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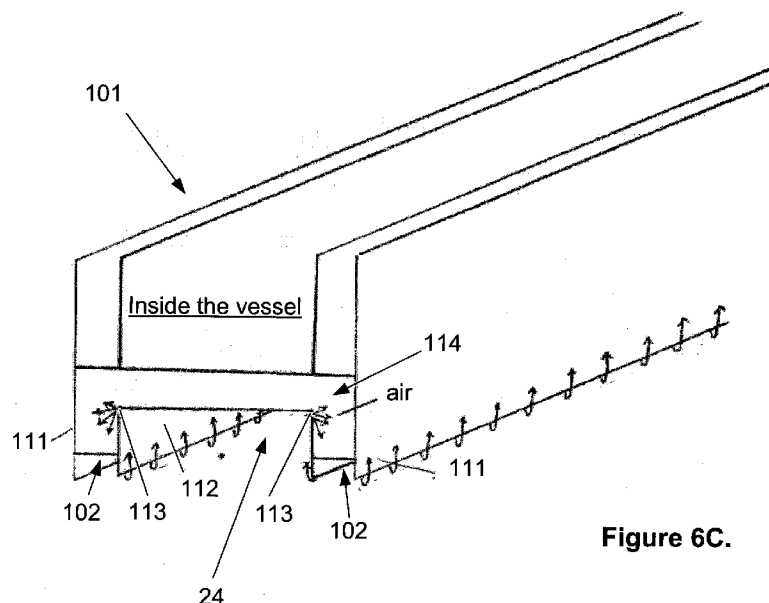
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(54) Title: METHOD FOR AIR-DRIVEN PROPULSION OF A VESSEL AND AIR-DRIVEN VESSEL



**Figure 6C.**

(57) Abstract: Method for air-driven propulsion of vessel and air-driven vessel. The method is characterized by that propulsion is provided by that air under high pressure is ejected under the sea surface, and that air rising again from the sea is captured for providing an air cushion between the hull and the vessel. It is further described a solution for re-use of the air captured for further propulsion. The invention also describes a solution for reducing the friction between the hull and the vessel by utilizing captured air for providing an air cushion between the hull and the sea.

**METHOD FOR AIR-DRIVEN PROPULSION OF A VESSEL AND AIR-DRIVEN VESSEL**

The present invention relates to a method for air-driven propulsion of a vessel, according to the preamble of claim 1.

5 The present invention also relates to an air-driven vessel, according to claim 5.

**Background**

There is an increasing focus on energy effective vessels and propulsion systems. There is a major focus on hybrid and electrical propulsion systems, and design of energy favorable hulls for vessels.

10 There exist hovercrafts utilizing air for moving the vessel above the surface the vessel is moving on.

The principle of hovercrafts is per time not transferred to more traditional vessels, something the present invention seeks to present.

15 **Object**

The main object of the present invention is to provide an air-driven vessel and a method which utilizes pressurized air for propulsion of the vessel.

It is further an object of the present invention to provide an air-driven vessel and a method which utilizes pressurized air for providing minimal friction between hull of the vessel and surface  
20 of sea.

**The invention**

A method for air-driven propulsion of a vessel is described in claim 1. Preferable features of the method are described in the claims 2-4.

25 An air-driven vessel is described in claim 5. Preferable features of the vessel are described in the claims 6-23.

*The present invention is based on utilizing pressurized air for propulsion of a vessel. The idea is based on collecting air above the surface of the sea and pressurizing this by means of suitable means, and further by means of suitable means using this pressurized air for propulsion of the vessel.*  
30

This pressurized air is preferably conveyed from upper part of the vessel to lower part of the vessel, i.e. lower part of hull of the vessel, preferably firstly to front part of the hull, where the pressurized air is blown out via one or more openings positioned under the sea surface, i.e. in  
35 opposite direction of moving direction of the vessel, for therethrough to move the vessel forward.

