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VARIABLE BUOYANCY CONTROL SYSTEM

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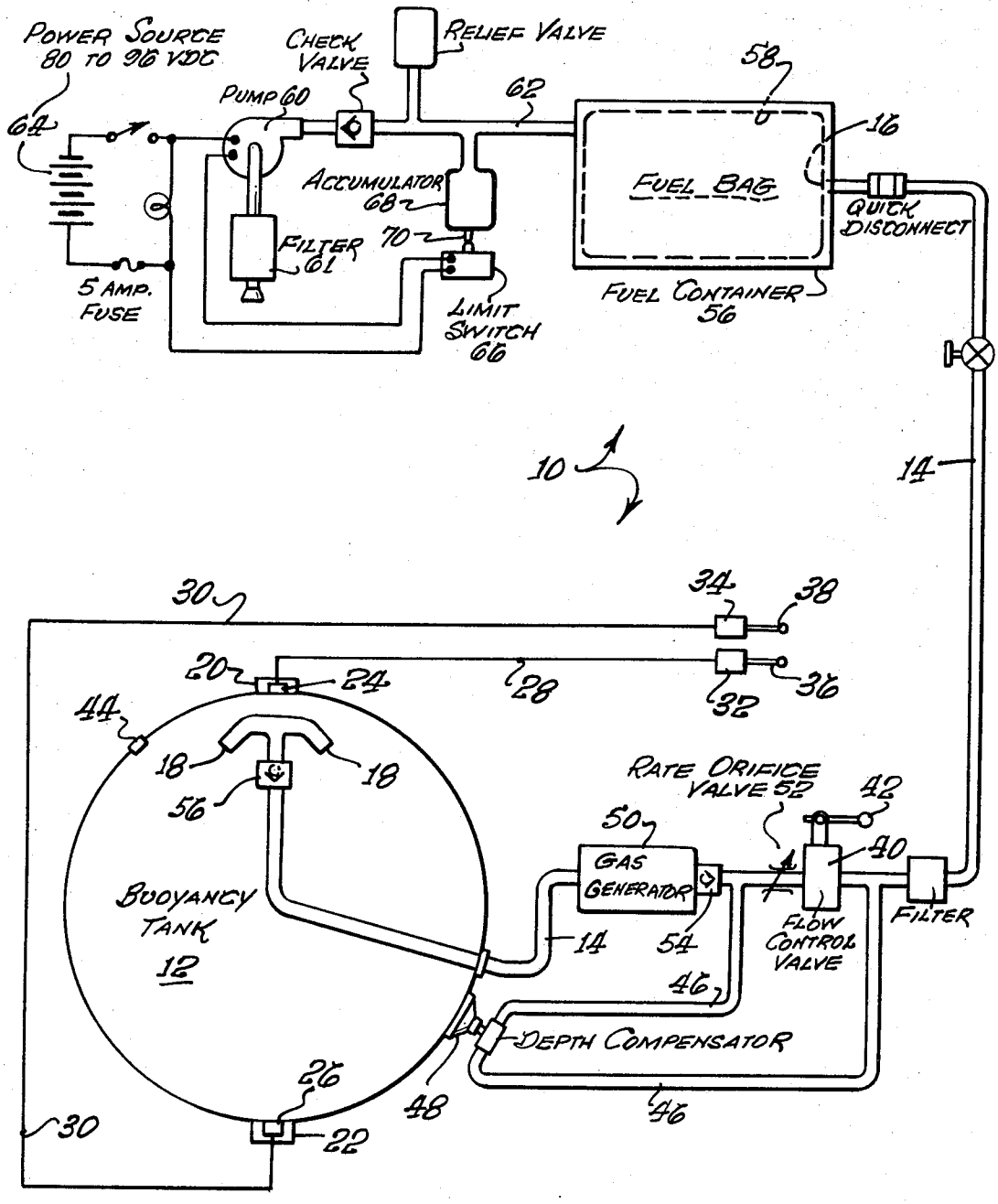

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VARIABLE BUOYANCY CONTROL SYSTEM

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ABSTRACT OF THE DISCLOSURE

A variable buoyancy control system for an underwater vehicle including a buoyancy tank; a main fluid pressure line which is connected to the tank; the tank having top and bottom butterfly valves; means for selectively opening and closing the top and bottom butterfly valves; a flow control valve connected in the fluid pressure line for selectively controlling the fluid pressure to the tank; a relief valve mounted in the buoyancy tank for relieving pressure from the tank upon the occurrence of positive pressure differential of the tank over ambient; a secondary fluid pressure line connected to the main fluid pressure line across said flow control valve; and a depth compensator valve connected in the secondary fluid pressure line and pressure responsive to the buoyancy tank and ambient water for by-passing fluid to the buoyancy tank upon the occurrence of a negative pressure differential between the tank and ambient.

