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(54) **DEVICE FOR AUTOMATIC CONTROL OF BUOYANCY, HEEL, TRIM, DEPTH AND ALTITUDE IN SUBMERSIBLE VEHICLES**

VORRICHTUNG ZUR AUTOMATISCHEN STEUERUNG VON AUFTRIEB, KRÄNGUNG,
TRIMMUNG, TIEFE UND HÖHE IN UNTERWASSERFAHRZEUGEN

DISPOSITIF POUR LA COMMANDE AUTOMATIQUE DE LA FLOTTABILITÉ, DU ROULEMENT, DU
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Description

Technical field

[0001] The present description falls within the technical field of solutions of motion and equilibrium control of submersible vehicles, namely in terms of their heel, trim, depth and altitude, evidencing an automated operation solution of that type of vehicles.

Technical Background

[0002] Upon completion of immersion manoeuvres, submersible vehicles are subject to various factors which can affect their stabilization in the liquid mass, making their navigation or their operability difficult and putting at risk the comfort or even the safety of their occupants.

[0003] The most common causes of change of the equilibrium conditions are variation of the density of the aquatic environment, as a result of temperature and/or pressure and/or water salinity changes, loss of vehicle weight by the elimination of products or consumables loss and the variation of their volume as a consequence of the modification the external pressure caused by the depth variation. In addition, the variation of the internal distribution of weights during a mission, either by the movement of movable weights (e.g. crew), or by the differentiated or not conveniently compensated consumption of materials (e.g. diesel or compressed air), can cause changes to the trim and heel angles which are also drawbacks to the vehicle navigation.

[0004] The technical solutions aiming at the correction of these imbalances usually consist of filling in or emptying of air buoys or tanks of liquid ballast, as it is necessary to, respectively, increase or decrease buoyancy. Likewise, the differentiated operation of the stern and bow tanks allows the correction of the trim angle, while the differentiated operation of the port and starboard tanks allows acting on the heel angle.

[0005] These manoeuvres, carried out manually, are very demanding and require time and attention to the extent that the factors which determine these manoeuvres, though always present, are variable and often unpredictable.

[0006] Thus, in a small submersible vehicle with low capacity, it means that one person has to reserve a significant amount of her/his time to maintain the vehicle equilibrium, having less availability to other tasks or simply to enjoy the dive.

[0007] The analysis to the state of the art in this field shows the existence of some documents with similar goals to the one here presented. Some aim at the automatic compensation but not the control of the trim and heel angles.

[0008] For instance, document GB191422337A describes a trim compensation system, via tanks situated towards the bow and the stern of a submarine, the trim compensation being secured by water pumping to said

tanks. However, the automatic correction of the heel and trim angles are not predicted nor can be achieved with this document, what highly reduces the interest of its application to small submarines, submarine vehicles remotely operated and autonomous submarine vehicles.

[0009] Document US2012/0128425 A1 describes a device to buoyancy compensation which allows a diver or a submersible object to reach or keep a predetermined depth, regardless of the orientation or direction of said diver or submersible object. However, also here, the automatic correction of the heel and trim angles are not predicted nor can be achieved with this document, what highly reduces the interest of its application to small submarines, submarine vehicles remotely operated and autonomous submarine vehicles. Document US2003/0075096 describes a device for automatic control of buoyancy depth and altitude of a submarine object with a non pressurised tank of liquid ballast.

General description

[0010] The present solution allows automatically reset the neutral buoyancy of submersible vehicles, as well as automatically correct the heel and trim of a submersible vehicle and, thus, automatically achieve and/or maintain a certain depth or altitude.

[0011] In the context of the present solution, trim shall be understood as the rotation around the transversal horizontal axis of the submersible vehicle; and heel as the rotation around the longitudinal horizontal axis of the same vehicle.

[0012] The state of the art known to date does not allow to conjugate the automatic maintenance of the neutral buoyancy with the automatic correction of the heel and trim angles, or if that conjugation is allowed, the alternative is excessively heavy, energetically costly and therefore not suitable to its application in submersible vehicles.

[0013] The existing systems are based on the water pumping among tanks which can be subject to an important pressure differential between the exterior and the interior (hard ballast) and have therefore to be pressurised tanks (pressure vessels). On the one side, for a very same drained flow, the electrovalves used in water drainage have to have considerably higher dimensions and weight than the ones used in air drainage. Or, as an alternative, assuming the equivalent dimensions and weight of the equipment, the operation duration would be up to thirty times longer than the one achieved by the now proposed solution.

[0014] The now presented solution is based on the drainage control of compressed air. As air density is much inferior to water density in the same temperature and pressure conditions; and a much superior pressure differential being able to be imposed, the air drainage is much faster and has lesser energy losses than the water drainage.

[0015] The advantages of the present invention are, thus, evident. It allows dispensing the existence of a wa-

ter pump and of electrovalves for water drainage, thus enabling the considerable reduction of the dimensions and weight of the equipment to use. It also allows the use of flexible buoys or non-pressurised tanks (working with a very low pressure differential between the interior and the exterior) and therefore less demanding from the structural point of view. The possibility of significantly limiting the use of mechanical equipment in direct contact with sea water, also adds to the straightforward advantage of dimension and weight reduction of these equipment.

[0016] The present solution finds application in the submersible vehicles construction industry, like, for instance, submersible vehicles, remotely operated submersible vehicles, submersible autonomous vehicles.

[0017] The solution now described aims at automatically resetting neutral buoyancy, as well as automatically correcting the heel and trim of a submersible vehicle and, thus, automatically achieving and/or maintaining a certain depth or altitude.

[0018] The following are the component elements in a preferred embodiment of the present device:

- Flexible buoys or non-pressurised tanks of liquid ballast, which freely communicate with the exterior through a hole near their base, judiciously distributed over the submersible vehicle, each one containing two solenoid type valves, one for air entry and the other for air exhaustion, to be operated by the automatic control unit;
- Automatic control unit for independent opening and closing of the various valves, comprising the acquisition and processing of data through the various sensors (gyroscope, depth gauge and CTD - conductivity, temperature and pressure);
- Production or storage of compressed air device (reservoir) for system feeding;
- Dashboard, capable of showing in real time the correction operations that the system makes and of enabling the operator to introduce manual changes, if desired.

