

[54] PRESSURE CONTROL SYSTEM

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[51] Int. Cl. **H04b 13/00**

[58] Field of Search **340/8, 10, 12, 13, 14, 340/8 PC**

[56] References Cited

UNITED STATES PATENTS

3,501,741	3/1970	Wallen et al.	340/8 R
3,345,607	10/1967	Nelkin et al.	340/8 PC
2,429,104	10/1947	Olson	340/8 PC
3,000,216	9/1961	Peters et al.	340/8 PC
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Primary Examiner—Samuel Feinberg

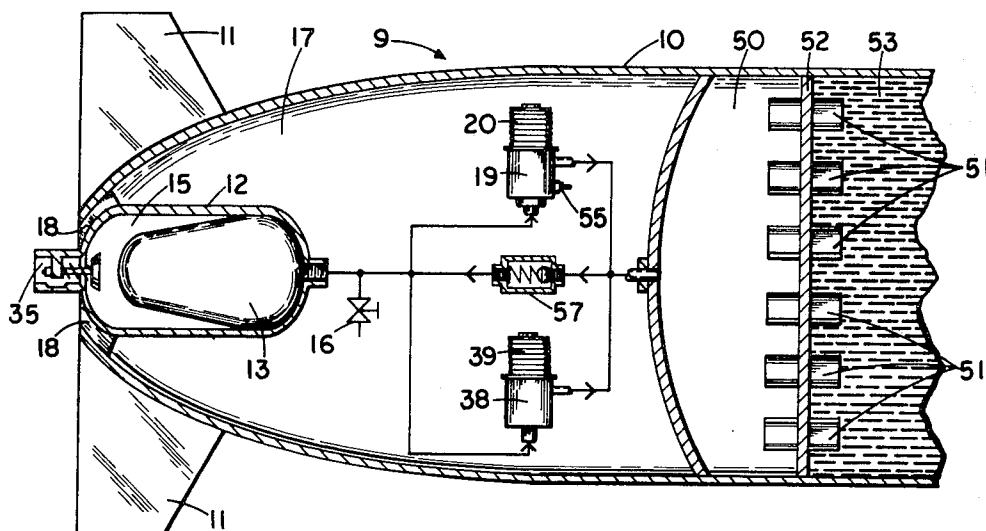
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[57] ABSTRACT

A control system for continuously maintaining pressure equilibrium between the outside and inside of a submersible body. The system comprises an inelastic accumulator lined with a gas charged flexible bladder connected to a unique valve arrangement capable of passing flow in two directions and actuated by bellows apparatus. The bladder is precharged to a pressure dependent on the expected depth of submergence. The system operates when ambient fluid pressure compresses the bellows apparatus of the valve arrangement allowing gas to flow into a pressure balancing chamber as the system is submerged. Upon ascending, flow is reversed through the valve arrangement back to the bladder until a predetermined pressure differential between the inside of the system and ambient pressure is reached, at which point remaining gas pressure is discharged to the ambient fluid.

