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(54) **UNDERWATER VESSEL**

(57) According to the present invention there is provided an underwater vessel comprising: a body; a thruster operable to produce thrust, wherein the thruster is deployable from the body; an actuator assembly connected to the thruster and operable to deploy the thruster, wherein the actuator assembly is operable to deploy the thruster in a first configuration in which the thruster is oriented to produce a thrust having a vertical component when the thruster is operated.

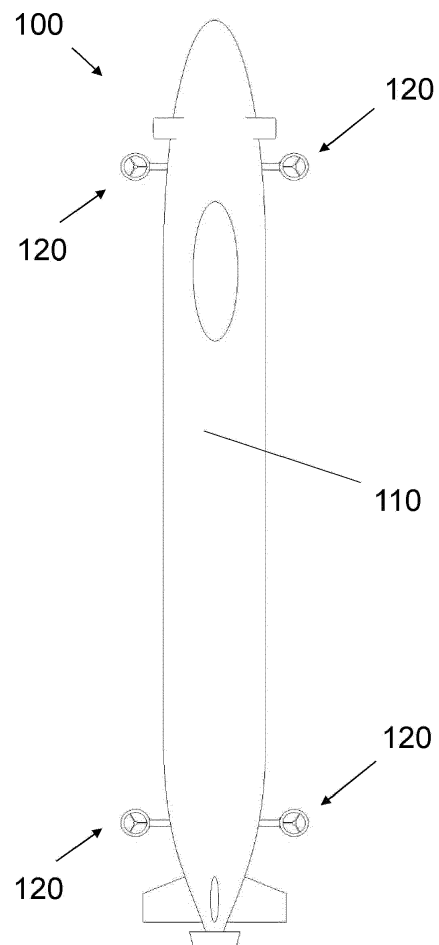


Fig. 1

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Description

FIELD

[0001] The present invention relates to an underwater vessel.

BACKGROUND

[0002] Underwater vessels are vessels suited to operation under water. Underwater vessels include submarines, submersibles, crewed and uncrewed underwater vessels, remotely operated vehicles (ROVs), bathyscaphes, and the like.

[0003] Maintaining stability of the vessel and controlling position and depth underwater is an important consideration in the field. Various techniques are employed to this end. Conventional techniques include use of ballasts (including variable ballasts such as trim tanks), control surfaces, and pump systems to cause movement of water about the vessel.

[0004] However, such techniques require heavy or complex systems, and/or require large spatial volumes, which ultimately increase the size, complexity, or weight of underwater vessels. Moreover, failure of these systems can be catastrophic.

[0005] It is an object of the present invention to provide an improved underwater vessel and/or address one or more of the problems discussed above, or discussed elsewhere, or to at least provide an alternative underwater vessel.

SUMMARY

[0006] According to an aspect of the present invention, there is provided an underwater vessel comprising: a body; a thruster operable to produce thrust, wherein the thruster is deployable from the body; an actuator assembly connected to the thruster and operable to deploy the thruster, wherein the actuator assembly is operable to deploy the thruster in a first configuration in which the thruster is oriented to produce a thrust having a vertical component when the thruster is operated.

[0007] In one example, the actuator assembly is operable to deploy the thruster by rotation about a first axis.

[0008] In one example, the thruster is stowable in the body, preferably stowable completely within the body.

[0009] In one example, the actuator is operable to stow the thruster.

[0010] In one example, the actuator assembly is operable to deploy the thruster in a second configuration in which the thruster is oriented to produce a thrust having a horizontal component when the thruster is operated.

[0011] In one example, the actuator assembly is operable to move the thruster from the first configuration to the second configuration.

[0012] In one example, the actuator assembly is operable to move the thruster from the first configuration to

second configuration by rotation about a second axis.

[0013] In one example, the actuator assembly is operable to deploy the thruster in the second configuration in the event of failure of a primary propulsion system of the submarine, thereby to provide a secondary propulsion system.

[0014] In one example, the underwater vessel comprises a control system arranged to control operation of the thruster based on an operating condition of the vessel.

[0015] In one example, the control system is arranged to control operation of the thruster to maintain a substantially constant operating condition.

[0016] In one example, the control system is arranged to: control the actuator assembly to deploy the thruster in the first configuration; and control operation of the thruster based on an operating condition of the vessel, preferably to maintain a substantially constant operating condition.

[0017] In one example, the thruster comprises a rim driven thruster.

[0018] In one example, the underwater vessel comprises a plurality of thrusters, preferably four thrusters.

[0019] In one example, the thrusters are independently operable.

[0020] In one example, the underwater vessel is a submarine.

BRIEF DESCRIPTION OF THE FIGURES

[0021] Embodiments of the invention will now be described by way of example only with reference to the figures, in which:

Figure 1 shows a plan view of an underwater vessel having a plurality of thrusters deployed, each thruster in the first configuration;

Figure 2 shows a perspective view of a thruster and an actuator assembly;

Figure 3 shows a plan view of the thruster and the actuator assembly of Figure 2;

Figure 4 shows a side view of the thruster and the actuator assembly of Figure 2;

Figure 5 shows a front view of the thruster and the actuator assembly of Figure 2;

Figure 6 shows a part of an underwater vessel having the thruster and the actuator assembly stowed in the body;

Figure 7 shows the thruster deployed in a first configuration;

Figure 8 shows the thruster deployed in a second configuration; and

Figure 9 shows the underwater vessel of Figure 1 having a control system.

DETAILED DESCRIPTION

[0022] Referring to Figure 1, an underwater vessel 100

is shown. Here, the underwater vessel is a submarine 100. The submarine 100 comprises a body 110. The submarine 100 comprises a thruster 120 operable to produce thrust. The thruster 120 is deployable from the body 110. An actuator assembly 130 is connected to the thruster 120 and is operable to deploy the thruster 120. The actuator assembly 130 is operable to deploy the thruster 120 in a first configuration in which the thruster 120 is oriented to produce a thrust having a vertical component when the thruster 120 is operated.