The same air which is utilized for propulsion of the vessel will further rise up again from the water and by means of arrangement of means for catching this air it can be provided an air cushion between the hull of the vessel and the sea which reduces friction.

The present invention is preferably further arranged for reuse of the air which is trapped under the hull by conveying it from the air space under the hull and blowing it out again in the same way as described above at rear end of the hull.

For making the propulsion even more effective the present invention can include pulsation devices, which are arranged for pulsing the air which is used for propulsion.

For making the present invention even more energy effective it includes means for minimizing friction between the hull of the vessel and the sea. This can be achieved by that excess air from the air cushion provided under the hull is caught and let out again at sides of the hull, and at the bow.

Further preferable features and details of the present invention will appear from the following example description.

15

### Example

The present invention will below be described in more detail with references to the attached drawings, where:

Figure 1 is a principle drawing of a first embodiment of the present invention,  
Figure 2 is a principle drawing of means for catching air at rear end of the hull of the vessel,  
Figure 3 show different cross-sectional views of a vessel,  
Figures 4A-G show a first embodiment of a device for improving the efficiency of the propulsion of the vessel,  
Figures 5A-B show a second embodiment of a device for improving the efficiency of the propulsion of the vessel,  
Figures 6A-F show principle drawings of a hull for minimizing the friction between the hull and the sea according to the present invention,  
Figure 7 shows an alternative embodiment for supplying air to air channels, and  
Figures 8A-B show principle drawings of alternative embodiments for opening and closing air openings in air channels.

Reference is first made to Figure 1 showing a principle drawing of a first embodiment for air-driven propulsion of a vessel 100 of the present invention. The present invention is especially directed to a vessel 100 having a hull structure which corresponds to a multi-hull vessel, such as catamaran, trimaran, etc. Hull parts 101 of the vessel preferably exhibit an open channel 102 at

their lower end which is open against the sea, as e.g. shown in Figure 6E. The idea is based on collecting air at upper part of the vessel, pressurizing this air and utilizing it as propulsion by blowing this air out in the channel 102 of the hull parts which is open against the sea. This is achieved by that the air-driven vessel is provided with air inlet 11 arranged in a fan room 12 which  
5 collects air, which air further is pressurized/compressed by means of one or more powerful motors or air compressors (fans) 13. The pressurized air is next conveyed by means of one or more air channels or ducts 14 extending from the fan room 12 and down to the open channel 102 of the hull parts ending in an opening 15 where air is blown out under the sea surface 150 for providing propulsion of the vessel. The opening 15 is preferably arranged in approximately horizontal  
10 position in the longitudinal direction of the vessel, i.e. in opposite direction of the moving direction and thus moves the vessel forwards. E.g. it can be arranged nozzles at the ends 15 of the duct 14, or the air can be blown directly out.

This air will not only work as propulsion, but the air will also rise up again from the sea under the hull, and by capturing this air by means of a hull construction 20, arranged under the hull, one  
15 will be able to provide an air cushion under the hull which reduces the friction between the hull of the vessel and the sea, something which is called air lubrication. In this way the present invention provides energy effective propulsion of the vessel due to that the same air is used both as propulsion and for reducing friction.

The captured compressed air can also be reused and utilized for further propulsion of the  
20 vessel, which will be further described below. This can be achieved by that the vessel is provided with a hull construction 20 as shown in Figure 2. The hull construction 20 is as mentioned arranged for capturing the compressed air which is under the hull. The hull construction 20 includes for this one or more sealing means 21 for capturing the air under the hull and preventing it from escaping, e.g. to the side of the hull. The sealing means 21 are e.g. formed by rubber sleeves which by  
25 means of controllable means, such as piston/cylinder units, wire or similar 22, where these can be hydraulically or electrically/mechanically driven, for moving the sealing means 21 up towards or away from the hull of the vessel. In this way one can capture air present under the hull of the vessel such that it provides an air cushion under the hull. The same air can be conveyed further into one or more air channels or ducts 23 leading from an air space 24 created under the hull to  
30 the rear end of the hull, i.e. in front of the hull construction 20, and ends in an opening 25 in the open channel 102 of the hull parts, where the air is blown out below the sea surface 150 for providing the vessel with further propulsion. The opening 25 is preferably arranged in approximately horizontal position in the longitudinal direction of the vessel, i.e. in opposite direction of the moving direction and thus moving the vessel forwards. In the same way as above,  
35 the end of the duct 23 can be provided with nozzles or blowing the air out directly.