15 Claims, 5 Drawing Figures



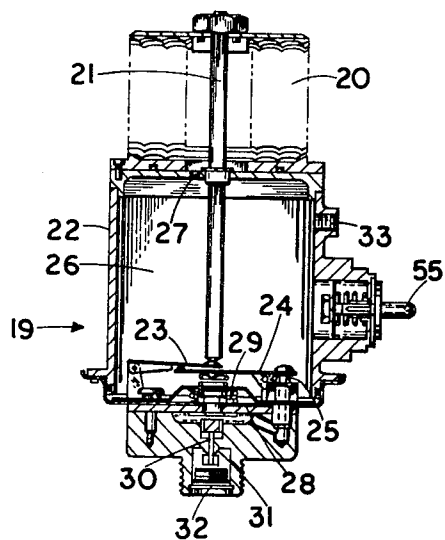
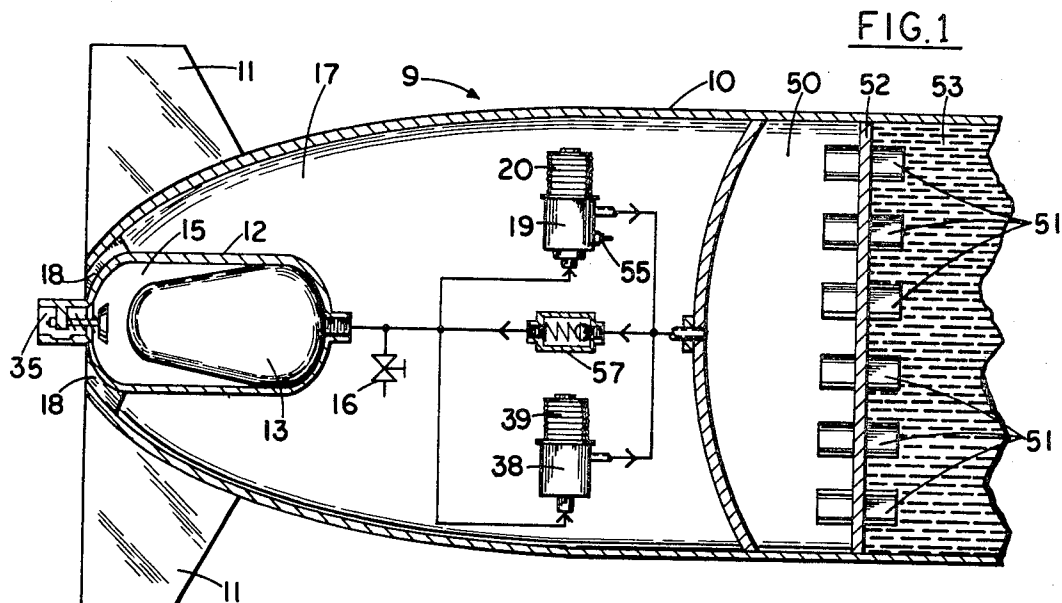


FIG. 2

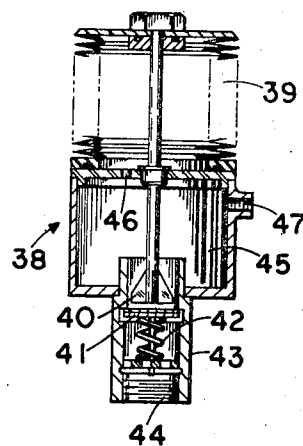
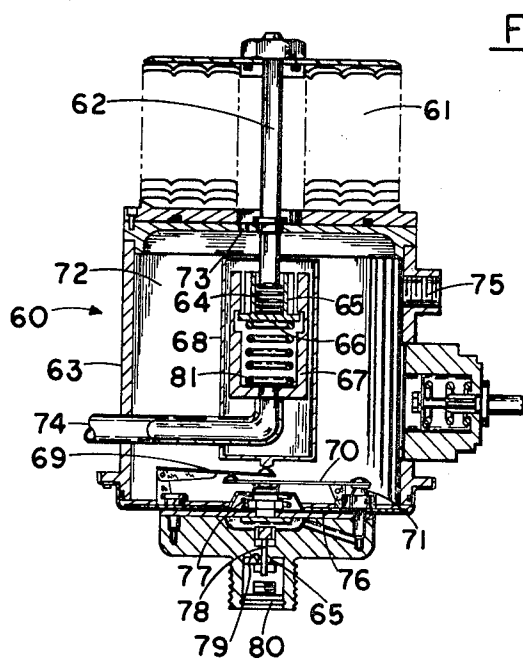
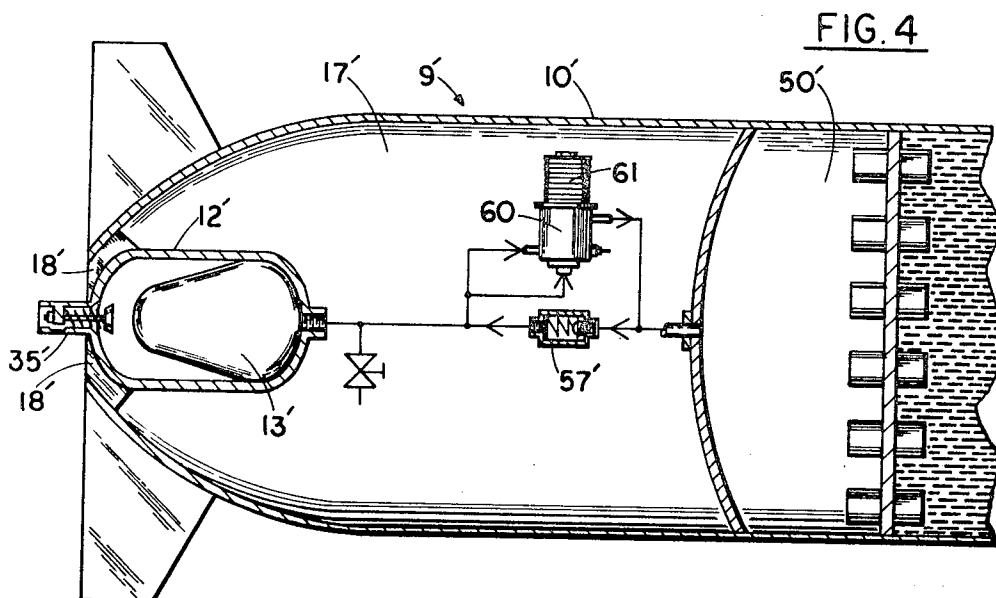


