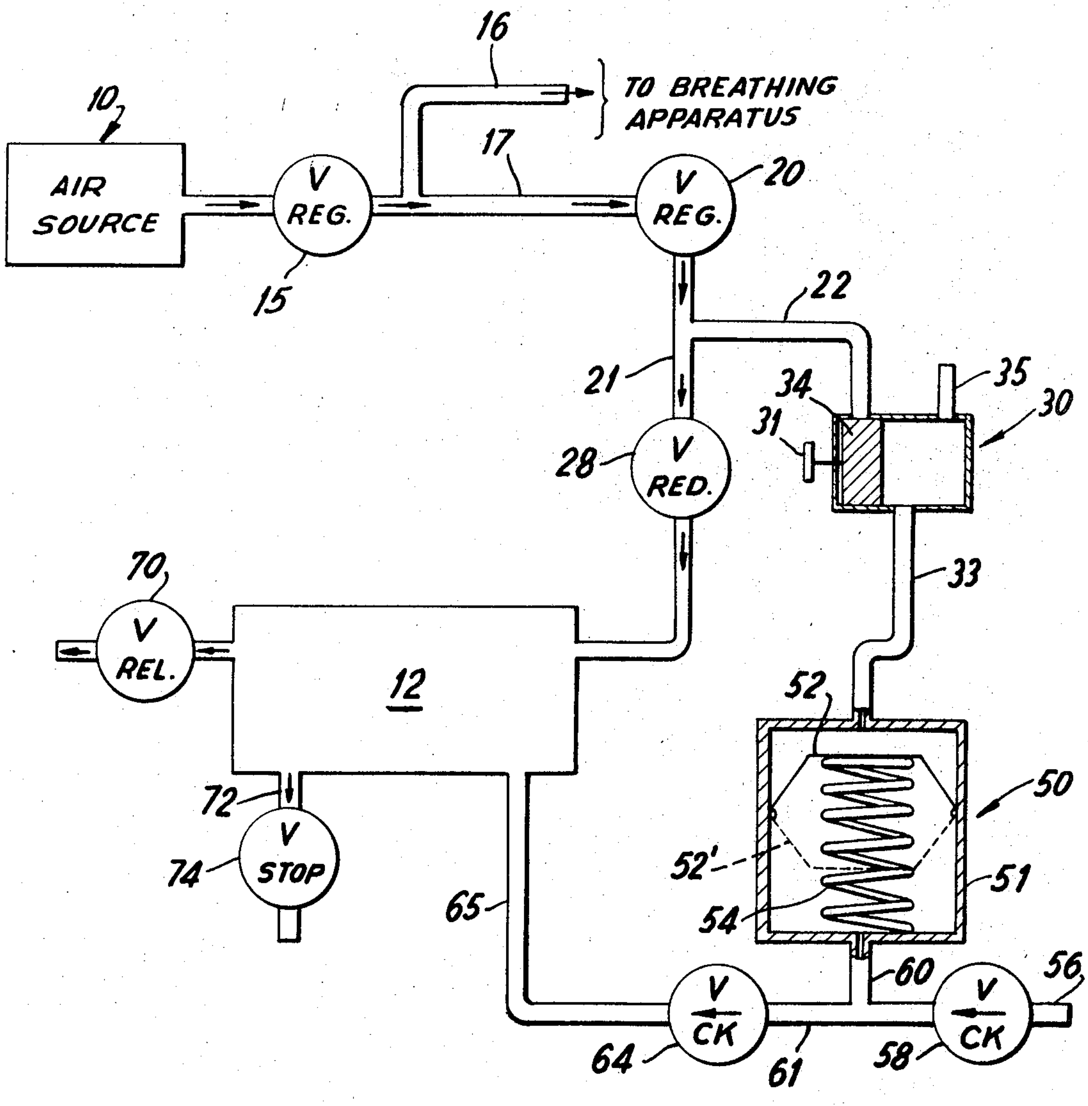
[56] **References Cited**
UNITED STATES PATENTS

3,179,962	4/1965	Shear et al.	9/8
3,204,596	9/1965	Fallon	114/16

Primary Examiner—Trygve M. Blix
Attorney—Davis, Hoxie, Faithfull & Hapgood

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 cock to allow expulsion of water from the tank.