[0019] In case flexible buoys are chosen, these can be automatically and in an autonomous way partially or totally filled in or emptied, increasing or decreasing the buoyancy of the whole, or even transferring buoyancy from any of them to any other.

[0020] In case tanks of liquid ballast are chosen, these can be automatically and in an autonomous way ballasted or unballasted, increasing or decreasing the weight of the whole, or even transferring weight from any of them to any other.

[0021] The flexible buoys or tanks of liquid ballast option is, in most of the embodiments below, equivalent. Therefore, for simplification purposes and whenever it is not necessary to distinguish them, only tanks will be referred to in the text.

[0022] The control unit evaluates and processes the

relevant information given by the sensors, calculating the corrections to be made and acting on the solenoid valves to establish the adequate air circuits, during the time frame needed.

[0023] In an embodiment to automatically reset neutral buoyancy, as well as to automatically correct the heel and the trim of a submersible vehicle and, thus, automatically achieve and/or maintain a given depth or altitude, it will be necessary to predict, at least, four tanks of liquid ballast: for instance, two at the stern and two at the bow, two at starboard side and two at port side.

[0024] In another embodiment, the buoyancy compensation and the trim correction are made with two ballast tanks. One of the ballast tanks is located on the submersible vehicle stern, while the second ballast tank is located on the bow of the submersible vehicle.

[0025] In another embodiment, the buoyancy compensation and the heel correction are made with two tanks, one of the ballast tanks being now located on the port side of the submersible vehicle, and the second ballast tank located on the starboard side of the submersible vehicle.

[0026] Still in another embodiment, if only buoyancy compensation and depth or altitude definition or maintenance is desired, a ballast tank is sufficient, the device being taken to embodiments already known.

[0027] Three tanks only placed along two axis clearly allow controlling both the trim and the heel of the submersible vehicle. It is also clear that 4 tanks allow an easier control of the trim and of the heel.

[0028] It is described a device for automatic control of buoyancy, heel, trim, depth and/or altitude in submersible vehicles, comprising:

- 3 or more flexible buoys or tanks of liquid ballast, each with an air inlet valve and an air outlet valve, with electrically controlled opening and closing;
- an electronic control unit for independent opening and closing of the air inlet and outlet valves of the tanks of liquid ballast;
- a reservoir for storing compressed air connected to the air inlet valves of the tanks of liquid ballast;

wherein said tanks of liquid ballast comprise a free communication with the exterior of the tank via one or more holes placed on the inferior part of the tank;

and wherein said flexible buoys or tanks of liquid ballast are to be in different sections of the submersible vehicle placed along two directions of the horizontal plane of the submersible vehicle.

[0029] In an embodiment, the flexible buoys or tanks of liquid ballast are 4.

[0030] In an embodiment, the two directions of the horizontal plane are orthogonal directions.

[0031] In an embodiment, the sections of the submersible vehicle where said tanks of liquid ballast are placed are sections of:

stern and starboard; stern and port; bow and starboard; and bow and port; or
central stern, central bow, central starboard and central port;
or any of the intermediate arrangements between the two previous arrangements.

[0032] In an embodiment, the electronic control unit is configured to proceed with the opening and closing of the air inlet and outlet valves for moving up, moving down, maintaining depth, maintaining altitude, obtaining a predefined depth, obtaining a predefined altitude.

[0033] In an embodiment, the electronic control unit is configured to proceed with the opening and closing of the air inlet and outlet valves for correcting the trim and heel angles.

[0034] In an embodiment, the valves are solenoid type valves electrically controlled by the electronic control unit.

[0035] In an embodiment, the inlet valve and the outlet valve of a flexible buoy or tank of liquid ballast are in the same valve body.

[0036] An embodiment additionally comprises circuits with manually operated valves in parallel with each of the electrically controlled circuits.

[0037] It is also described a submersible vehicle comprising any of the previous devices for automatic control of buoyancy, heel and trim in submersible vehicles.

[0038] In an embodiment, the submersible vehicle is a submarine with crew or a remotely operated submersible vehicle or a submersible autonomous vehicle.

[0039] It is also described a method of operating any of the previous devices for automatic control of buoyancy, heel and trim in submersible vehicles, comprising by the automatic control unit:

calculating the corrections to be made and the corresponding actions on the valves to obtain the desired buoyancies in each of the tanks of liquid ballast; acquiring and processing the data collected by the sensors comprising gyroscope, depth gauge and CTD;
visualising in real time the corrections that the device proposes and/or makes.

[0040] An embodiment comprising three procedure modes: continuing automatic mode; one shot automatic mode, assisted manual mode, relating to a preselected correction or definition procedure comprising buoyancy correction, trim correction, heel correction, depth definition, altitude definition, or their combinations; wherein:

the continuing automatic mode comprises initiating and permanently activating one or more (preselected) procedures, and wherein the procedures are automatically restarted with a previously defined periodicity or whenever they excessively deviate from the preselected correction or definition;

wherein the one shot automatic mode comprises performing simultaneously and at once one or more times preselected correction or definition procedures;

wherein the assisted manual mode comprises automatically performing a preselected correction or definition isolated procedure, according to the values defined by the pilot out of the system proposals.

[0041] In an embodiment, the one shot automatic mode can be repeated at the initiative of the operator.

[0042] It is also described an automatic control unit configured for operating a device according to any of the previous methods.

[0043] It is also described a computer program for operating a device according to any of the previous methods.

[0044] It is also described a computer readable non-transitory medium for storing code executable by a computer processor for operating a device according to any of the previous methods.

[0045] In an embodiment of the solution and for security purposes and to avoid systems redundancy, the possibility of performing an automatic operation can be deactivated, thus initiating the operation procedure in manual mode and performing the procedures as they are usually performed nowadays, i.e. manually opening or closing mechanical valves and keeping them activated by estimate, by feeling, of the quantities of ballast to move, or until the visual observation of the measurement instruments indicates that the manoeuvre goal has been achieved.