FIG. 3



PRESSURE CONTROL SYSTEM

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

This invention relates generally to balanced pressure underwater acoustic projectors; and more particularly to pressure control systems therefor.

In underwater acoustic projectors, for example as shown in U. S. Pat. No. 3,501,741 to Wallen et al., a low acoustic impedance of viscous medium is positioned opposed to the desired direction of sonic propagation. The internal pressure of the viscous medium must be maintained equal to the external pressure of the ambient fluid in order to achieve maximum propagation efficiency irrespective of continuously changing depth. The Wallen et al. patent utilizes an open, compressed air, pressure control system to maintain pressure balance. This system is limited to relatively short operational periods because the air supply is exhausted by maintaining pressure equilibrium at continuously changing depths. Whenever the system ascends from a submerged depth, either because of currents, tides, or towing, air pressure is exhausted to the ambient fluid in order to maintain the desired pressure equilibrium within the system. This open system is also limited to relatively few successive submergences at considerably reduced maximum depths before it must be recharged with compressed air.

In the Wallen et al. patent, for instance, a pressurized tank of air is connected through a pressure regulator to the internal chamber of an acoustic projector to increase internal system pressure as ambient fluid pressure increases with increasing depth of submergence. Upon ascent, a valve continuously releases air to the ambient fluid as the internal pressure becomes greater than the decreasing ambient fluid pressure. This system is seriously limited in that it can only be used for a limited period of time until all of the precharged air in the tank is exhausted. The usable period of time is dependent on the quantity of air contained in the tank, and the frequency and depths of submergence of the projector. A typical usable period of time for such a system is of an order of magnitude of less than one hour. Another limitation is a maximum operating depth of approximately 300 feet.

SUMMARY OF THE INVENTION

Accordingly, it is a general purpose and object of the present invention to provide an improved pressure balancing control system. It is a further object to significantly extend the time and increase the successive depths to which an underwater acoustic projector may be submerged. Another object is to provide a hybrid closed-open pressure balancing system to increase the operating efficiency of acoustic projectors.

Briefly, these and other objects are accomplished according to the invention by a system comprising an inelastic accumulator housing lined with a gas-inflated bladder which connects through a unique pressure activated valve arrangement to a pressure balancing chamber of the acoustic projector. During descent the bladder

provides gas to the chamber until completely collapsed by the ambient fluid pressure transmitted through an opening in the housing having a normally open, slidably mounted section of the housing. During ascent, the valve arrangement permits gas to flow from the chamber back into the bladder, and above a predetermined depth, the gas is exhausted to the ambient fluid as required to maintain pressure balance in the chamber.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 represents a schematic view of a preferred embodiment of a pressure balancing system in an underwater acoustic projector constructed according to the invention;

FIG. 2 represents a longitudinal cross-sectional view of a bellows-actuated differential pressure regulator of FIG. 1;