Accordingly, it is provided an air-driven vessel which firstly is using pressurized air for propulsion if the vessel, which air further rises up from the sea and provides an air cushion under the hull, which air again is reused for providing further propulsion.

One can further adapt the air space wall plate construction with a bow shape so that occurring  
5 adjustments of the hull construction 20 upwards or downwards do not result in wear and tear in the sealing means 21. The hull construction 20 can be controlled so that it with necessary force captures as much air as possible under the hull, and at the same time avoids resistance for propulsion of the vessel.

Reference is now made to Figure 3 which shows a cross-sectional view of the vessel 100  
10 according to the invention. The chassis or hull of the vessel can, according to the invention, be designed as a U-shape turned upside down or with different U-cross-section views as shown in Figure 3 by 30A, 30B, 30C, 30D, 30E and 30F, and similar, and combinations which can capture air in an air space 24 between the bottom of the hull and the sea. By means of the rear bow construction 20, a closed void is formed; limited by the hull parts and the sea surface, and the air  
15 inside this void will contribute to so-called air lubrication, something which greatly reduces the frictional resistance for the propulsion of the vessel in the sea.

Reference is now made to the Figures 4A-E showing a first embodiment of a device for improving the efficiency of the propulsion of the vessel 100. The device is arranged for pulsing and pumping the air backwards and into the sea as a jet motor.

20 The device is arranged for arrangement in the ducts 14 and alternatively 23, preferably at the ends 15 and 25, respectively, of the ducts 14, 23, but can also be arranged further into the ducts 14, 23. The device is based on a valve principle which opens and closes for the air which is let out of the ducts 14, 23 and therethrough provides a kind of pulsation which provides increased effect for the propulsion.

25 According to the first embodiment of this device it includes a first plate 40 (shown in detail in Figure 4B), which plate 40 is fixed in the duct 14, 23 and is provided with a number of holes 41 for letting air through, which plate 40 is arranged close to the opening 15, 25 of the ducts 14, 23. It further includes an opening and closing device 42 (shown in detail in Figure 4C), arranged inside the plate 40 (seen from the end 15, 25 of the duct 14, 23), which opening and closing device 42 is  
30 arranged with the same axis 43 as the first plate, and is provided with arms 44 and plates 45 adapted the holes 41, so that by rotation of the opening and closing device 42 it will open and close all the holes 41, alternating. The device further includes a plate 46 arranged inside the opening and closing device 42, as shown in Figure 4D, which plate 46 can have any shape so that it does not close the air passage out of the duct 14, 23. The plate 46 is preferably fixed to the duct  
35 14, 23 or the plate 40 and is preferably shaped as a hemisphere, and provided with openings/cuts

47 around the periphery which allows air to flow through and the plate 46 will contribute to improved pulsation force. The plate 46 will have the function that it ensures effective blowout due to the air on the way out is pushed by a hard base.

Accordingly, the rotation of the opening and closing device 42 will open and close the air  
5 passage through the duct 14, 23 and provide pressure increase at the backside of the device when the opening and closing device 42 is closing the holes 41 and a following expelling air pulse and jet-like force which provides improved effect of the propulsion of the vessel 100 in the sea when the opening and closing device 42 opens for the holes 41.