[0023] In the embodiment illustrated in Figure 1, the submarine 100 comprises four thrusters 120. Two thrusters 120 are provided proximal the fore of the submarine 100, one either side of the body 110. Two thrusters are provided proximal the aft of the submarine 100, one either side of the body 110. Furthermore, the submarine comprises four actuator assemblies 130, one actuator assembly 130 associated with each thruster 120. Of course, it will be understood by the skilled person that the submarine 100 may comprise a single actuator assembly operable to deploy each of a plurality of thrusters (in this case, the four thrusters 120). Each thruster 120 is substantially identical in structure and operation. In this exemplary embodiment, each thruster 120 is independently operable. Each actuator assembly 130 is substantially identical in structure and operation, apart from appropriate modifications in directions of deployment and stowing, as will be appreciated by the skilled person from the description provided herein.

[0024] Referring to Figures 2 to 5, a thruster 120 and an actuator assembly 130 are shown.

[0025] The thruster 120 is a rim-driven thruster (RDT). The RDT 120 is absent a hub for the transmission of driving torque. The RDT 120 comprises a plurality of blades 122. The blades 122 are mounted on a ring (not shown). The ring functions as the rotor of an electric motor. The ring is surrounded by a stator, which is correspondingly ring shaped, and creates the desired torque. The stator and ring are housed in an annular housing 124. RDTs have a small spatial profile, thereby reducing the volume necessary in which to stow the RDT 120 within the body 110 of the submarine 100. Furthermore, since the rotor is electromagnetically driven, no shaft and no gearbox is needed, which reduces the weight of the thruster 120. In this way, deployment of the thruster 120, which involves movement of the thruster 120, is made easier.

[0026] The actuator assembly 130 comprises a structure 132 having an arm 134 connected to the thruster 120. The actuator assembly 130 further comprises two rotary actuators (not shown) housed within the structure 132. A first one of the rotary actuators is operable to rotate the arm 134 by 90 degrees about a first axis A-A. The first axis A-A is perpendicular to the longitudinal axis of the arm 134. A second one of the rotary actuators is operable to rotate the arm 132 by 90 degrees about a second axis B-B. The second axis B-B is parallel to the longitudinal axis of the arm 134.

[0027] Referring to Figures 6 to 8, rear end views of the port side (that is, lefthand side) of the body 110 of the submarine 100 are shown. In Figures 6 to 8, the port side aft thruster 120 is shown.

[0028] Referring to Figure 6, the thruster 120 is shown stowed within the body 110. In this stowed configuration, the plane of the thruster 120 - that is, the plane perpendicular to the direction of thrust when the thruster 120 is operated - is perpendicular to the length of the body 110 of the submarine 100. In this example, the thruster 120 is stowed completely within the body 110, with no part of the thruster 120 projecting from the body 110. In this way, hydrodynamic properties of the submarine 100 are optimised when the thruster 120 is not deployed. Furthermore, platform performance is improved.

[0029] Referring to Figure 7, the thruster 120 is shown deployed in a first configuration in which the thruster 120 is oriented to produce a thrust having a vertical component when the thruster 120 is operated. In this exemplary embodiment, the thruster 120 is oriented to produce a vertical thrust. Here, the plane of the thruster 120 is parallel to the width of the body 110 of the submarine 100. In this way, the thruster 120 is operable to produce a vertical thrust which allows the submarine 100 to maintain a constant depth or height above the seabed. In this way, the submarine 100 can hover in the water.

[0030] Movement of the thruster 120 from the stowed configuration to the first configuration is performed by operating the actuator assembly 130 to rotate the arm 134 by 90 degrees about the first axis A-A. In this way, the thruster 120 is moved to swing out away from the body 110. In combination with this first rotation, actuator assembly 130 is operated to rotate the arm 134 by 90 degrees about the second axis B-B. In this way, the thruster 120 is moved to be oriented with the plane of the thruster 120 being horizontal. In this way, the actuator assembly 130 is operable to deploy the thruster 120 in the first configuration.

[0031] Referring to Figure 8, the thruster 120 is shown deployed in a second configuration in which the thruster is oriented to produce a thrust having a horizontal component when the thruster 120 is operated. In this exemplary embodiment, the thruster 120 is oriented to produce a horizontal thrust. Here, the plane of the thruster 120 is perpendicular to the length of the body 110. In this way, the thruster 120 is operable to produce a horizontal thrust which allows the submarine 100 to be propelled through the water. The actuator assembly 130 is operable to deploy the thruster 120 in the second configuration in the event of failure of a primary propulsion system of the submarine 100, thereby to provide a secondary propulsion system. In this way, redundancy is incorporated into the submarine 100. In this exemplary embodiment, the actuator assembly 130 is operable to deploy the aft thrusters 120, on both the port and starboard side, in the second configuration in the event of failure of a primary propulsion system of the submarine 100. In other exemplary embodiments, one or more pairs of thrusters, in-

cluding port side thrusters, starboard side thrusters or both pairs of fore and aft thrusters, may be deployed and operated in the event of failure of a primary propulsion system.

[0032] Movement of the thruster 120 from the first configuration to the second configuration is performed by operating the actuator assembly 130 to rotate the arm 134 by 90 degrees about the second axis B-B. Movement of the thruster 120 from the stowed configuration to the second configuration is performed by operating the actuator assembly 130 to rotate the arm 134 by 90 degrees about the first axis A-A. In this way, the actuator assembly 130 is operable to deploy the thruster 120 in the second configuration.

[0033] It will be understood that movement from the second configuration to (or, back to) the first configuration is performed by operating the actuator assembly 130 to rotate the arm 134 by 90 degrees about the second axis B-B. This rotation may include rotation in an opposite direction to the direction of rotation of the arm 134 from the first configuration to the second configuration.

[0034] When the thruster 120 is not in use or no longer required, which may be when a primary propulsion system of the submarine 100 is to be used, the actuator assembly 130 is operated to move the thruster from the first or second configuration to the stowed configuration.

[0035] Of course, the thruster 120 is repeatedly movable between the stowed configuration, first configuration and second configuration. Such movement of the thrusters 120 may otherwise be known as a vectorable thruster.

[0036] Referring to Figure 9, the submarine 100 comprises a control system 200. The control system is arranged to control operation of the thrusters 120. In one exemplary embodiment, the control system is arranged to control operation of the actuator assembly 130. In this way, the control system is arranged to control deployment of the thrusters 120.