FIG. 3 represents a longitudinal cross-sectional view of a bellows-actuated reversible check valve of FIG. 1;

FIG. 4 represents a schematic view of another preferred embodiment of a pressure balancing system in an underwater acoustic projector constructed according to the invention; and

FIG. 5 represents a longitudinal cross-sectional view of a differential regulator, bellows-actuated reversible check valve of FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1, which represents one of the preferred embodiments, the pressure balancing control system is contained within an acoustic projector 9 having a shell 10 with a plurality of stabilizing fins 11, attached to one end. The shell 10 represents a fragmented view of the aft end of an acoustic projector, for example as shown in Wallen et al. (FIG. 1). Although this configuration is used for illustrative purposes, it should be pointed out that the pressure balancing control system as hereinafter described can be configured to suit acoustic projectors of any particular configuration or any submerged chamber requiring pressure equalization. Contained within the shell and attached thereto is the control system comprising an inelastic accumulator housing 12 lined with an inflatable bladder 13, and having a slidably-mounted housing section 35 at its exterior which allows ambient fluid to be transmitted into a cavity 15. The bladder 13 is filled with a compressible medium, including but not limited to a gas, at a filler valve 16. The specific pressure in the bladder 13 is determined by the expected depth of submergence of the acoustic projector 9 and is high, for example, in excess of 500 pounds per square inch. Initial gas pressure in the bladder 13 must be greater than the pressure at the maximum fluid depth at which the acoustic projector 9 is to be operated.

The control system functions as the acoustic projector 9 begins to submerge. Ambient fluid enters a control system cavity 17 through an annular opening 18 at the aft end of the shell 10. Ambient fluid fills the cavity 17 producing a hydrostatic pressure equal to the pressure of the ambient fluid at the particular depth of submergence. The hydrostatic pressure causes a differential pressure regulator 19 to actuate as a result of force exerted on a bellows 20.

Referring to FIG. 2, the bellows 20 is compressed by the differential of the ambient pressure over the pressure inside the bellows 20, which is initially at atmospheric pressure. A downward force is exerted on a piston 21 contained in a housing 22 forcing a demand valve lever 23 of a demand valve assembly 24 to open a flapper valve 25 and allow low pressure gas to enter an interior chamber 26 and flow through a bellows equalization port 27 into the interior of the bellows 20. When internal pressure in the bellows 20 equals hydrostatic pressure, the bellows 20 expands to a neutral position closing the flapper valve 25 and cutting off further gas flow into the interior chamber 26. This is an instantaneous condition which occurs only when internal gas and ambient fluid pressure equilibrium exists. As the system continues to submerge the equilibrium is disrupted and this procedure is repeated continuously until a depth is reached where the ambient pressure equals gas pressure in the bladder 13.

Referring now to FIG. 1, the slidably-mounted housing section 35 opens allowing ambient fluid to enter the cavity 15 and exert a pressure on the bladder 13 equal to ambient fluid pressure at the particular depth of submergence.

Referring now to FIG. 2, the bellows 20 is compressed due to the slightly higher ambient fluid pressure upon further descent, actuating the flapper valve 25, as before, and also transmitting the downward force through a diaphragm 28 by means of a spring 29 to a valve stem 30, which moves off of a valve seat 31 and allows the gas to flow from an inlet port 32 through the valve aperture into the interior chamber 26 and out of an outlet port 33. Due to the gas flow restriction caused by the small aperture at valve seat 31, an insufficient amount of gas is passed to maintain system pressure equalization with external fluid pressure.

Referring now to FIG. 1, flow must be directed through a bellows actuated reversible check valve 38 by means of parallel tubing. Hydrostatic pressure in the cavity 15 compresses a bellows 39 causing gas to flow through the check valve 38.

Referring to FIG. 3, the bellows actuated reversible check valve 38 is a novel check valve which allows flow in two directions depending upon system pressure conditions, as more fully described hereinafter. The bellows 39 is compressed due to an excess of hydrostatic fluid pressure over internal system gas pressure. A downward force is exerted upon an actuator 40 overcoming the gas pressure acting on the underside of a seal 41 and compressing a spring 42 to open a reversible check valve 43. Gas is allowed to flow through an inlet port 44 into an interior chamber 45 through a bellows equalization port 46 into the interior of the bellows 39, and out of an outlet port 47.