Rotation of the opening and closing device 42 can be performed by means of a motor 50  
10 arranged for controlling the pulsation frequency, as shown in Figure 4E, alternatively as shown in Figures 4F-G. In Figures 4F-G it is shown a solution where the opening and closing device 42 is driven by means of the air in the air channel 14, 23. In Figure 4F it is shown a curved duct 51 arranged between two circular plates which by means of air supply from the inside of the air outlet 52 in Figure 4G, can rotate and at the same time rotate the opening and closing device 42  
15 with it, which in turn opens and closes the holes 41, which results in that a pressurized air pulsation. A controllable closing valve 53 is preferably arranged for adjusting the air amount and pulsation frequency, as shown in Figure 4G.

As shown in Figure 4C the opening and closing device 42 preferably includes a ring 48 provided with small balls 49, see Figure 5B, working as a ball-bearing, arranged under the ring 48, resulting  
20 in that the opening and closing device can rotate or pivot steady with minimal distance from the base, so that the disc 45 of the opening and closing device 42 entirely or partly can close the air passage through the holes 41 of the plate 40.

Reference is now made to Figures 5A-B which show a second embodiment of a device for enhancing efficiency of the propulsion of the vessel 100. According to the second embodiment it  
25 includes a cylindrical body 70 provided with holes 71 which can be arranged in the ducts 14, 23. A rotating opening and closing device 72 provided with arms 73 and plates 74 adapted to the holes 71 is arranged inside the cylindrical body 70, which opening and closing device 72 is arranged for rotating in relation to the cylindrical body 70, and the plates 74 will alternately open and close the holes 71, and therethrough the above mentioned pulsating air force is achieved. The opening  
30 and closing device 72 can be driven in the same way as described for the opening and closing device 42. This alternative can also be modified so that the opening and closing device 72 is arranged on the outside of the cylindrical body 70 and is closing the holes 71 from the outside.

One can also arrange one or more ducts 60 with valves which extending to the atmosphere, see Figure 1, in the air space 24, so that one can empty the air space 24 in desired cases.

Above is described how one can move vessel forward by means of pressurized air at the front of the vessel, and capture air rising up again from the sea to form an air cushion under the vessel.

It is further described that the captured air can be utilized for providing further propulsion at the rear end of the vessel for therethrough to achieve higher propulsion force.

5       The present invention is best suited for a multi-hull vessel, such as a catamaran, trimaran or similar, seen from behind, i.e. the hull exhibits several hull parts 101 having side walls 111, 112 which are in the sea and the vessel is supported on.

Below will be described how one can reduce friction between the hull parts which are in contact with the sea.

10       The solution is as above to provide an air cushion between the hull parts 101 and the sea.

Reference is now made to Figures 6A-F showing principle drawings of a hull of a vessel 100 according to the present invention. The figures show how one utilize air rising up under the hull of the vessel to provide an air cushion between the hull of the vessel and sea, and similarly in the outer 111 and inner 112 walls of the hull parts 101, as shown in Figure 6C-F.

15       As mentioned and described above, air which is used for propulsion of the vessel will rise up again from the sea under the vessel and be captured under the hull due to the hull construction 20. According to the invention this air is utilized to reduce friction between the hull and the sea by providing an air cushion between the hull parts 101 and the sea, and between the bow and sea. For achieving this the walls 111, 112 of the hull parts 101 are provided with air openings 113 which  
20       will convey compressed air from the air space 24 under the vessel into a limited part 114 of the hull parts 101 over the open channel 102, between the walls 111, 112, as shown in Figure 6C. The air will further be conveyed out in the open channels 102 of the hull parts against the sea through openings 115 arranged between the limited part(s) 114 of the open channel 102 of the hull parts 101, as shown in Figure 6D.

25       In the open channels 102 is further arranged covers 116, as shown in Figure 6D, arranged to the openings 115 for guiding air which is conveyed through the openings 115 backwards along the entire vessel, as shown in Figure 6D.