FIELD OF THE INVENTION

The present invention relates to a variable buoyancy control system which includes a buoyancy tank for an underwater vehicle wherein the tank is automatically pressure compensated and can be selectively ballasted and deballasted with ambient water.

DESCRIPTION OF THE PRIOR ART

In Pat. No. 3,434,443 to Estabrook there is shown an underwater buoyancy transport vehicle which is operated by a diver for lifting and transferring loads within the ocean. This vehicle has thrusters for propelling the vehicle in desired directions and a variable buoyancy control system including a buoyancy tank for ascending or descending the vehicle with or without its payload. In the patent the buoyancy tank is described as having top and bottom butterfly valves and a pressure line from the surface for selectively ballasting and deballasting the tank. An improved ballasting and deballasting system was required so that the vehicle would be self contained and not be constrained by a tethered pressure line to the ocean's surface. Further, since the vehicle transcends various depths and undergoes various pressures, it became desirable that the buoyancy tank be automatically pressure compensated whether it ascends or descends. Without pressure compensation an opening of either butterfly valve after some descent will cause a rapid rush of water into the buoyancy tank because of the greater ocean pressure. This can cause the vehicle to drop uncontrollably in the ocean. An opposite effect occurs upon ascent when the bottom butterfly valve is opened. Also, pressure compensation enables the buoyancy tank to be constructed of minimum wall thickness and the diver can relieve his mind of pressure compensation while he is operating the vehicle. The prior art did not demonstrate an embodiment which would provide these advantages.

SUMMARY OF THE INVENTION

The present invention provides a variable buoyancy control system which is especially adapted for use on an underwater vehicle, such as the buoyancy transport vehicle described in the aforementioned patent. This control system includes a buoyancy tank which has the primary advantage of being automatically pressure compensated whether the vehicle ascends or descends in the water. The buoyancy control system includes the buoyancy tank; a main fluid pressure line which is connected to the tank; the tank having top and bottom butterfly valves; means for selectively opening and closing the butterfly valves; a flow control valve connected in the main fluid pressure line for selectively controlling the fluid pressure to the tank; a relief valve mounted in the buoyancy tank for relieving pressure from the tank upon the occurrence of a positive pressure differential of the tank over ambient; a secondary fluid pressure line connected to the main fluid pressure line across the flow control valve; and a depth compensator valve connected in the secondary fluid pressure line and pressure responsive to the buoyancy tank and ambient water for by-passing fluid to the buoyancy tank upon the occurrence of a negative pressure differential between the tank and ambient.

STATEMENT OF THE OBJECTS OF THE INVENTION

An object of the present invention is to provide an automatically pressure compensated variable buoyancy control system for an underwater vehicle.

Another object is to provide a buoyancy control system for a tank which has top and bottom butterfly valves wherein the system enables fine control of buoyancy of the tank when the butterfly valves are selectively opened and closed.

A further object is to provide a variable buoyancy control system which is adapted for self contained utilization on an underwater vehicle, and which includes a buoyancy tank which can be constructed of a minimum wall thickness and thereby minimum weight.

Other objects and many of the attendant advantages of this invention will be readily appreciated as it becomes better understood by reference to the description and accompanying drawings which follow.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic illustration of the variable buoyancy control system.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1 there is shown therein a variable buoyancy control system **10** which includes a buoyancy tank **12**, which may be spherical, and a main fluid pressure line **14** which has an inlet **16** and an outlet **18**, the inlet being adapted to receive fluid and the outlet opening into the buoyancy tank **12** for introducing pressurized fluid therein. The buoyancy tank **12** has top and bottom butterfly valves **20** and **22** respectively, and means are provided for selectively opening and closing these butterfly valves so as to allow water to enter and exit the buoyancy tank. The opening and closing means may include hydraulic rotary actuators **24** and **26** which are connected to the pivot shafts of the top and bottom butterfly valves **20** and **22** respectively, and hydraulic lines **28** and **30** which slave the hydraulic rotary actuators **24** and **26** respectively to linear actuators **32** and **34** respectively. The linear actuators **32** and **34** in turn have control handles **36** and **38** which can be controlled by a diver for selectively opening and closing the butterfly valves **20** and **22**. For further control by the diver there is provided