[0046] The following data are the system permanent inputs, i.e. typical of every submersible vehicle:

- Underwater displacement:	D
- Metacentric height:	$\overline{MG}$
- Plan area:	A_p
- Form factor:	C_d
- Trim correction arm:	B_t
- Heel correction arm:	B_h

[0047] A set of sensors permanently feeds a central controller with values of the different navigation parameters. At each time, with a sampling period which depends of each measurement apparatus but which typically is of around the tenths or hundredths of a second, the following parameters are measured and stored:

- Liquid ballast volume in tank T1;
- Liquid ballast volume in tank T2;
- Liquid ballast volume in tank T3;
- Liquid ballast volume in tank T4;

- Vertical velocity;
- Water temperature;
- Water salinity;
- Trim angle;
- Heel angle;
- Depth;
- Altitude.

[0048] The system predefines a calculation range (Δt) that the pilot can confirm or modify according to his/her experience or sensitivity. From the measurements made to the instantaneous values of each variable within the sampling interval (between $t-\Delta t$ and t), the board computer calculates, based on that interval, projects on the screen and permanently updates the average values of the following variables (Fig. 1):

- Liquid ballast volume in tank T1: v_1
- Liquid ballast volume in tank T2: v_2
- Liquid ballast volume in tank T3: v_3
- Liquid ballast volume in tank T4: v_4
- Vertical velocity: V_v
- Trim angle: A_t
- Heel angle: A_h
- Water density: d
- Depth: h
- Altitude: H

[0049] For the selected time interval (Δt), the board computer also calculates, at each instant, the average values of the following variables:

- Buoyancy, given, in N, by $F = 500 \times d \times C_d \times A_p \times V_v \times |V_v|$;
- Proposed buoyancy compensation, in litres, given by: $C_f = F/9,81/d$, also dividing by the four tanks. We shall have, $C_{f1} = C_{f2} = C_{f3} = C_{f4} = C_f/4$;
- Trim imbalance arm given, in meters, by:

$$b_t = \sin A_t \times \overline{MG}$$

- Heel imbalance arm given, in meters, by:

$$b_h = \sin A_h \times \overline{MG}$$

- Trim proposed correction given, in litres, by:

$$C_t = 1000 \times d \times D \times b_t/B_t;$$

- We shall have, $C_{t1} = C_{t2} = C_t/2$ and $C_{t3} = C_{t4} = -C_t/2$;
- Heel proposed correction given, in litres, by:

$$C_h = 1000 \times d \times D \times b_h/B_h.$$

- We shall have, $C_{h1} = C_{h3} = C_h/2$ and $C_{h2} = C_{h4} = -C_h/2$;
- Global correction proposed, in litres, at each time, for each tank,

$$C_1 = C_{f1} + C_{t1} + C_{h1}$$

$$C_2 = C_{f2} + C_{t2} + C_{h2}$$

$$C_3 = C_{f3} + C_{t3} + C_{h3}$$

$$C_4 = C_{f4} + C_{t4} + C_{h4}$$

[0050] These last values, which refer accordingly to tanks T1 to T4, are also posted on the dashboard (Fig. 1), in the interior of the corresponding buttons. In this example, meter and litre are respectively used as length and volume units. Any other unit system is, of course, possible.

[0051] The correction in water volume by each tank is obtained by the compressed air injection or exhaustion.

[0052] The system interface with the user is done through a panel, as presented in Fig. 1.

[0053] The operation starts with the selection, by the operator, of the kind of manoeuvre which is intended to be performed. There are five options of manoeuvres that can be selected:

- Buoyancy compensation to cancel any vertical speed which has been installed;
- Trim correction to eliminate any trim angle which has been installed;
- Heel correction to eliminate any heel angle which has been installed;
- Definition of a fixed dive depth, which automatically manoeuvres the submersible vehicle until it reaches this depth and sequentially maintains it at this depth;
- Definition of a fixed dive altitude (distance until the bottom), which automatically manoeuvres the submersible vehicle until it reaches this altitude and sequentially maintains it at this depth;

[0054] In an embodiment, after selection of the intended type of manoeuvre, the system presents three acting modes, namely (Fig 1):

- Continuing automatic mode;
- One shot automatic mode (One shot), made by initiative of the pilot, according to the parameters proposed by the system;
- Assisted manual mode (Assisted), automatically controlled but started by initiative of the pilot, according to the parameters the pilot selects from the values proposed by the system.

[0055] An embodiment allows choosing the continuing automatic mode. The continuing automatic mode (Automatic) and (Go) allows starting and leaving permanently activated the correction procedure of the selected effect(s) (buoyancy compensation, trim correction, heel correction, depth definition or altitude definition). This procedure is automatically restarted with a previously defined periodicity (for instance, every 2 minutes), or whenever the concerned variable is too distant from the previously defined value.

[0056] In another embodiment, the selection of the one shot automatic mode (One shot) and (Go) allows performing at once the simultaneous correction of the selected effect(s), and according to the values posted at the time of activation (Go). It can be repeated by initiative of the pilot, whenever he/she so desires.

[0057] Still in another embodiment, the choice of the assisted manual mode (Assisted), is only applicable to the three first manoeuvre options (buoyancy compensation, trim correction, heel correction) and allows the pilot to manually define the following points:

- The selection of the correction to be performed (compensation, trim or heel), acting separately in one of these buttons or commands;
- The liquid ballast origin (Tank 1 and/or Tank 2 and/or Tank 3 and/or Tank 4, or exterior);
- The liquid ballast destiny (Tank 1 and/or Tank 2 and/or Tank 3 and/or Tank 4, or exterior);
- The volume to be shifted, in litres.

After performing the options, in an embodiment, the key (Go) activates the selected procedure which is performed only once.

[0058] In any of the modes, in an embodiment, the key (Go) starts the procedures necessary to the transfer(s) of liquid ballast in the conditions defined by the selected mode. The control unit calculates the predictable flow for each solenoid valve according to the pressure differential and to the other parameters, and will then activate the opening of the adequate valves, as long as needed.