Referring now to FIG. 1, gas flows from the bladder 13 through port 33 of the differential pressure regulator 19 and through port 47 of the bellows actuated reversible check valve 38 to a pressure balancing chamber 50, as shown in Wallen et al. The pressure in the chamber 50, which is continuously maintained equal to ambient fluid pressure at any depth, is transmitted through a plurality of piston assemblies 51 mounted in a baffle plate 52 to a viscous medium 53 within the acoustic projector 9 to maintain a balanced pressure between the external fluid and the viscous medium 53, resulting in maximum propagation efficiency. Gas flow continues until the bladder 13 becomes completely col-

lapsed. This represents maximum equalized submergence depth.

On ascending, ambient fluid pressure begins to decrease below system gas pressure in the pressure balancing chamber 50, the differential pressure regulator bellows 20, and the reversible check valve bellows 39, causing both bellows 20 and 39 to expand. Flow through the differential pressure regulator 19 is cut off and the reversible check valve 38 closes.

Referring now to FIG. 3, an upward force exerted by the spring 42 on the seal 41 closes the reversible check valve 43 restricting flow from the inlet port 44 to the outlet port 47. Due to the increasing pressure differential of internal system gas pressure over ambient fluid pressure on ascent, gas flows out of the pressure balancing chamber 50 (FIG. 1) through the outlet port 47 and overcomes a preselected spring force, compressing the spring 42 and allowing gas to flow out of the inlet port 44 in a reverse free flow direction.

Referring now to FIG. 1, as the system ascends gas continues to flow from the pressure balancing chamber 50 back through the bellows actuated reversible check valve 38 to the bladder 13, which completely fills the accumulator housing 12 forcing all ambient fluid out of the cavity 15 through the slidably-mounted housing section 35. The housing section 35 closes and gas pressure builds up in the bladder 13 until it reaches a differential of three pounds per square inch above ambient fluid pressure. At this pressure differential, gas discharges into control system cavity 17 through an exhaust valve 55 integral in the body of the differential pressure regulator 19. This condition does not occur until the system has ascended a considerable distance as more fully described hereinafter in a typical use.

In FIG. 1, an alternate, but unessential method for returning the gas from the pressure balancing chamber 50 to the bladder 13 is shown by introducing a ball check valve 57 operatively connected by a bypass tube. The ball check valve 57 is designed to operate at a lower pressure differential than the bellows actuated reversible check valve 19. For example, the reversible check valve 19 is set to operate at a ½ pound per square inch pressure differential, while the ball check valve 57 is set to operate at a ¼ pound per square inch pressure differential. This alternate method produces a slightly more responsive return system and provides redundancy and thus increased reliability of operation.

Referring now to FIG. 1, in a typical use of the pressure balancing control system the intended depth of submergence will be, for instance, 1,000 feet. The bladder 13 is pressurized to 500 pounds per square inch. As the acoustic projector 9 submerges, the pressure balancing control system operates to equalize internal system pressure and external fluid pressure as hereinbefore described in detail. At a depth of 800 feet in this typical case, a state of pressure equilibrium exists with respect to the ambient fluid, and ambient fluid enters the cavity 15 and applies external pressure to the bladder 13. Both bellows, 20 and 39, are compressed due to the slight excess of ambient fluid pressure over internal system pressure, and the gas continues to flow through the differential pressure regulator 19 and the reversible check valve 38 to the pressure balancing chamber 50. This flow process continues as the system continues to submerge until the bladder 13 expends its entire gas supply and collapses, which in this typical case occurs at approximately 1,400 feet. On ascending,

the system operates as hereinbefore described. Upon reaching a depth of approximately 800 feet, internal system pressure builds up as a result of decreasing ambient fluid pressure. When a differential of 3 pounds per square inch exists, the remaining gas in the chamber 50 exhausts to the control system cavity 17 through the exhaust valve 55 in the body of the differential pressure regulator 19. The total operating time on a single charge of the bladder 13 depends on the number of times the acoustic projector 9 is submerged and elevated. In this typical case the degree of pressure equalization is controlled so carefully that a range of 600 feet may be traversed without discharging the gas. In normal use the amount of fluctuation due to fluid dynamics is well below 600 feet, insuring that the system will remain operative for greatly increased periods of time of up to 1,000 hours over prior "open" pressure balancing systems, which were only operative for periods of 30-45 minutes.