a flow control valve **40** which is connected in the main fluid pressure line **14** for selectively controlling the fluid pressure to the buoyancy tank **12** so as to ascend or descend the vehicle depending upon the positions of the butterfly valves **20** and **22**. The flow control valve **40** may be operated by a handle **42**.

It is desirable that the buoyancy tank be constructed of minimum wall thickness so that it will be as light as possible. In this manner, the lifting capacity of the buoyancy tank will be optimized. While separate controls could have been provided for the driver to pressure compensate the tank it is more desirable that the tank be automatically pressure compensated upon ascent or descent and that the diver be freed of this additional responsibility. This has been accomplished by providing the wall of the buoyancy tank with a relief valve **44** which is capable of relieving pressure from the tank when there is a positive pressure differential of the tank pressure over ambient ocean pressure. Further, a secondary fluid pressure line **46** is connected to the main fluid pressure line **14** across the flow control valve **40**. A depth compensator valve **48** is connected in the secondary fluid pressure line **46** and is mounted to the tank **12** in communication with its interior and ambient pressure so as to be pressure responsive to both the buoyancy tank and ambient water for by-passing fluid to the buoyancy tank **12** upon the occurrence of a negative pressure differential between the tank and ambient. Accordingly, when the buoyancy tank **12** ascends to a lesser pressure the pressure within the tank is vented through the relief valve **44**, and when the buoyancy tank descends to a higher pressure the depth compensator **48** senses this condition and opens the secondary fluid pressure line **46** to introduce fluid for raising the pressure within the tank.

In the preferred embodiment of the invention the buoyancy control system utilizes hydrazine as the working fluid. In order to convert the hydrazine into a pressurized gas, a gas generator **50** is mounted in the main fluid line **14** between the buoyancy tank **12** and both legs of the secondary fluid pressure line **46**. In order to limit the maximum flow of the hydrazine through the flow control valve **40** and thereby achieve fine trimming adjustments of the buoyancy of the tank **12** a rate orifice valve **52** is disposed in the main fluid pressure line **14** between the gas generator **50** and both legs of the secondary fluid pressure line **46**.

The gas generator **50** contains a catalyst bed where the hydrazine is catalytically decomposed into hydrogen, nitrogen, and ammonia. This process is exotheromic and results in a gas generator exhaust gas temperature exceeding 1,000° F. On the inlet side of the gas generator and in the main fluid pressure line **14** there is disposed a check valve **54** for preventing the generated gases from exiting upstream thereof. The main fluid pressure line **14** extends from the outlet of the gas generator into the buoyancy tank **12** and extends upwardly terminating in the outlet or outlets **18** which may take the configuration of a pair of stove pipes. Disposed in the main fluid pressure line **14** is another check valve **56** just below the outlets **18** and within the buoyancy tank. Since the generated gases are extremely hot the extension of the main fluid pressure line between the gas generator **50** and the check valve **56** will reduce the temperature so as to protect the check valve **56**.

The buoyancy control system may further include a fuel delivery means which is generally shown in the top portion of FIG. 1. The fuel delivery means may include a container **56** with a fuel bag **58** therein for containing the hydrazine fuel. The fuel bag **58** has an outlet which is connected to the inlet **16** of the main fluid pressure line. A pump **60** has an inlet **61** to ambient water and an outlet which is connected by a water line **62** to the container **56** so as to apply water pressure to the fuel bag **58** within the container. Battery power means **64** may be provided for operating the pump and a push button limit

switch **66** may be provided for turning the power means on and off. An accumulator **68** in the water line **62** may be provided with a plunger **70** for turning the limit switch on when water pressure in the accumulator and container drops below a predetermined value and turning the limit switch off when the water pressure in the accumulator and container are at said predetermined value. Accordingly, a constant pressure is maintained on the fuel bag **58** to supply hydrazine under pressure to the flow control valve **40** and the pressure compensator valve **48**. The fuel delivery means is described in more detail in a co-pending application Ser. No. 187,484 entitled "Constant Pressure Liquid Supply System" by Alvah T. Strickland.