[0059] All the system valves are, in an embodiment, of two positions (2V/2P) and of the N/C type (usually closed). The answer of the submersible vehicle is permanently monitored through the sensors, whose information can determine the interruption of the operation as soon as the goals are reached. As previously mentioned, the system can also be deactivated, referring to a type of a fully manual piloting, from mechanical valves.

[0060] In case it is considered to be of advantage, each 2V/2P type valve can be substituted by other equivalent valve, for instance each set of two 2V/2P valves can be substituted by one 3V/3P valve.

Brief description of the drawings

[0061] For an easier understanding of the embodiment there are attached figures, which represent preferred embodiments, which however, are not intended to limit the scope of the present embodiment.

Figure 1: Schematic representation of the control panel of an embodiment of the automatic compensation device and of automatic correction of the trim and of the heel.

Figure 2: Operating scheme of an embodiment of the device with 4 tanks wherein each tank is connected to two air collectors, wherein one is of high pressure (pressure higher than the external ambient pressure) and another of low pressure (pressure lower than the external ambient pressure), via solenoid valves.

Figure 3: Schematic representation of the control panel of an embodiment of the compensation device and automatic correction of the trim and of the heel.

Figure 4: Operating scheme of an embodiment of the ballast transfer module among compensation tanks.

Detailed description

[0062] Figure 1 shows a possible arrangement of the command screen of the system now revealed. At the top of the screen, in a first row, the different manoeuvre types which can be performed are depicted:

- Buoyancy compensation;
- Trim correction;
- Heel correction;
- Imposition of a dive depth;
- Imposition of a dive altitude.

[0063] The second row allows the choice of the desired automation level, among three possible ones:

- Continuing automatic mode (Automatic),
- One shot automatic mode (One Shot) and
- Assisted manual mode (Assisted).

[0064] Right below, in the central part, the system depicts the current values of the relevant navigation parameters: depth, altitude, vertical velocity, liquid density, and trim and heel angles.

[0065] On the left side the four tanks are represented,

each one posting the current volume of ballast and the volume proposed by the system for transfer. On the right side, a similar scheme reveals in each tank the final ballast volume (the manoeuvre being supposedly concluded).

[0066] On the second last command line, the left-hand side button shows the quantity of water needed to ballast the submarine, in case the vertical speed is positive or when the increase of diving depth or altitude decrease is intended.

[0067] The inferior right-hand side button shows the quantity of water needed to deballast the submarine, if the vertical speed is negative or when the decrease of diving depth or altitude increase is intended.

[0068] In the centre, below the navigation parameters, two dials with two triangular buttons each allow the manual definition of the requested volumes for each transfer or the depth or altitude level at which navigation is intended, in the event of the assisted manual manoeuvre option.

[0069] The central inferior key (Go), allows starting the selected procedure, in the defined conditions. Finally in the last row, there are two buttons to the left and to the right to cancel the selected definition or the whole previous programming, respectively.

[0070] Figure 2 briefly shows the general scheme of the device, in a configuration wherein there are four tanks (T1 to T4). It is represented in the figure: A - Compressed air reservoir; B - Air exhaustion; C - Pressure reduction valve; D - Non-return valve; E - Digital manometer (pressure transmitter); F - Acquisition, data processing and control unit; G - CTD - conductivity, temperature and depth; H - DVL - Doppler velocity logger; I - Manual mechanical valve; J - Solenoid valve 2P/2V.

[0071] Each tank is connected to two air collectors, wherein one is of high pressure (pressure higher than the external ambient pressure) and another of low pressure (pressure lower than the external ambient pressure), via two solenoid valves (J). These valves and also the measurement instruments are connected to a controller, or electronic control unit, which commands their status (open or closed) and the activation time.

[0072] Figure 3 represents a (schematic) control panel of an embodiment of the automatic compensation device and of automatic correction of the trim and of the heel.

[0073] Figure 4 represents an operating scheme of an embodiment of the ballast transfer module among compensation tanks via water pumping.

[0074] The above described embodiments are combinable.

[0075] Although in the present invention only particular embodiments have been represented and described, the person with ordinary skill in the art will be able to introduce modifications and substitute some technical characteristics by other equivalent ones, depending on the requisites of each situation, without departing from the protection scope as defined in the appended claims.

[0076] The following claims set out particular embod-

iments of the invention.

Claims

1. Device for automatic control of buoyancy, heel, trim, depth and altitude in submersible vehicles, comprising:

3 or more non-pressurised tanks of liquid ballast, each with an air inlet valve and an air outlet valve, with electrically controlled opening and closing;
an electronic control unit for independent opening and closing of the air inlet and outlet valves of the tanks of liquid ballast;
a reservoir for storing compressed air connected to the air inlet valves of the tanks of liquid ballast;

wherein said tanks of liquid ballast comprise a free communication with the exterior of the submersible vehicle via one or more holes placed on the inferior part of the tank;

and wherein said tanks of liquid ballast are to be in different sections of the submersible vehicle placed along two directions of the horizontal plane of the submersible vehicle;

the device being arranged to conjugate the automatic maintenance of neutral buoyancy with the automatic correction of heel and trim angles.

2. Device according to the previous claim wherein the tanks of liquid ballast are 4.

3. Device according to any of the previous claims wherein the two directions of the horizontal plane are orthogonal directions.

4. Device according to the previous claim wherein the sections of the submersible vehicle where said tanks of liquid ballast are placed are the sections of:

stern and starboard; stern and port; bow and starboard; and bow and port; or
central stern, central bow, central starboard and central port;
or any of the intermediate arrangements between the two previous arrangements.

5. Device according to any of the previous claims wherein the electronic control unit is configured to proceed with the opening and closing of the air inlet and outlet valves for correcting the trim angle and correcting the heel angle.

6. Device according to any of the previous claims wherein the electronic control unit is configured to proceed with the opening and closing of the air inlet

and outlet valves for moving up, moving down, maintaining depth, maintaining altitude, obtaining a predefined depth, obtaining a predefined altitude.