In the alternate embodiment of FIG. 4, a variation is shown of the embodiment of FIG. 1 wherein the bellows actuated reversible check valve 38 is incorporated in the regulator housing 22 of the differential pressure regulator 19. The resultant apparatus is a unique differential regulator/reversible check valve 60 operated by a bellows 61. Functional operation of this alternate control system is as described in detail hereinbefore.

Operation of the alternate control system begins when the acoustic projector 9' begins to submerge. Ambient fluid enters a control system cavity 17' through an annular opening 18' at the aft end of shell 10'. Ambient fluid fills the cavity 17' producing a hydrostatic pressure equal to the ambient pressure of the surrounding fluid at the particular depth of submergence. Hydrostatic pressure causes the valve 60 to actuate due to the force it exerts on the bellows 61.

Referring to FIG. 5, the bellows 61 is compressed by the differential of the ambient pressure over the pressure inside the bellows 61, which is initially at atmospheric pressure. A downward force is exerted on a push rod 62 contained in a housing 63 compressing a check valve actuator spring 64 housed in a spring cap 65. The force, however, is not sufficient to overcome the force of the high pressure gas acting on the bottom of a seal 66 keeping the gas from flowing through a check valve 67. A cage 68 is forced downward upon a demand valve lever 69 of a demand valve assembly 70 opening a flapper valve 71 and allowing low pressure gas to enter an interior chamber 72 and flow through a bellows equalization port 73 into the interior of the bellows 61. When internal pressure in the bellows 61 equals the hydrostatic pressure of the ambient fluid, the bellows 61 expands to a neutral position closing the flapper valve 71 and cutting off further gas flow into the interior chamber 72. As hereinbefore mentioned, this is an instantaneous condition which occurs when internal gas and external fluid pressure are equal. As the system continues to submerge, the pressure equilibrium is disrupted and the aforementioned procedure is repeated continuously until a depth is reached where the pressure of the ambient fluid equals gas pressure in the bladder 13'.

Referring now to FIG. 4, a slidably-mounted housing section 35' opens allowing ambient fluid to enter a cavity 15' in an inelastic accumulator housing 12', and exerting a pressure on the bladder 13' equal to the ambi-

ent fluid pressure at the particular depth of submergence.

Referring now to FIG. 5, upon further descent the bellows 61 is compressed due to the slightly higher external fluid pressure. Due to equal pressure on both sides of the seal 66, the downward force exerted on the push rod 62 compresses the actuator spring 64 overcoming the force of the gas acting on the bottom of the seal 66, and opening the check valve 67. Gas is now allowed to flow from a check valve inlet port 74 to an outlet port 75. Simultaneously, the flapper valve 71 is opened, and the downward force exerted by the cage 68 is transmitted through a diaphragm 76 by means of a spring 77 to a valve stem 78, which moves off of a valve seat 79 and allows the gas to flow from a regulator inlet port 80 through the valve aperture into the interior chamber 72 and out of the outlet port 75. Due to the restriction at the valve aperture, virtually no gas will flow through the regulator portion during this phase of the descent, with practically all of the gas flowing through the check valve 67 to the pressure balancing chamber 50' of FIG. 4. Flow continues in this manner until the bladder 13' is completely collapsed.

On ascent, reversed free flow through the check valve 67 from the outlet port 75 to the inlet port 74 occurs when pressure in the pressure balancing chamber 50' of FIG. 4 overcomes the preselected force of a check valve return spring 81.

The advantages of a single housing containing both a bellows operated differential pressure regulator and a reversible check valve are numerous. They include but are not limited to simplicity, compactness, manufacturing cost savings, ease of maintenance and trouble shooting procedures, and instant response to system pressure demands due to elimination of tubing and close proximity of components.