INVENTORS
JULIAN GORDON
ROBERT H. MURPHY

BY

Davis, Hoxie, Faithfull & Hapgood
ATTORNEYS

VARIABLE BUOYANCY ARRANGEMENT

DISCLOSURE OF INVENTION

This invention relates to equipment carried by a person during his underwater activities to control the aggregate buoyancy of himself and his equipment to enable him to effect a desired buoyancy with respect to the depth of his activities or facilitate 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 considerably 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 weighing 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 supplying air characterized by a pressure within a fixed range above that of the ambient environment. A three-way, push button actuated valve is employed to selectively actuate a water pump, with the pump being responsive to each depression of the valve button to force a fixed quantity of water into the tank chamber. An output conduit is connected to the tank for selectively passing water outward therefrom, under control of a stop cock valve, with the water being discharged under the action of the above-ambient internal tank pressure when the stop valve is open.

The user of the above apparatus may decrease his 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 additional water supplies an incremental downward force while causing no additional water displacement thus not increasing the upward buoyancy force acting on the diver. Correspondingly, to increase the system buoyancy by a desired amount, the stop cock is opened and water is forced out of the pressurized chamber, thus reducing the system weight, but not its volume. 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**, the high pressure air undergoes several pressure reductions as follows. The source **10** is connected to a pressure regulating valve **15** of conventional form which reduces the air pressure, *e.g.*, to about 100 pounds per square inch above the ambient underwater pressure for delivery to two branch conduits, one **16** leading to the user's breathing apparatus and the other **17** leading to an additional pressure regulating valve **20**. Since the pressure of the air leaving the first pressure valve **15** is still too high for use in the buoyancy control devices, the second pressure reduction valve **20** further reduces the pressure, *e.g.*, to about 15 p.s.i. above ambient. From the exit port of second valve **20** two branch tubes **21** and **22** conduct the air, on one hand to the final pressure reduction valve **28** (in pipe **21**) to the tank **12**, the reduction being to about 5 p.s.i. above ambient pressure or 10 pounds below the supply which is regulated at 15 pounds above ambient. Alternatively, the valve **28** may also be of the regulating type to develop the requisite 5 p.s.i. above ambient. Thus, the branch **21** supplies air under pressure to the buoyancy tank **12** at its desired pressure.

The other branch **22** from the second pressure reduction valve **20**, is provided to supply air pressure to a system for controlling and adjusting the amount of water in the tank **12** to decrease its buoyancy. This is done selectively by providing in tube **22** a conventional two-position button-actuated valve **30** to one exit port of which is connected a tube **33** leading to an air pressure actuated pump **50**. The valve **30** normally is biased as shown in the drawing to connect the conduit **33** to a vent tube **35** exposed to the underwater environment. The valve has a button **31** which when pressed by the user interconnects the tubes **22** and **33**. When the button **31** is released the return of the valve plunger **34** to normal position reconnects the tubes **33** and **35** while blocking the conduit **22**. Suitable embodiments for the valves **15**, **20**, **28** and **30** discussed hereinabove, as well as additional valve elements considered below, are well known to those skilled in the art, and these devices need not be described further.

The pump **50** includes a housing **51** having an "air" port at one end and a "water" port at its opposite end, also has therein a piston or a flexible diaphragm **52** biased upward, *i.e.* toward its "air" end by a compression spring **54**. Water may selectively flow into the pump housing **51** through its "water" end, "water" end, *i.e.* beneath the diaphragm **52** through the entrance port **56** of a one-way check valve **58** whose exit port is connected by a conduit **60** to the pump's water end. When the button **31** of the pump control valve is depressed, compressed air at 15 p.s.i. above the underwater ambient pressure flows through the elements **22–30–33** to the pump **50**, thereby forcing the diaphragm **52** to the downward position **52'** as shown in a dashed line in the drawing. This forces out of the pump a fixed quantity of water defined by the volume between the diaphragm in its up and down positions **52** and **52'**. To deliver this volume of water to tank **12**, a branch **61** from the conduit **60** connects to the inlet of a one-way check valve **64** whose outlet is connected by a conduit **65** to tank **12**. The unidirectional nature of the check valves **58** and **64** prevent discharge of water from the pump except to the tank, and prevent flow of water from the tank back into the pump.