7. Device according to any of the previous claims wherein the valves are solenoid type valves electrically controlled by the electronic control unit.
8. Device according to any of the previous claims wherein the inlet valve and the outlet valve of a tank of liquid ballast are in the same valve body.
9. Device according to any of the previous claims additionally comprising circuits with manually operated valves in parallel with each of the electrically controlled circuits.
10. Device according to any of the previous claims, wherein the automatic control unit is configured for operating the device by:

calculating the corrections to be made and the corresponding actions on the valves to obtain the desired weight in each of the tanks of liquid ballast;
acquiring and processing the data collected by the sensors comprising gyroscope, depth gauge and CTD;
visualising in real time the corrections that the device proposes and/or makes.

11. Device according to the previous claim, wherein the automatic control unit is configured for operating the device by comprising three procedure modes: continuing automatic mode; one shot automatic mode, assisted manual mode, relating to a preselected correction or definition procedure comprising buoyancy correction, trim correction, heel correction, depth definition, altitude definition, or their combinations; wherein:

the continuing automatic mode comprises initiating and permanently activating one or more preselected procedures, and wherein the procedures are automatically restarted with a previously defined periodicity or whenever they excessively deviate from the preselected correction or definition;
wherein the one shot automatic mode comprises performing simultaneously and at once one or more times preselected correction or definition procedures;
wherein the assisted manual mode comprises automatically performing a preselected correction or definition isolated procedure, according to the values defined by the pilot out of the system proposals.

12. Device according to the previous claim wherein the one shot automatic mode can be repeated at the initiative of the operator.

13. Submersible vehicle comprising the device according to any of the previous claims.
14. Submersible vehicle according to the previous claim wherein the submersible vehicle is a manned submarine or a remotely operated submersible vehicle or a submersible autonomous vehicle.

Patentansprüche

1. Vorrichtung zur automatischen Steuerung von Auftrieb, Krängung, Trimmung, Tiefe und Höhe in Unterwasserfahrzeugen, umfassend:

3 oder mehr drucklose Flüssigballasttanks, mit jeweils einem Lufteinlassventil und einem Luftauslassventil, mit einer elektrischen Steuerung zum Öffnen und Schließen;
eine elektronische Steuereinheit zum unabhängigen Öffnen und Schließen der Lufteinlass- und Luftauslassventile der Flüssigballasttanks;
einen Speicher zum Speichern von Druckluft, der mit den Lufteinlassventilen der Flüssigballasttanks verbunden ist;

wobei die genannten Flüssigballasttanks eine freie Verbindung mit der äußeren Umgebung des Unterwasserfahrzeugs über eine oder mehrere Öffnungen, die im unteren Teil des Tanks angeordnet sind, umfasst;

und wobei die genannten Flüssigballasttanks in verschiedenen Abschnitten des Unterwasserfahrzeugs in zwei Richtungen entlang der horizontalen Ebene des Unterwasserfahrzeugs angeordnet sind;
die Vorrichtung so angeordnet ist, dass sie das automatische Beibehalten des neutralen Auftriebs mit der automatischen Korrektur der Krängung- und Trimmungswinkel kombiniert.

2. Vorrichtung nach dem vorhergehenden Anspruch, wobei es 4 Flüssigballasttanks gibt.
3. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei die beiden Richtungen der horizontalen Ebene rechtwinklige Richtungen sind.
4. Vorrichtung nach dem vorhergehenden Anspruch, wobei es sich bei den Abschnitten des Unterwasserfahrzeugs, in denen die genannten Tanks für Flüssigballast angebracht sind, handelt um:

Heck und Steuerbord; Heck und Backbord; Bug und Steuerbord; und Bug und Backbord; oder

Mitte Heck, Mitte Bug, Mitte Steuerbord und Mitte Backbord;
oder irgendeine der Zwischenanordnungen zwischen den beiden vorher genannten Anordnungen.

5. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei die elektronische Steuereinheit so konfiguriert ist, um durch Öffnen und Schließen der Lufteinlass- und -auslassventile den Trimmungs- und den Krängungswinkel zu korrigieren.

6. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei die elektronische Steuereinheit so konfiguriert ist, um durch Öffnen und Schließen der Lufteinlass- und -auslassventile eine Auf- und Abbewegung, die Beibehaltung der Tiefe, die Beibehaltung der Höhe, das Erreichen einer im Voraus festgelegten Tiefe und das Erreichen einer im Voraus festgelegten Höhe zu erreichen.

7. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei die Ventile Magnetventile sind, die über die elektronische Steuereinheit elektrisch gesteuert werden.

8. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei sich das Einlassventil und das Auslassventil eines Flüssigballasttanks im gleichen Ventilkörper befinden.

9. Vorrichtung nach einem der vorhergehenden Ansprüche, zusätzlich umfassend Schaltungen mit manuell betriebenen Ventilen, die parallel zu jedem der elektrisch gesteuerten Schaltkreise vorhanden sind.

10. Vorrichtung nach einem der vorhergehenden Ansprüche, wobei die automatische Steuereinheit so konfiguriert ist, um die Vorrichtung zu steuern durch:

Berechnen der vorzunehmenden Korrekturen und der entsprechenden Einstellungen an den Ventilen, um das gewünschte Gewicht in jedem der Flüssigballasttanks zu erreichen;
Erfassen und Verarbeiten der von den Sensoren erfassten Daten, umfassend Gyroskop, Tiefenmesser und CTD-Rosette;
Visualisieren der von dem Gerät vorgeschlagenen und/oder durchgeführten Korrekturen in Echtzeit.