OPERATION OF THE INVENTION

The diver adjusts the buoyancy of the tank **12** by selectively controlling the three control handles **36**, **38**, and **42**. To decrease the tank's buoyancy, in order to descend, the top butterfly valve **20** is opened, the bottom butterfly valve **22** is closed, and the flow control valve **40** is closed. If a rapid decrease in buoyancy is required the diver will also open the bottom butterfly valve **22**. If the diver desires to increase the buoyancy of the tank in order to ascend, the top butterfly valve **20** is closed, the bottom butterfly valve **22** is opened, and the flow control valve **40** is opened. When a static condition is desired (maintaining trim) all of the valves are placed in a closed position. If the buoyancy tank is partially above the water line and the operator desires to descend, both butterfly valves **20** and **22** will be opened while the flow control valve **40** is closed. When the rate orifice valve **52** is open the above changes can be made quickly and when this valve is closed, buoyancy increases are made more slowly, which is desirable for close positioning of the buoyancy tank.

It is now readily apparent that the present invention provides a unique arrangement of components for enabling a change of buoyancy in an underwater vehicle with minimum control by the diver. By automatic pressure compensation of the buoyancy tank the diver's mind is relieved of this responsibility and the tank can be constructed of minimum wall thickness.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

I claim:

1. A variable buoyancy control system for an underwater vehicle comprising:

a buoyancy tank;

a main fluid pressure line having an inlet and an outlet, the inlet being adapted to receive fluid and the outlet opening into the buoyancy tank for introducing pressurized fluid therein;

said buoyancy tank having top and bottom butterfly valves;

means for selectively opening and closing said top and bottom butterfly valves so as to allow water to enter and exit the buoyancy tank;

a flow control valve connected in the main fluid pressure line for selectively controlling the fluid pressure to said tank so as to ascend or descend the vehicle depending upon the positions of the butterfly valves;

a relief valve mounted in the buoyancy tank for relieving pressure from the tank upon the occurrence of a positive pressure differential of the tank over ambient;

a secondary fluid pressure line connected to the main fluid pressure line across said flow control valve; and

a depth compensator valve connected in the secondary fluid pressure line and pressure responsive to the buoyancy tank and ambient water for by-passing fluid to the buoyancy tank upon the occurrence of a

negative pressure differential between the tank and ambient.

2. A variable buoyancy control system as claimed in claim 1 including:

a gas generator mounted in the main fluid line between the buoyancy tank and both legs of the secondary fluid pressure line.

3. A variable buoyancy control system as claim in claim 2 including:

a rate orifice valve disposed in the main fluid pressure line between the gas generator and flow control valve for limiting maximum flow through the flow control valve.

4. A variable buoyancy control system as claimed in claim 2 including:

the main fluid pressure line extending upwardly within buoyancy tank; and

a check valve disposed in the main fluid pressure line upstream from the gas generator and another check valve disposed in the main fluid pressure line within the buoyancy tank.

5. A variable buoyancy control system as claimed in claim 2 wherein fuel delivering means includes:

a container with a fuel bag disposed therein, said fuel bag having an outlet which is connected to the inlet of the main fluid pressure line;

a pump having an inlet to ambient water and an outlet which is connected by a water line to said container so as to apply water pressure to the fuel bag within the container;

power means for operating said pump and a push button limit switch for turning the power means on and off; and

an accumulator having means for turning the limit switch on when water pressure in the accumulator and container drops below a predetermined value and turning said switch off when the water pressure in the accumulator and container are at said predetermined value.

6. A variable buoyancy control system as claimed in claim 5 including:

a rate orifice valve disposed in the main fluid line between the gas generator and the flow control valve.

7. A variable buoyancy control system as claimed in claim 6 including:

the main fluid pressure line extending upwardly within the buoyancy tank; and

a check valve disposed in the main fluid pressure line upstream from the gas generator and another check valve disposed in the main fluid pressure line within the buoyancy tank.

8. A variable buoyancy control system as claimed in claim 7 including:

said fuel;

the fuel being hydrazine and being disposed in said fuel bag.

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