[0037] Control of operation the thrusters 120 is based on an operating condition of the submarine 100. The operating condition includes one or more of: position (including current or desired position), depth, weight, buoyancy, attitude, stability, centre of mass, centre of buoyancy, centre of gravity, and the like. The control system 200 is arranged to receive information relating to the operating condition from sensors provided on the submarine 100. The control system 200 is arranged to control operation of the thrusters 120 to maintain a substantially constant operating condition. In one exemplary embodiment, the control system 200 is arranged to control operation of the thrusters 120 to maintain a constant depth, or height above the seabed. That is, the control system 200 controls the thrusters 120 to cause the submarine 100 to hover at a constant depth. In doing so, the control system 200 can also account for environmental conditions, including water temperature, water speed, density, and the like.

[0038] In one mode of operation, the control system 200 controls the actuator assembly 130 to deploy the

thrusters 120 in the first configuration, thereby to provide a vertical thrust component, and control operation of the thrusters 120 based on the desired depth which is desired to maintain. As mentioned above, the thrusters 120 are independently operable, and the control system 200 is operable to control the thrusters 120 independently to maintain or obtain the operating condition. Independent operation of the thrusters 120 advantageously provides for maximum control of the stability, positioning and depth of the submarine 100.

[0039] In another mode of operation, the control system 200 controls the actuator assembly 130 to deploy the thrusters 120 in the first and/or second configuration, and control operation of the thrusters 120 to maintain a desired level of stability of the submarine 100. In this way, complex systems, including pump systems, for maintaining stability of the submarine 100 may not be necessary, or can be supplemented by the present system, thereby reducing weight and complexity of the submarine 100.

[0040] It is to be understood that the singular forms "a," "an," and "the" include plural referents unless the context clearly dictates otherwise. The terms "front", "rear", "side", "upper", "lower", "over", "under", "inner", "outer" and like terms are used to refer to the apparatus and its components in the orientation in which it is illustrated, which is the orientation in which it is intended to be used but should not be taken as otherwise limiting. Like reference numerals are used to denote like features throughout the figures, which are not to scale.

Claims

1. An underwater vessel comprising:

a body;
a thruster operable to produce thrust, wherein the thruster is deployable from the body;
an actuator assembly connected to the thruster and operable to deploy the thruster,
wherein the actuator assembly is operable to deploy the thruster in a first configuration in which the thruster is oriented to produce a thrust having a vertical component when the thruster is operated.

2. An underwater vessel according to claim 1 wherein the actuator assembly is operable to deploy the thruster by rotation about a first axis.

3. An underwater vessel according to claim 1 or claim 2 wherein the thruster is stowable in the body, preferably stowable completely within the body.

4. An underwater vessel according to claim 3 wherein the actuator assembly is operable to stow the thruster.

5. An underwater vessel according to any one of the preceding claims wherein the actuator assembly is operable to deploy the thruster in a second configuration in which the thruster is oriented to produce a thrust having a horizontal component when the thruster is operated. 5
6. An underwater vessel according to claim 5 wherein the actuator assembly is operable to move the thruster from the first configuration to the second configuration. 10
7. An underwater vessel according to claim 5 or claim 6 wherein the actuator assembly is operable to move the thruster from the first configuration to second configuration by rotation about a second axis. 15
8. An underwater vessel according to any of claims 5 to 7 wherein the actuator assembly is operable to deploy the thruster in the second configuration in the event of failure of a primary propulsion system of the submarine, thereby to provide a secondary propulsion system. 20
9. An underwater vessel according to any one of the preceding claims comprising a control system arranged to control operation of the thruster based on an operating condition of the vessel. 25
10. An underwater vessel according to claim 9 wherein the control system is arranged to control operation of the thruster to maintain a substantially constant operating condition. 30
11. An underwater vessel according to claim 9 or claim 10 wherein the control system is arranged to: 35

control the actuator assembly to deploy the thruster in the first configuration; and

control operation of the thruster based on an operating condition of the vessel, preferably to maintain a substantially constant operating condition. 40
12. An underwater vessel according to any one of the preceding claims wherein the thruster comprises a rim driven thruster. 45
13. An underwater vessel according to any one of the preceding claims comprising a plurality of thrusters, preferably four thrusters. 50
14. An underwater vessel according to claim 13 wherein the thrusters are independently operable. 55
15. An underwater vessel according to any one of the preceding claims wherein the underwater vessel is a submarine