11. Vorrichtung nach dem vorhergehenden Anspruch, wobei die automatische Steuereinheit zum Betreiben der Vorrichtung so konfiguriert ist, dass sie drei Betriebsarten umfasst: kontinuierlicher Automatikbetrieb; einmaliger Automatikbetrieb (*one shot*), assistierter manueller Betrieb in Bezug auf ein im Voraus gewähltes Korrektur- oder Einstellverfahren,

umfassend Auftriebskorrektur, Trimmungskorrektur, Krängungskorrektur, Festlegen der Tiefe, Festlegen der Höhe oder Kombinationen von diesen; wobei:

der kontinuierliche Automatikbetrieb das Einleiten und das dauerhafte Aktivieren eines oder mehrerer im Voraus ausgewählter Verfahren umfasst und wobei die Verfahren automatisch mit einer im Voraus festgelegten Periodizität neu gestartet werden oder wann immer diese stark von der im Voraus gewählten Korrektur oder Einstellung abweichen;
wobei der einmalige Automatikbetrieb (*one shot*) das gleichzeitige und sofortige Durchführen eines oder mehrerer im Voraus gewählter Verfahren zur Korrektur oder Einstellung umfasst;
wobei der assistierte manuelle Betrieb das automatische Durchführen eines in Voraus gewählten isolierten Verfahrens zur Korrektur oder Einstellung gemäß den vom Piloten aus dem vom System vorgeschlagenen Werten umfasst.

12. Vorrichtung nach dem vorhergehenden Anspruch, wobei der einmalige Automatikbetrieb (*one shot*) auf Initiative des Bedieners wiederholt werden kann.

13. Unterwasserfahrzeug umfassend die Vorrichtung gemäß einem der vorhergehenden Ansprüche.

14. Unterwasserfahrzeug nach dem vorhergehenden Anspruch, wobei das Unterwasserfahrzeug ein bemanntes U-Boot oder ein ferngesteuertes Unterwasserfahrzeug oder ein autonomes Unterwasserfahrzeug ist.

Revendications

1. Dispositif pour la commande automatique de la flottabilité, du roulement, du tangage, de la profondeur et de l'altitude dans des véhicules submersibles comprenant :

3 ou plus réservoirs de ballast liquide non-présurisés, chacun avec une valve d'entrée d'air et une valve de sortie d'air, avec ouverture et fermeture contrôlées électriquement ;
une unité de commande électronique pour une ouverture et fermeture indépendante des valves d'entrée et de sortie d'air des réservoirs de ballast liquide ;
un réservoir pour stocker de l'air comprimé lié aux valves d'entrée d'air des réservoirs de ballast liquide ;

dans lequel lesdits réservoirs de ballast liquide com-

- prennent une communication libre avec l'extérieur du véhicule submersible via un ou plusieurs trous placés sur la partie inférieure du réservoir ; et dans lequel lesdits réservoirs de ballast liquide devront être dans des sections différentes du véhicule submersible, placés le long de deux directions du plan horizontal du véhicule submersible ; le dispositif étant arrangé pour conjuguer le maintien automatique de la flottabilité neutre avec la correction automatique des angles du roulement et du tangage.
2. Dispositif selon la revendication précédente dans lequel les réservoirs de ballast liquide sont 4.
 3. Dispositif selon l'une quelconque des revendications précédentes dans lequel les deux directions du plan horizontal sont des directions orthogonales.
 4. Dispositif selon la revendication précédente dans lequel les sections du véhicule submersible dans lequel lesdits réservoirs de ballast liquide sont placés sont les sections de :
 - arrière et tribord ; arrière et bâbord ; avant et tribord ; et avant et bâbord ; ou
 - central arrière, central avant, central tribord, central bâbord ;
 - ou l'un quelconque des arrangements intermédiaires entre les deux arrangements précédents.
 5. Dispositif selon l'une quelconque des revendications précédentes dans lequel l'unité de commande électronique est configurée pour procéder à l'ouverture et à la fermeture des valves d'entrée et de sortie d'air pour corriger l'angle de tangage et pour corriger l'angle de roulement.
 6. Dispositif selon l'une quelconque des revendications précédentes dans lequel l'unité de commande électronique est configurée pour procéder à l'ouverture et à la fermeture des valves d'entrée et de sortie d'air pour monter, descendre, maintenir la profondeur, maintenir l'altitude, obtenir une profondeur prédéfinie, obtenir une altitude prédéfinie.
 7. Dispositif selon l'une quelconque des revendications précédentes dans lequel les valves sont des valves de type électrovalve commandées électriquement par l'unité de commande électronique.
 8. Dispositif selon l'une quelconque des revendications précédentes dans lequel la valve d'entrée et la valve de sortie d'un réservoir de ballast liquide sont dans le même corps de vanne.
 9. Dispositif selon l'une quelconque des revendications
- précédentes comprenant en plus des circuits avec des valves opérées manuellement en parallèle avec chacun des circuits commandés électriquement.
10. Dispositif selon l'une quelconque des revendications précédentes, dans lequel l'unité de commande automatique est configurée pour opérer le dispositif en :
 - calculant les corrections à faire et les actions correspondantes sur les valves pour obtenir le poids souhaité dans chacun des réservoirs de ballast liquide ;
 - acquérant et traitant les données recueillies par les capteurs comprenant le gyroscope, la jauge de profondeur, et la sonde CTD ;
 - visualisant en temps réel les corrections que le dispositif propose et/ou fait.
 11. Dispositif selon la revendication précédente, dans lequel l'unité de commande automatique est configurée pour opérer le dispositif en comprenant trois modes de procédure :
 - mode automatique continu ; mode automatique simple, mode manuel assisté, lié à une procédure de correction ou de définition présélectionnée comprenant une correction de flottabilité, une correction de tangage, une correction de roulement, une définition de profondeur, une définition d'altitude, ou des combinaisons de celles-ci, dans lequel :
 - le mode automatique continu comprend l'initiation et l'activation permanente d'une ou de plusieurs procédures présélectionnées, et dans lequel les procédures sont automatiquement redémarrées avec une périodicité préalablement définie, ou lorsqu'elles dévient excessivement de la correction ou définition présélectionnée ;
 - dans lequel le mode automatique simple comprend la réalisation simultanée et d'un coup une ou plusieurs fois de procédures de correction ou définition présélectionnées ;
 - dans lequel le mode manuel assisté comprend automatiquement la réalisation d'une procédure isolée de correction ou de définition présélectionnée, selon les valeurs définies par le pilote à partir des propositions du système.
 12. Dispositif selon la revendication précédente dans lequel le mode automatique simple peut être répété par initiative de l'opérateur.
 13. Véhicule submersible comprenant le dispositif selon l'une quelconque des revendications précédentes.
 14. Véhicule submersible selon la revendication précédente dans lequel le véhicule submersible est un sous-marin piloté ou un véhicule submersible opéré à distance ou un véhicule autonome submersible.