In other words, when the air space 24 under the hull is filled with air as a result of the propulsion means described in Figures 1-5 and is rising again from the sea and captured by the hull  
30       construction 20, air will flow from the air space 24 and into the limited parts 114 of the hull parts 101 and filling them as a consequence of pressure from the vessel against the sea. This further results in that the air by means of the openings 115 and covers 116 are filling the open channels 102 with air and the excess air will flow out from the sides as shown in Figures 6A, 6C, 6D and 6E and thus provide an air cushion between the hull parts 101 and sea. Figure 6D is incidentally a

transparent illustration so that the open channels 102 and covers 116 in the practical design are not visible from the outside.

The open channels 102 of the hull parts 102 extend preferably the entire length along the lower part of the hull, preferably around the entire vessel and ensure that the vessel is encircled by an  
5 air cushion reducing the friction between the hull and sea water when the vessel is sailing and moving.

The open channels 102 can further preferably be closed at the rear end of the vessel, i.e. at the very rear end of the vessel.

As regards the bow of the vessel which first is in contact with the sea, it needs more air,  
10 something which is solved by arranging a mainly vertically extending air channel 117, which extends from below and up along the bow and follows the bow a distance under the water surface, as shown in Figures 6A and 6B, so that air is blown vertically down or up for providing an air cushion between the sea and the bow for reducing the resistance from the sea water.

In this case one can arrange air valves 118 up on the bow which can be closed if necessary.

15 In other words, the figures show how air flows into the limited parts 114 of the hull parts 101 through openings 115 along the entire hull, at both sides, and which is conveyed out in the open channels 102 of the hull parts through the openings 115 and covers 116, and which is further forced out from the open channels 102 and rising along the sides 120A-B of the walls 111, 112, inside and outside, for therethrough to provide an air cushion between the sea and the hull of the  
20 vessel.

For controlling this function it is preferably arranged a closing device 130, as shown in Figure 6F, in the form of a closing disc provided with openings 131 which is arranged over the openings 115, i.e. in the limited parts 114 of the hull parts 101. In this way one can by adjusting the closing device 130 adjust the air flow to the open channels 102 between entirely open, entire closed or a  
25 position between.

Reference is now made to Figure 7 which utilize springs 140, 141 arranged to one or more closing valves 142 arranged in a mounting point 143, either by use of one of the springs 140, 141 or by use of both, as an alternative to the prior shown embodiments, for controlling the outlet of air from the open channels 102 and possibly the vertical air channel 117. When one shall supply air  
30 for providing the air cushion around side walls positioned in the sea, the pressurized air from the means 13 will open the closing valve 142 to an open position 143 by means of the air pressure and thus let air out. When the pressure is removed the spring 140, alternatively the springs 140 and 141, will move the closing valve 142 to closed position again. The pressure from the sea water itself will also contribute to moving the closing valve 142 to closing position again.

In another embodiment the closing valve 142 is arranged to open and close for air to both the open channels 102 and the vertical air channel 117. If necessary it can be arranged a separate spring for opening and closing for air in the air channel 117.

5 In a further embodiment the springs 140, 141 are obeyed so that it is only the pressure from the sea water which moves the closing valve 142 back to closed position.

Reference is now made to Figures 8A-8B which show principle drawings of alternative embodiments for opening and closing of air openings 113 in the open air channels 102. According to this embodiment it is arranged means 150 for opening and closing the openings 113 which lead into the open air channels 102. The means 150 is e.g. formed by a closing disc 151 provided with  
10 openings 152, which closing disc 151 extends in longitudinal direction of the hull parts 101 and is movably arranged to the hull parts 101 by means of suitable fastening means 153, such as angle sections, for movement over the openings 113. The closing disc 151 is further provided with power means 160 which are arranged for moving the closing disc 151 forwards and backwards for therethrough to move the openings 152 over the openings 113 for opening and closing the  
15 openings 113 by moving the closing disc 151 so that the openings 152 do not cover the openings 113. E.g. the power means 160 can be a motor (not shown) provided with a shaft 161 having toothed wheels 162 co-operating with an area 163 provided with teeth on the closing disc 151. In this way one can open and close the air supply from the air space under the vessel to the air openings 113.