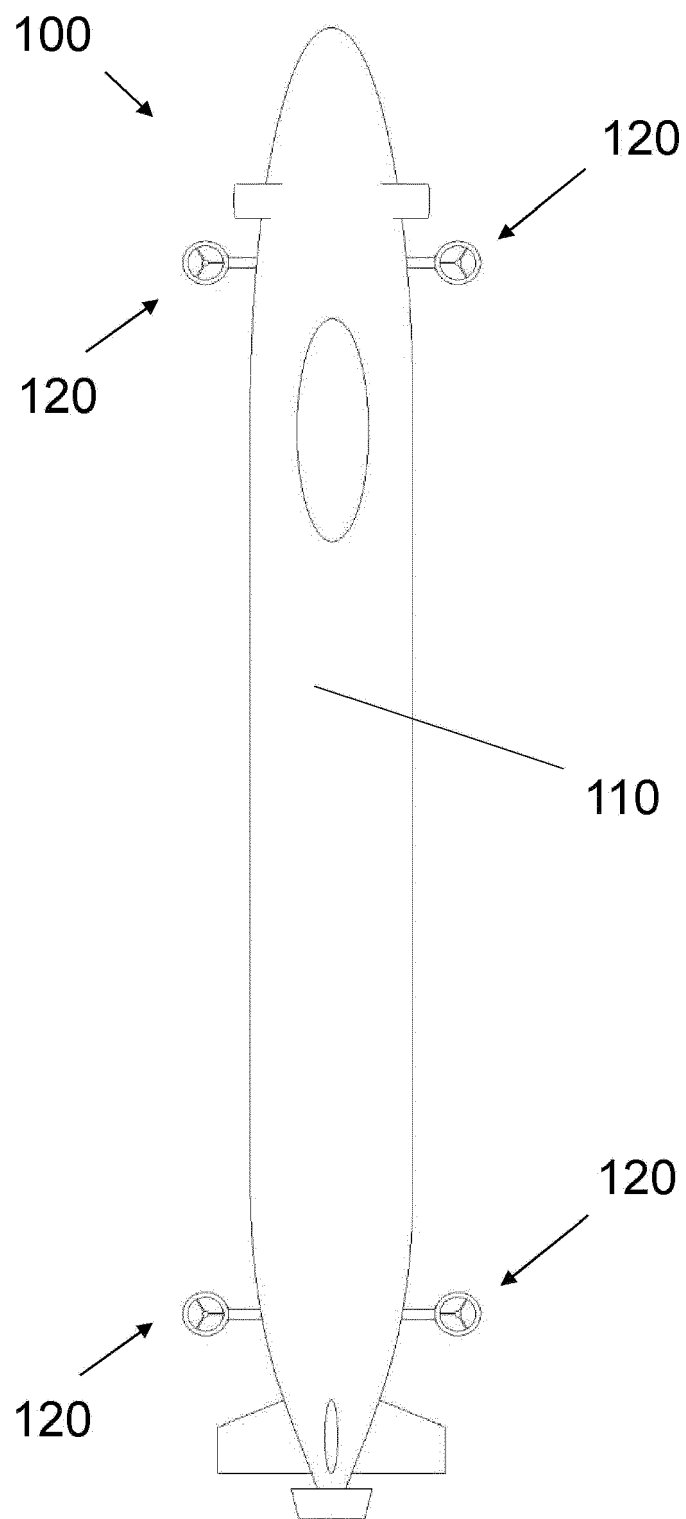
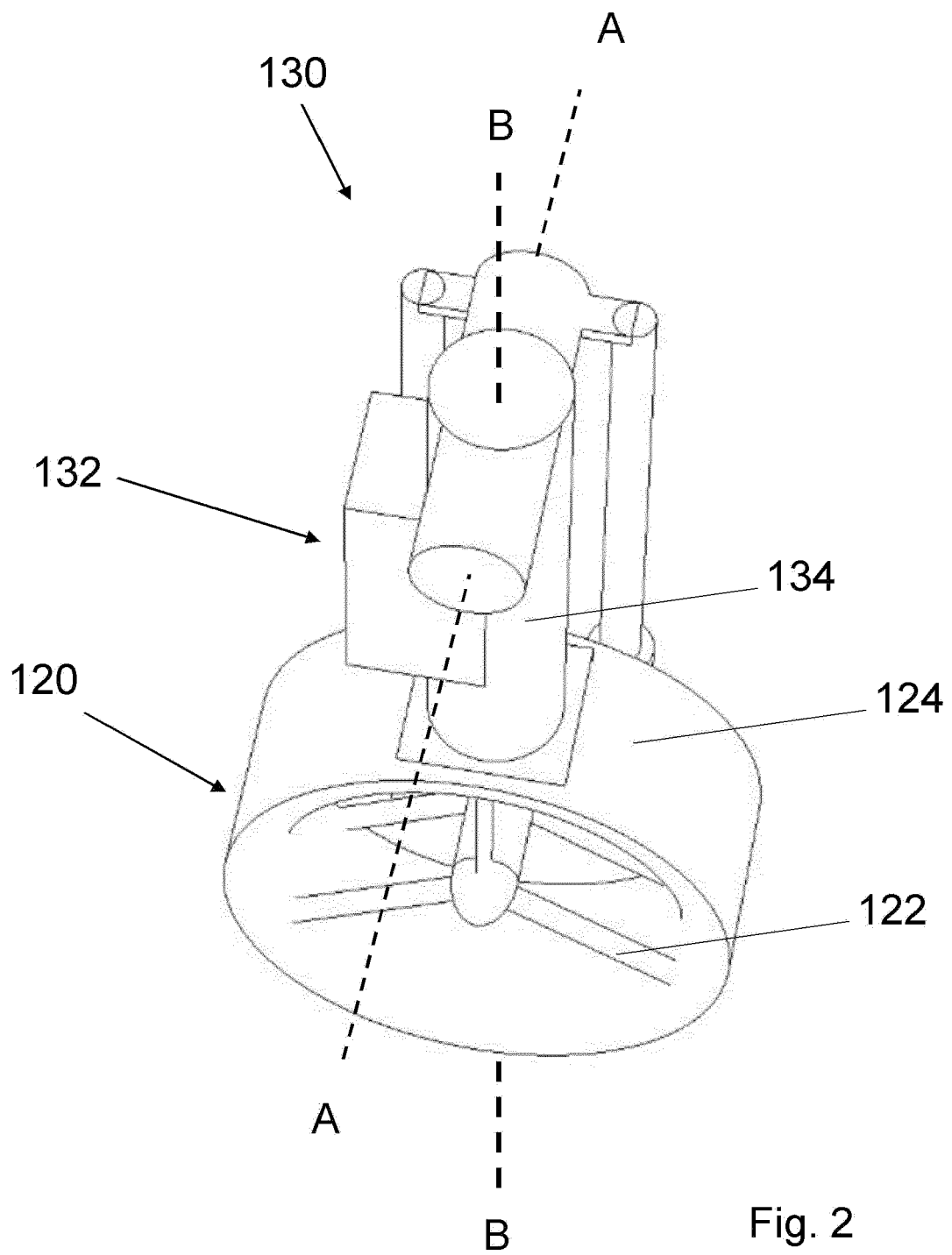