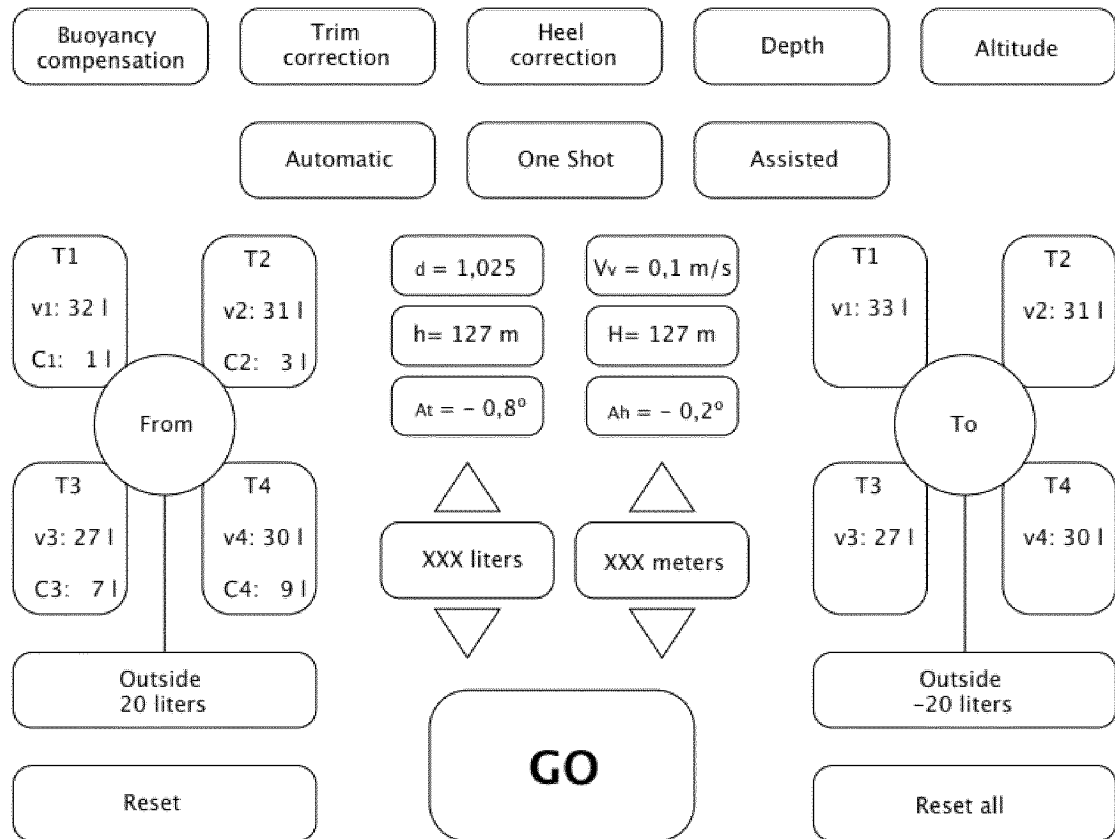


Fig. 1

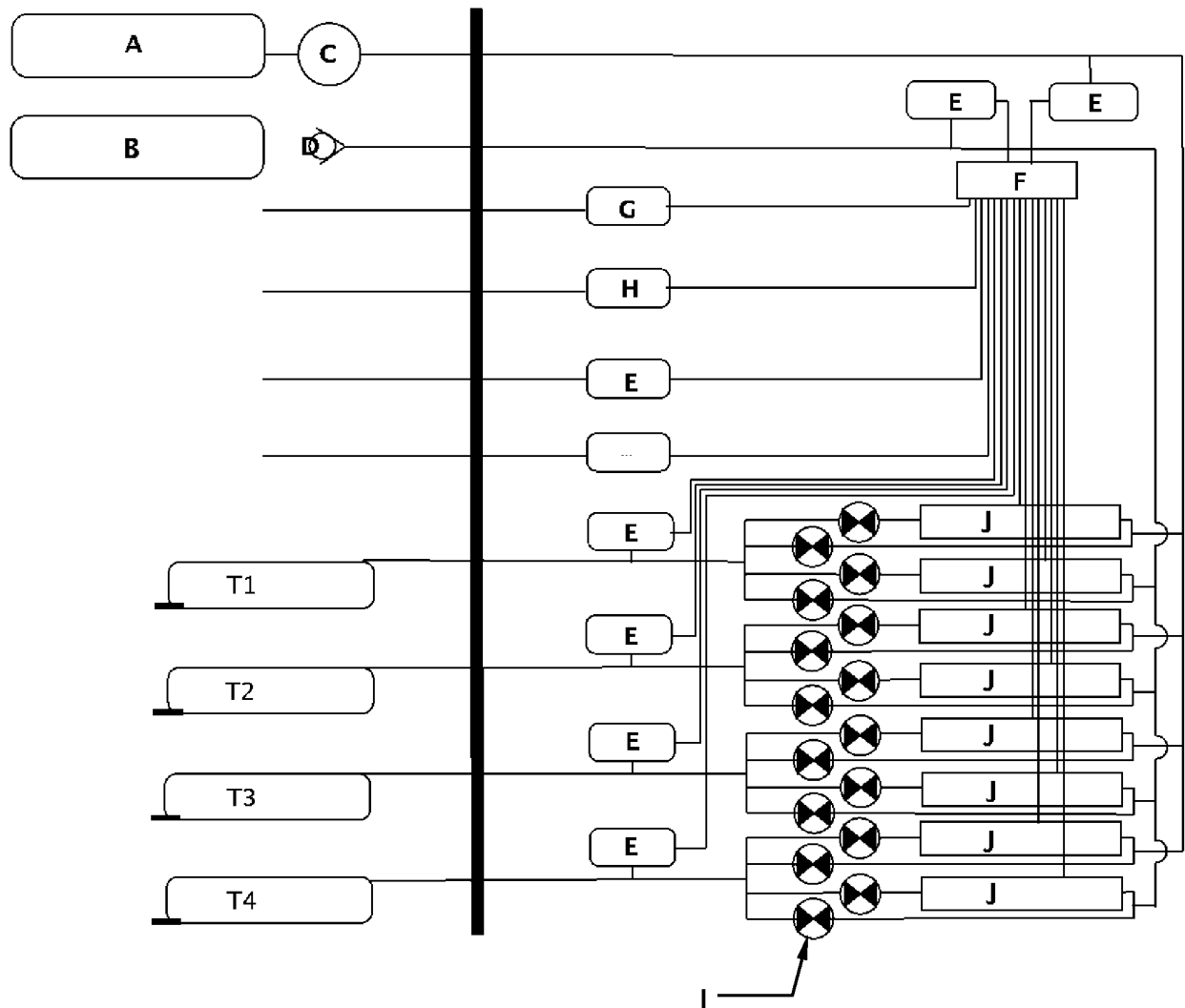


Fig. 2

Compensation

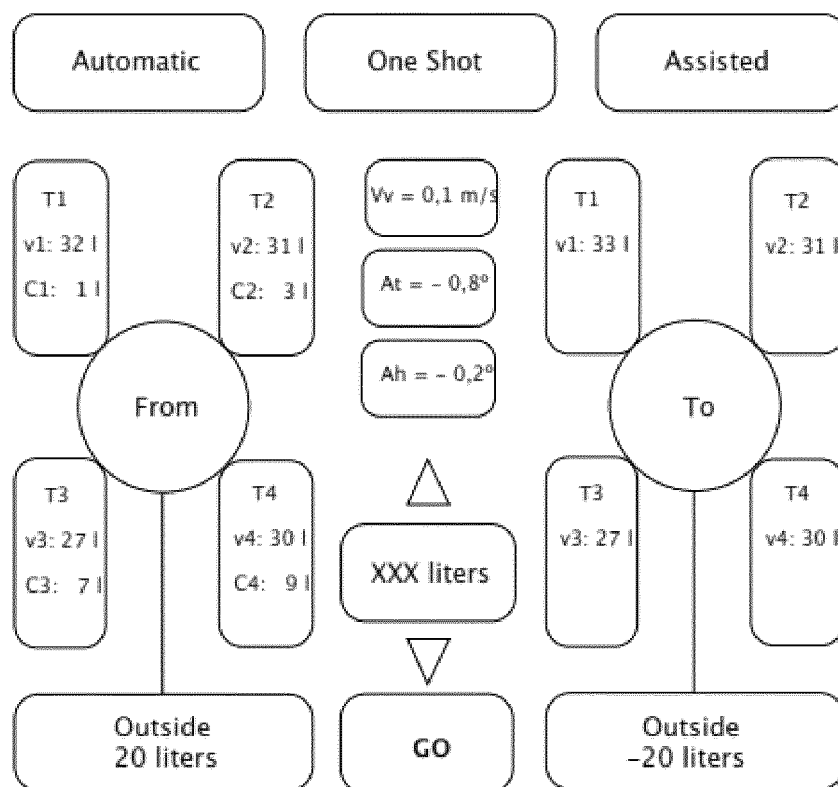