When the button **31** is released, the tube **22** is blocked by the valve **30**, and the area above the diaphragm **52** is vented to the ambient environment through the conduits **33** and **35**. Accordingly, with the pump actuating air pressure thus removed, the compressed spring **54** pushes the diaphragm **52** to its quiescent raised position. This motion of the diaphragm **52** creates a reduced pressure in the lower portion of the pump **50** which draws water therein through the check valve **58** and the conduits **56** and **60**. The pump **50** is thus charged and in a primed condition to discharge a like quantum of water in the tank **12** when the valve **30** is again actuated by the button **31**.

To selectively remove water from the tank **12**, a conduit **72** having a normally closed stop cook valve **74** affixed thereto is connected to the tank **12**. When the stop cock valve is opened, the internal pressure in the tank **12** which is always at least 5 p.s.i. above the external ambient pressure forces water out of the tank through the elements **72**—**74**.

Finally, a pressure relief valve **70** is connected to the tank **12** and adapted to open when the internal pressure of the tank **12** exceeds a predetermined pressure level above ambient, which pressure level is intermediate the pressures developed by the valves **20** and **28** , *e.g.*, 10 p.s.i. above ambient. This fixes the maximum internal pressure of the tank **12** at 10 p.s.i. above ambient, thus constraining the pressure within the tank **12** to always be in the range between 5–10 p.s.i. above ambient. This, in turn, assures that the 15 pounds pressure (above ambient) which actuates the pump **50** will always be sufficient to overcome the internal tank pressure and drive water into the tank **12** each time the button **31** is depressed, and further ensures that the internal pressure of the tank **12** is sufficiently greater than the ambient pressure to force water out of the tank **12** into the local environment when the stop cock valve **74** is opened.

The button **31** and the stop cock valve **74** are advantageously mounted in a convenient location readily accessible for user control. If desired, a two-position valve **20** embodying a remote control actuating mechanism in place of the valve button **31** may be employed, with the remote control mechanism being contained in a place convenient for the user and the remainder of the valve **30** being located as desired.

With the above arrangement in mind, an illustrative sequence of operation will now be described. A diver just beginning his journey starts with his tank **12** substantially free of water and with an internal pressure of 5 pounds per square inch above ambient, as produced by the high pressure air supply **10** acting through the regulating valves **15** and **20** and the reducing valve **28**. The user swims on the water surface to the diving area with the empty tank **12** being a flotation aid and not an encumbering weight which has to be transported.

At the diving location, the diver repeatedly actuates the button **31** to change his status from positive to neutral or slightly negative buoyancy. With each depression of the button **31** the pump **50** responds in the above-described manner to air pressure from the 15 p.s.i. above ambient regulator valve **20** acting through the conduits **22** and **33** and the valve **30** by forcing a fixed quantity of water through the path **60–64–65** into the tank **12**. Since the tank **12** is of a fixed volume it displaces a fixed volume of water when submerged. Thus when any water is introduced into the tank by the pump **50**, it directly subtracts from the buoyancy forces acting on the user and his submerged equipment.

At neutral or slightly negative buoyancy, the diver is free to move about under water 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 the 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, and as his buoyancy increases because the user expends his air supply or moves to shallower waters with less pressure and less "suit squeeze", the user simply pushes the button **31** to inject more water in the tank **12**.

Since the valve system **15**- **20–28** develops an output air pressure measured on an ambient, environmental-responsive basis, all pressure relationships are maintained, including the relatively small, 10 p.s.i. maximum gradient between the interior of the tank **12** and the water pressure on the outside thereof. Accordingly, the tank is not crushed at great water depths, even when fabricated of materials which are not naturally form-retaining or do not possess sufficient mechanical strength to retain the form of the tank at ambient underwater pressures.

When the diver wishes to increase his buoyancy, either as an assistance in rising or to correct for an overweighted condition, he opens the stop cock **74** for a desired interval. The element **74** opens and the air pressure within the tank **12**, being in the range of 5—10 p.s.i. above the external water pressure, forces water out of the tank through the conduits **72** and the valve **74**. Thus the downward weight force acting against the upward buoyant force is decreased.