Fig. 1



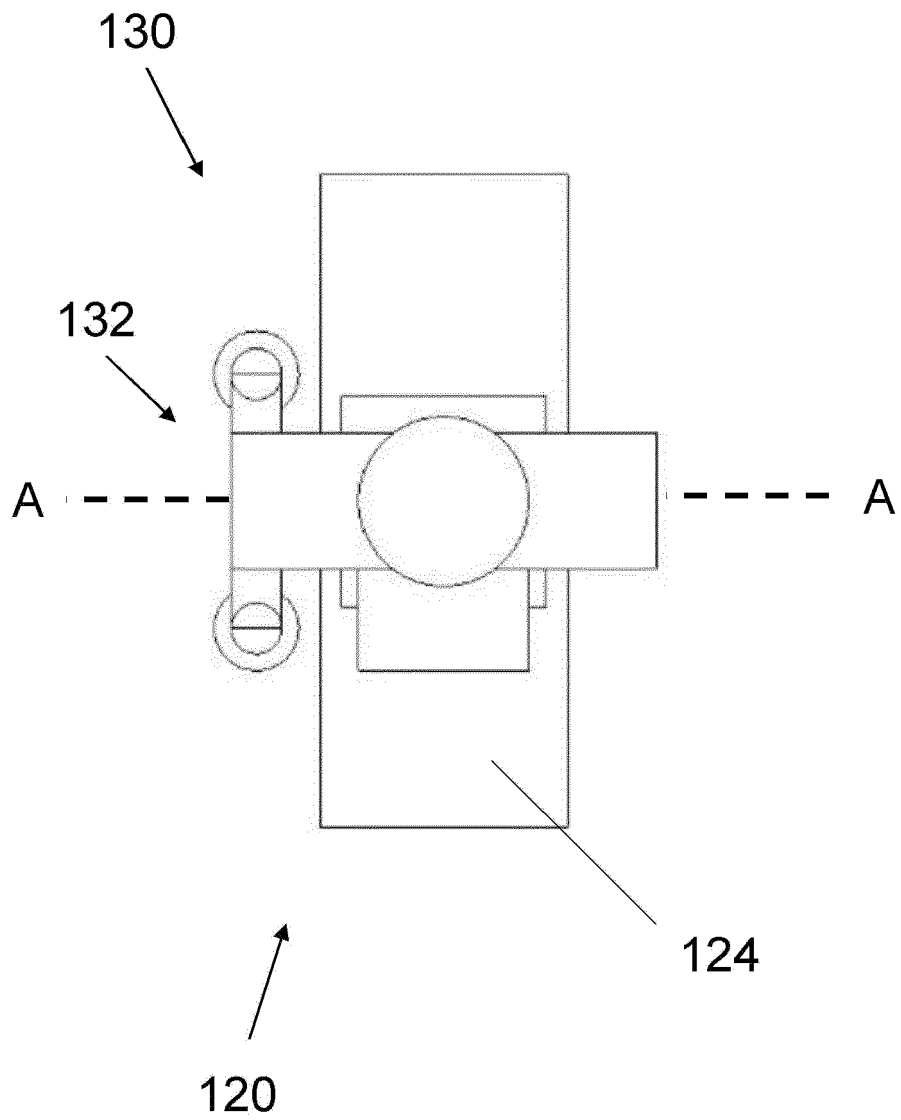
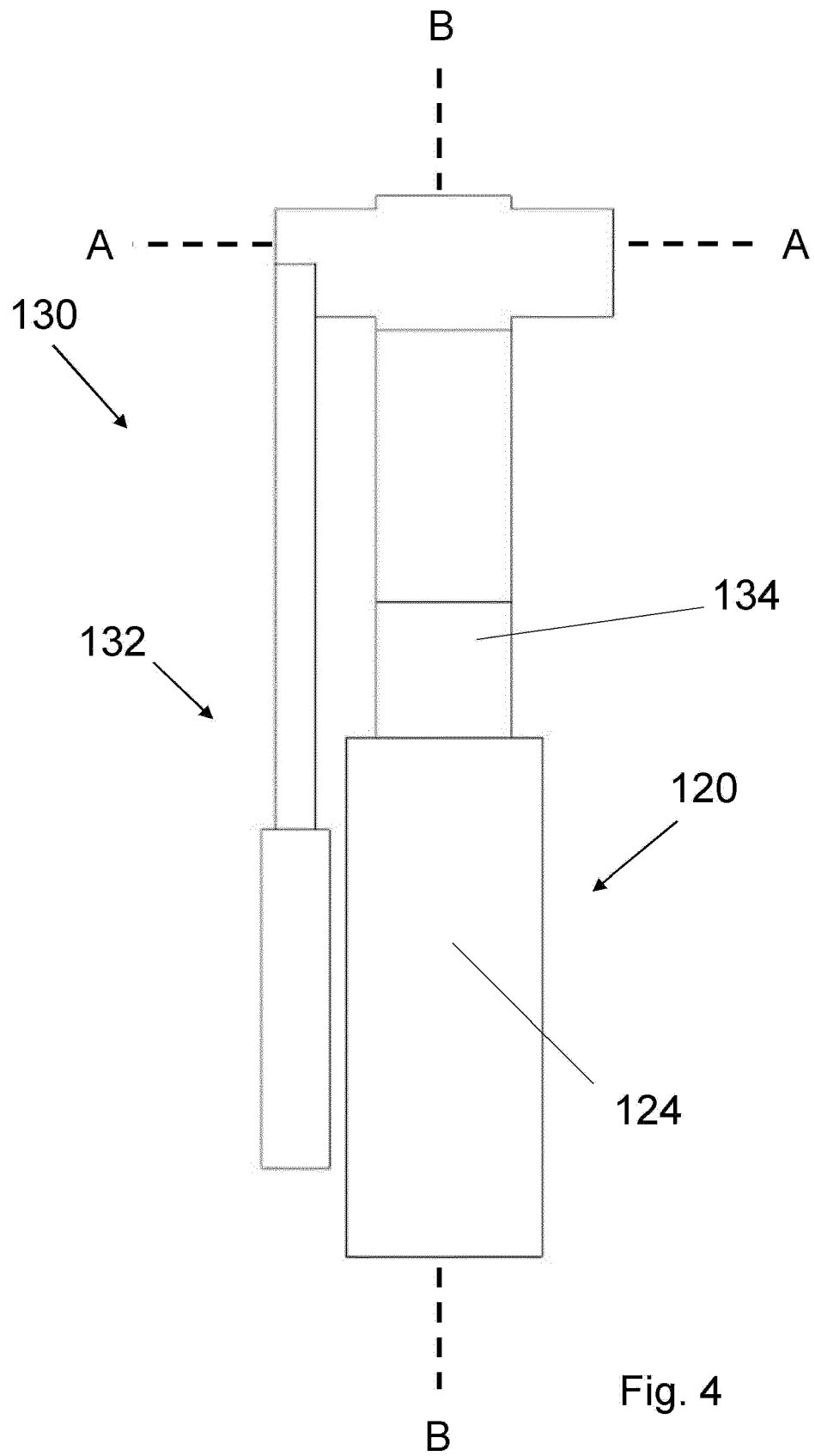