Referring now to FIG. 4, as in the embodiment of FIG. 1, an alternate, but unessential method for returning the gas from pressure balancing chamber 50' to bladder 13' is shown by adding a ball check valve 57' to the system. Its operation is exactly as described hereinbefore.

The pressure balancing system has been shown and described in a sonic projector only for illustration of one of its most practical applications. It will be understood that many other situations exist where the invention's capability of providing a closed pressure balancing system may have utility.

It is to be understood that the above-described embodiments are simply illustrative of the invention and that many other embodiments can be devised without departing from the scope and spirit of the invention.

What is claimed is:

1. A pressure balancing control system for an acoustic projector in an ambient fluid and of the type having a transducer pressure balancing chamber, comprising, in combination:

an accumulator means having an inelastic, vented housing formed to be secured to the projector, an inflatable bladder within said housing and having an opening therein, and a compressible fluid contained within said bladder;

a first valve means having an inlet and an outlet responsive to the pressure difference between said compressible fluid at the outlet thereof and the ambient fluid, operatively connected at the inlet

thereof to said bladder opening and formed to be connected at the outlet thereof to the chamber for opening when the ambient fluid pressure exceeds the compressible fluid outlet pressure;

a second valve means having an inlet and an outlet operatively connected at the inlet thereof to said bladder opening and at the outlet thereof to the outlet of said first valve means, said second valve means including first pressure differential means for opening when the ambient fluid pressure exceeds the compressible fluid inlet pressure, and second pressure differential means for opening when the outlet pressure exceeds the inlet pressure respectively of said compressible fluid, the pressure differentials being predetermined; and

a third valve means responsive to the pressure differential between the ambient fluid and the compressible fluid outlet pressure of said first valve means, operatively connected to said first valve means for opening when the compressible fluid outlet pressure thereof exceeds the ambient fluid pressure by an amount greater than the predetermined pressure differential of said second pressure differential means.

2. A pressure balancing control system as described in claim 1, wherein said accumulator means comprises: an inelastic housing formed to be secured to the projector;

a first opening in said housing for transmitting ambient fluid therethrough;

a slidably-mounted section of said housing urged normally open to produce said first opening;

a second opening in said housing; and

an inflatable bladder within said housing internally communicating with said second opening and urging said slidably-mounted housing section coplanar with internal surface of said housing when fully inflated.

3. A pressure balancing control system as set forth in claim 2, wherein said first valve means comprises:

a housing formed to contain an internal chamber, first and second apertures;

a bellows operatively connected to said housing sensitive to pressure differential between said housing and the ambient fluid;

a valve formed in said housing for passing fluid therethrough; and

a piston operatively connected between said bellows and said valve.

4. A pressure balancing control system as described in claim 3, wherein said second valve means comprises:

a housing formed to contain an internal chamber, first and second apertures;

a bellows operatively connected to said housing internally communicating with said housing sensitive to pressure differential between said housing and the ambient fluid;

a valve formed in said housing for passing said compressible fluid therethrough; and

an actuator communicating with said bellows and said valve.

5. A pressure balancing control system as set forth in claim 1, also including:

a fourth valve means having an inlet and an outlet operatively connected at the inlet thereof to said respective first and second valve means outlets and at the outlet thereof to said bladder opening for

passing said compressible fluid therethrough from the chamber to the bladder when the outlet pressure of said second valve means exceeds the inlet pressure thereof by a predetermined differential less than the predetermined pressure differential of said second valve means.

6. A pressure balancing control system as set forth in claim 1, further comprising:

said first and second valve means combined in a single housing each having an inlet and having a common outlet, being operatively connected at their respective inlets to said bladder opening and formed to be connected at said common outlet to the chamber.

7. A pressure balancing control system as set forth in claim 6, wherein said combined first and second valve means comprises:

a bellows operatively connected to said housing sensitive to pressure differential between said housing and the ambient fluid;

a first valve formed in said housing for passing fluid therethrough;

a second valve formed in said housing for passing fluid therethrough;

a cage surrounding said second valve and communicating with said first valve; and

a push rod communicating with said bellows and said cage and operatively connected to said second valve.