Fig. 3

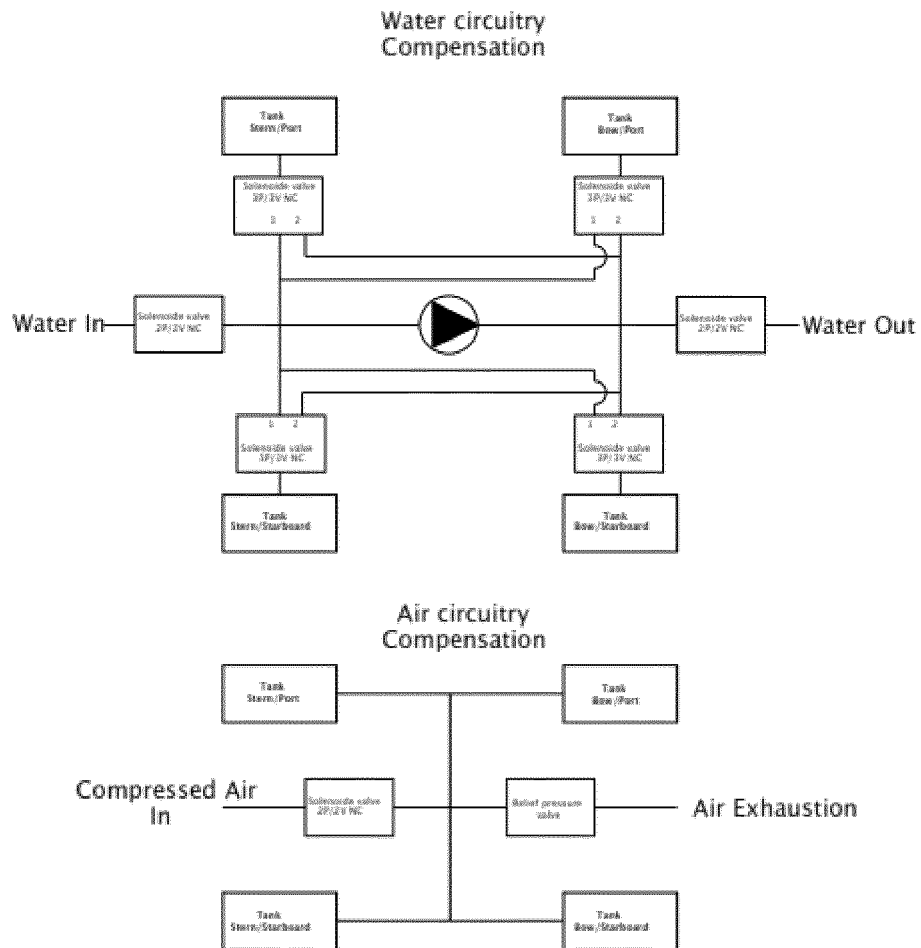


Fig. 4

REFERENCES CITED IN THE DESCRIPTION

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