Fig. 3



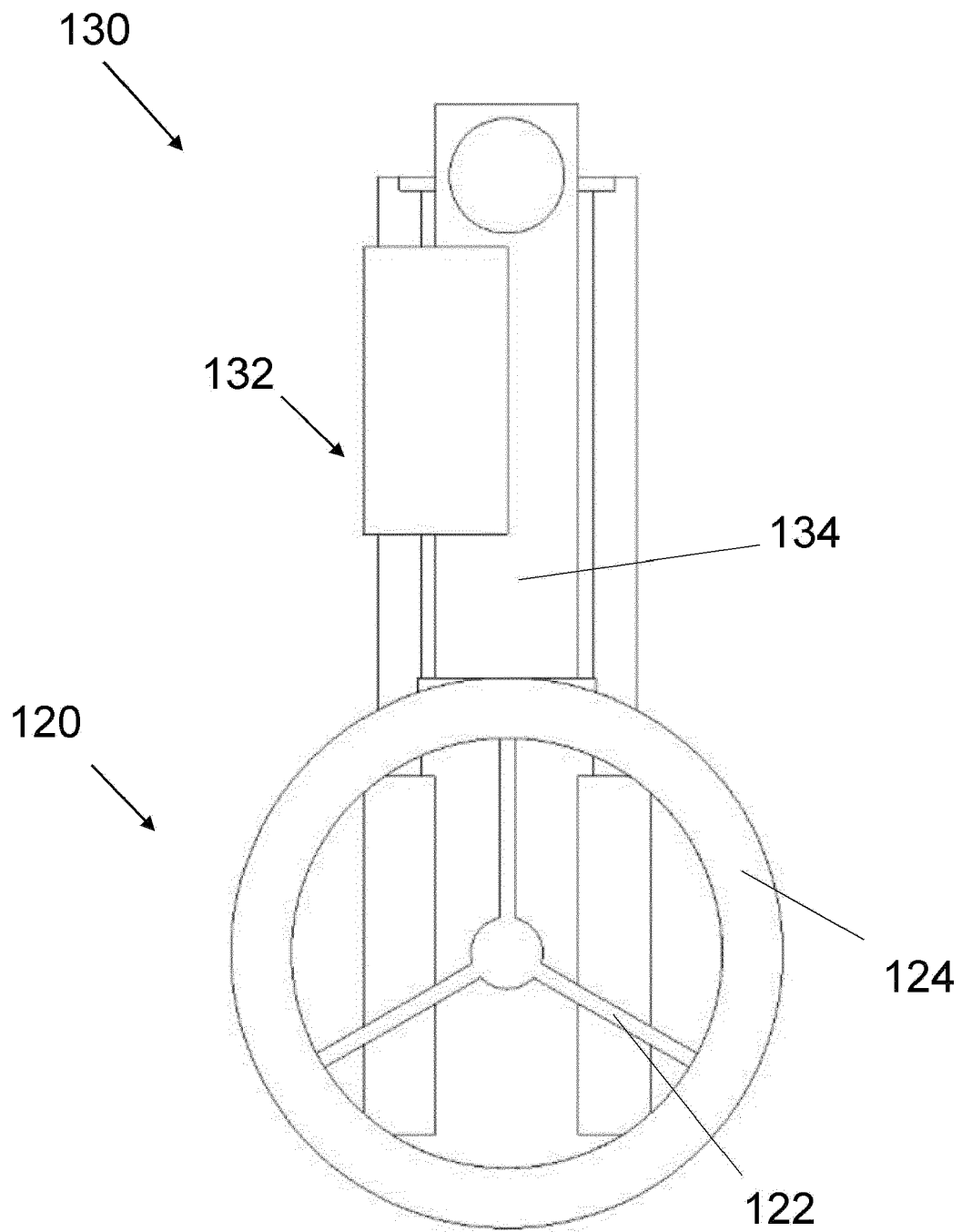


Fig. 5

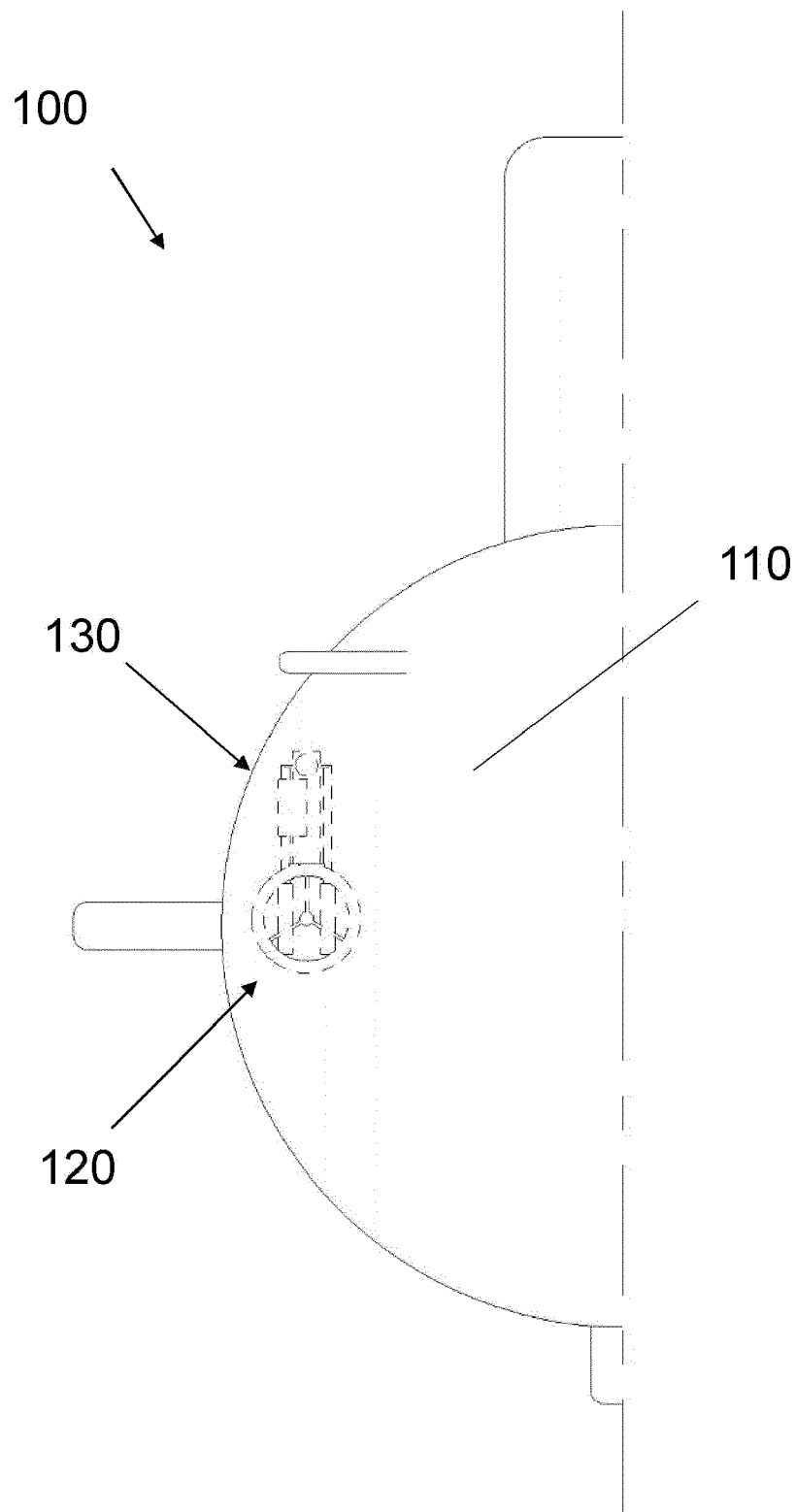


Fig. 6

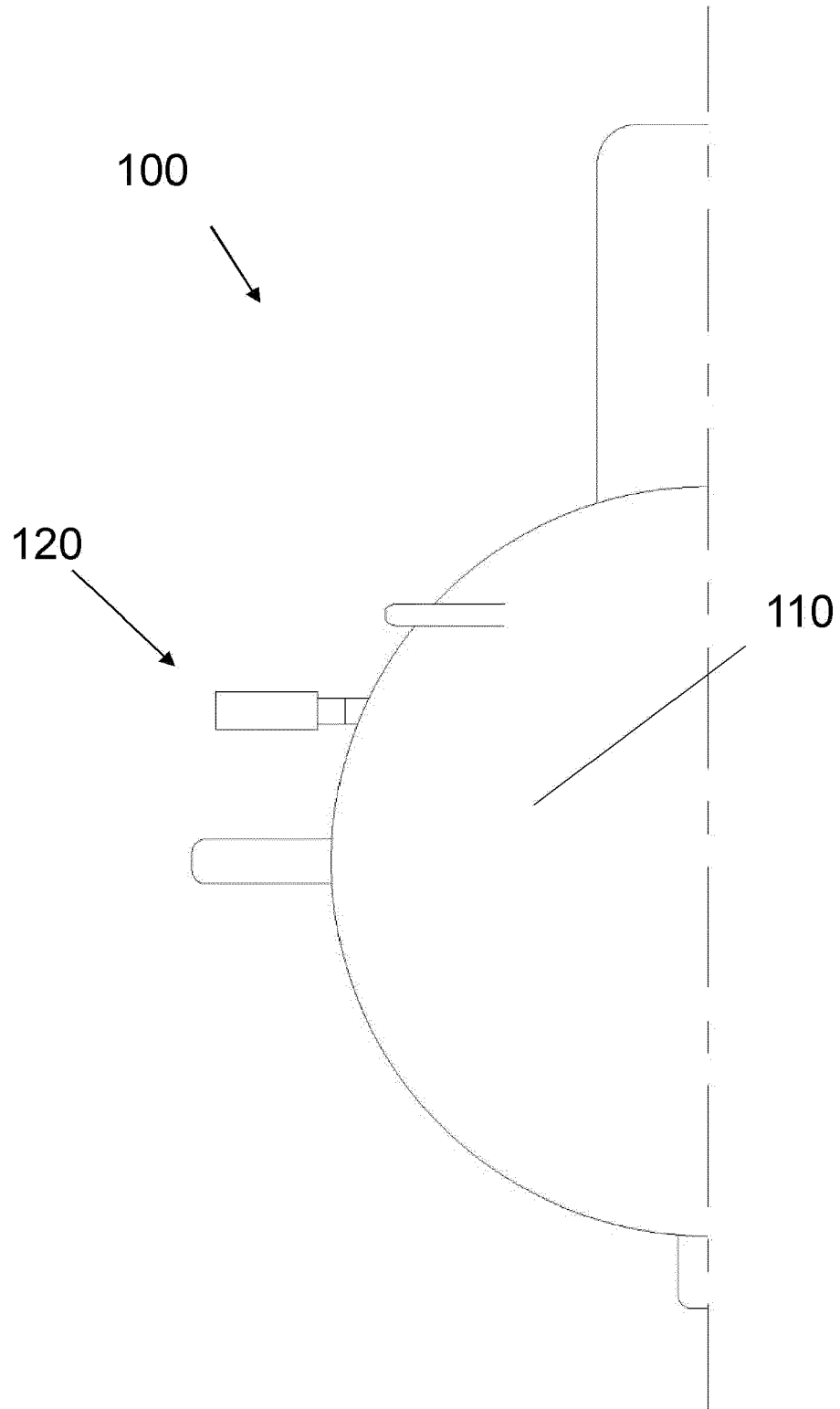


Fig. 7

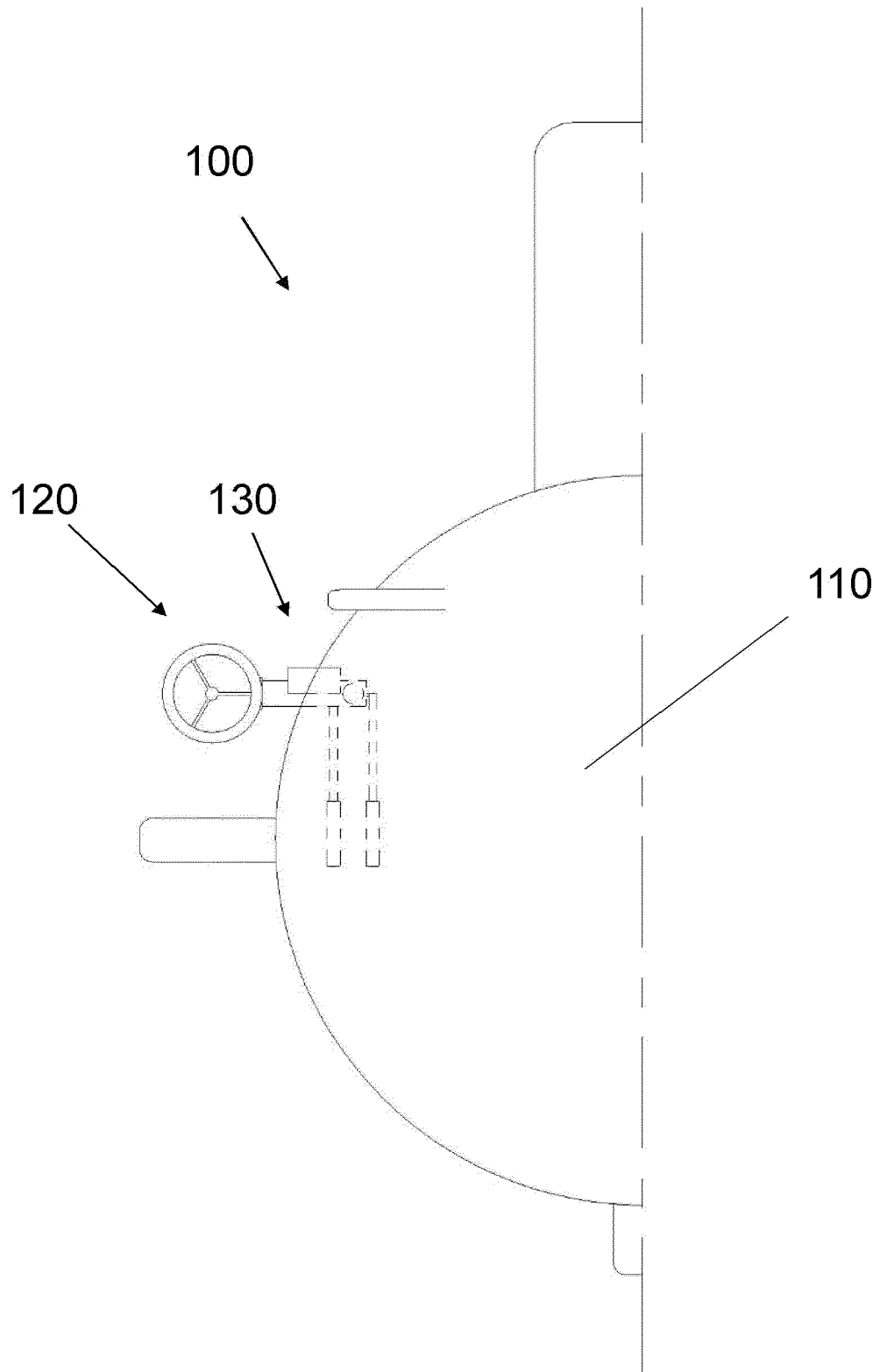