8. A pressure balancing control system as set forth in claim 7, further comprising:

a third valve formed in said housing for passing said fluid therefrom when the compressible fluid outlet pressure of said combined first and second valve means exceeds the ambient fluid pressure by an amount greater than a predetermined pressure differential.

9. A control system for a chamber in an ambient fluid comprising, in combination:

an inflatable accumulator means having a limited volume;

a compressible fluid contained within said accumulator means;

a first valve means having an inlet and an outlet operatively connected at the inlet thereof to said accumulator means and connected at the outlet thereof to the chamber for transmitting said compressible fluid therefrom when the ambient fluid pressure exceeds the pressure of said compressible fluid at said first valve means outlet;

a second valve means having an inlet and an outlet operatively connected at the inlet thereof to said accumulator means and connected at the outlet thereof to said first valve means outlet for transmitting said compressible fluid therethrough when the ambient fluid pressure exceeds the pressure of said compressible fluid at said second valve means inlet and when the pressure at said second valve means outlet exceeds the pressure at said second valve means inlet respectively of said compressible fluid; and

a third valve means operatively connected to said first valve means outlet for transmitting said fluid therefrom when the pressure of said compressible fluid at said first valve means outlet exceeds the ambient fluid pressure.

10. A control system as described in claim 9, wherein said accumulator means comprises:

an inelastic housing formed to be secured to a structure;

a first opening in said housing for transmitting ambient fluid therethrough;

a second opening in said housing; and
an inflatable bladder within said housing internally communicating with said second opening.

11. A control system as described in claim 10, wherein said first valve means comprises:

a housing formed to contain an internal chamber, first and second apertures;

a bellows operatively connected to said housing sensitive to pressure differential between said housing and the ambient fluid;

a valve formed in said housing for passing fluid therethrough; and

a piston operatively connected between said bellows and said valve.

12. A control system as described in claim 11, wherein said second valve means comprises:

a housing formed to contain an internal chamber, first and second apertures;

a bellows operatively connected to said housing sensitive to pressure differential between said housing internal chamber and the ambient fluid;

a valve formed in said housing for passing said compressible fluid therethrough; and

an actuator communicating with said bellows and said valve.

13. A control system as described in claim 9, further comprising:

said first and second valve means combined in a single housing each having an inlet and having a common outlet, being operatively connected at their respective inlets to said accumulator means and formed to be connected to the chamber at a common outlet.

14. A control system as described in claim 13, wherein said combined first and second valve means comprises:

a bellows operatively connected to said housing sensitive to pressure differential between said housing and the ambient fluid;

a first valve formed in said housing for passing fluid

therethrough;

a second valve formed in said housing for passing fluid therethrough;

a cage surrounding said second valve and communicating with said first valve; and

a push rod communicating with said bellows and said cage and operatively connected to said second valve.

15. A pressure balancing control system for submersible apparatus in an ambient fluid, comprising, in combination:

a sealed chamber formed to enclose the apparatus; an accumulator means having an inelastic, vented housing formed to be secured to the apparatus, an inflatable bladder within said housing and having an opening therein, and a compressible fluid contained within said bladder;

a first valve means having an inlet and an outlet responsive to the pressure difference between said compressible fluid at the outlet thereof and the ambient fluid, operatively connected at the inlet to said bladder opening and connected at the outlet to said chamber for opening when the ambient fluid pressure exceeds the compressible fluid outlet pressure;

a second valve means having an inlet and an outlet operatively connected at the inlet thereof to said bladder opening and at the outlet thereof to the outlet of said first valve means, said second valve means including first pressure differential means for opening when the ambient fluid pressure exceeds the compressible fluid inlet pressure, and second pressure differential means for opening when the outlet pressure exceeds the inlet pressure respectively of said compressible fluid, the pressure differentials being predetermined; and

a third valve means responsive to the pressure differential between the ambient fluid and the compressible fluid outlet pressure of said first valve means, operatively connected to said first valve means for opening when the compressible fluid outlet pressure thereof exceeds the ambient fluid pressure by an amount greater than the predetermined pressure differential of said second pressure differential means.

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