If the stop cock **74** is left open for an extended period, the diver will become underweighted, and rise to the surface. The orifice of the stop cock **74** is thus preferably sufficiently small to prevent the rate of ascent of from becoming too rapid, thus avoiding any potentially dangerous decompression problems.

During an ascent, the ambient pressure will reduce until it becomes 10 p.s.i. less than the pressure within the tank. Then the relief valve **70** will open. Air will exhaust from the tank **12** through the valve **70** to maintain the 10 p.s.i. tank-water pressure differential.

Thus, the variable buoyancy arrangement depicted in the drawing and discussed 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 above-described arrangement is only illustrative of the principles of the present invention. Numerous modifications and adaptations thereof will be apparent to those skilled in the art, without departing from the spirit and scope of the present invention. For example, this apparatus may be used to help a diver carry heavy objects picked up on the bottom, or it may be attached to such heavy objects he wishes to transport and it will then maintain their buoyancy regardless of their changing depth without the instability inherent in buoyancy tanks "open to the sea".

We claim:

1. In combination in a variable buoyancy arrangement adapted for underwater activity, a tank of substantially fixed volume for selectively storing water, means for selectively supplying compressed air to said tank and for selectively venting air from said tank 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.

2. A combination as in claim **1** wherein said selective water introducing means comprises a pump having a discharge port connected to said tank, a source of air at a pressure greater than the maximum pressure within said tank, and valve means for selectively energizing said pump to cause introduction of water into said tank.

3. 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 os said tank within a predetermined pressure range above the underwater ambient pressure range above the underwater ambient pressure means for selectively introducing water into said tank, 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, a source of air at a pressure greater than the maximum pressure within said tank, valve means for selectively energizing said pump to cause introduction of water into said tank, wherein said pump comprises a pump housing, piston means movable within said housing, means for biasing said piston means, and means for connecting one side of said piston means to said air source, the other side of said piston means communicating with said pump discharge port.

4. A combination as in claim 3 further comprising a check valve connected between said pump and said tank.

5. 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, means for selectively discharging water from said tank wherein said selective water introducing means comprises a pump having a discharge port connected port connected to said tank, a source of air at a pressure greater than the maximum pressure within said tank, valve means for selectively energizing said pump to cause introduction of water into said tank, wherein said tank pressure maintaining means includes pressure regulating means connected to the compressed air source providing a pressure of a predetermined value greater than the underwater ambient pressure and pressure reducing means connecting said pressure regulating means with said tank, and means for connecting said pressure regulating means to said pump.

6. A combination as in claim 5 further comprising pressure relief valve means connected to said tank.

7. A combination as in claim 5 wherein said selective discharge means comprises a stop cock connected to said tank.

8. A combination as in claim 1 wherein said selective discharge means comprises a stop cock connected to said tank.

9. 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, 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, a source of air at a pressure greater than the maximum pressure within said tank, valve means for selectively energizing said pump to cause introduction of water into said tank, wherein said pump comprises a pump housing, a diaphragm attached to said housing, means for biasing said diaphragm, and means for connecting one side of said diaphragm to said air source, the other side of said diaphragm communicating with said pump discharge port.

10. The combination as claimed in claim 2 having a connection between said valve means and said air source for energizing said pump as said valve means is operated.

FO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3 541 985 Dated November 24, 1970

Inventor(s) Robert H. Murphy & Julian Gordon

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

Col. 1, line 36, "considerably" should be --considerable--.

Col. 3, line 17, "cook" should be --cock--.

Col. 3, line 41, "20" should be --30--.

Col. 4, line 26, delete "of" (second occurrence).

Col. 4, claim 3, line 4, "os" should be --of--;

line 5, after "pressure" insert a comma ar delete "range above the";

line 5, delete "underwater ambient pressu

Col. 5, line 17 (claim 5, line 9) after "connected" (first occurrence) delete"port connected".

Signed and sealed this 30th day of March 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

WILLIAM E. SCHUYLER, J
Commissioner of Patent