Fig. 8

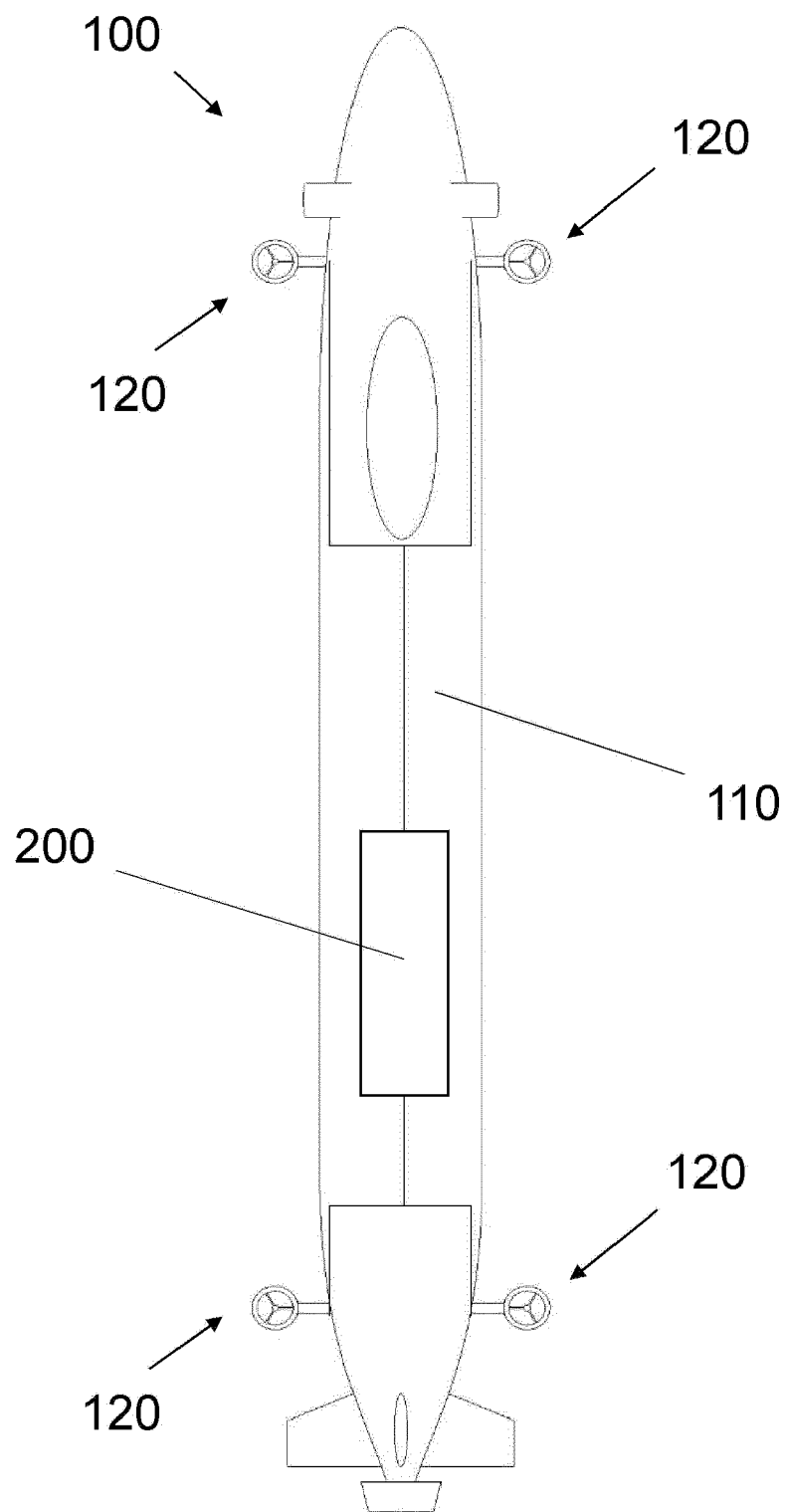


Fig. 9



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 Application Number
 EP 21 27 5069

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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 26 November 2021	Examiner van Rooij, Michael
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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