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### Modifications

In connection with long vessels it can preferably be arranged several re-use blow-outs in the longitudinal direction of the vessel. E.g. it can be arranged several hull constructions 20 capturing air at several places and which blows it out again 25.

25 The air-driven vessel can include several air inlets and several motors or pressure pumps (fans) for providing sufficient air amount for propulsion.

The air-driven vessel can further include separate air inlets, motors or pressure pumps (fans) for providing an air cushion around the hull of the vessel.

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## Claims

1. Method for propulsion of a vessel in the sea by means of air, which vessel includes a hull formed by several hull parts provided with channels being open against the sea, **characterized in** that the propulsion is provided by collecting air at part of the vessel being above the sea, pressurize this air and blowing it out below the sea level in the open channels of the hull parts, and providing an air cushion under the hull by capturing air rising again from the sea by means of a downwards extending hull construction arranged under the hull of the vessel.
2. Method according to claim 1, **characterized by** retrieving all or parts of the air forming the air cushion and use it for further propulsion of the vessel behind the hull construction.
3. Method according to claim 1, **characterized by** increasing the effect of the propulsion by alternating opening and closing for providing a pulsating blowout of the air.
4. Method according to claim 1, **characterized by** capturing air rising again from the sea or from the air cushion and using it for reducing friction between the hull and the sea by conveying it out in the open channels of the hull parts.
5. Air-driven vessel including a hull formed by several hull parts (101) which exhibit an open channel (102) at their lower end being open against the sea, **characterized in** that the vessel is provided with:
- means (11, 12) for collecting air at an upper part of the vessel being above the sea, means (13) for pressurizing this air, and means (14) for blowing the pressurized air out under a sea surface (150) in the open channels (102) of the hull parts, and
  - a hull construction (20) arranged for capturing air rising up from the sea for forming an air cushion under the hull of the vessel.
6. Air-driven vessel according to claim 5, **characterized in** that the vessel includes means (23) for retrieving all or parts of the air which is formed in the air cushion formed by the hull construction (20) and using this for further propulsion of the vessel behind the hull construction (20).
7. Air-driven vessel according to claim 5, **characterized in** that the vessel includes devices for increasing the effect of propulsion by alternating opening and closing for providing a pulsating blowout of the air for propulsion.

8. Air-driven vessel according to claim 5, **characterized in** that the vessel includes one or more air inlets (11) for capturing air in one or more fan rooms (13), and one or more motors or air compressors/fans (12) for pressurizing the air.

5 9. Air-driven vessel according to claims 5-8, **characterized in** that vessel includes one or more air channels or ducts (14) extending from the one or more fan rooms (13) and under the sea surface (150) in the open channels (102) of the hull parts, which air channels or ducts (14) end in an opening (15) arranged in approximately horizontal position in longitudinal direction of the vessel, in opposite direction of moving direction of the vessel for blowing out the pressurized air for  
10 propulsion.

10. Air-driven vessel according to claim 5, **characterized in** that the hull construction (20) includes one or more downwards extending bodies (21) arranged for movement towards and out from the hull of the vessel by means of controllable means (22) for capturing air rising up from the sea for  
15 forming an air cushion under the hull of the vessel.

11. Air-driven vessel according to claims 5-10, **characterized in** that the means (23) for retrieving air and providing further propulsion are formed by air channels or ducts extending for an air space (24) in front of the hull constructions (20) and ending in an opening (25) behind the construction  
20 (20), which opening (25) is arranged in approximately horizontal position in the longitudinal direction of the vessel, in opposite direction of the moving direction of the vessel.

12. Air-driven vessel according to claims 5-11, **characterized in** that the device for increasing the effect of the propulsion by alternating opening and closing for pulsating blowout of the air is  
25 arranged in the air channels or ducts (14, 23) and formed by:

- a first plate (40) firmly arranged in the air channel or duct (14, 23) and provided with a number of holes (41) for letting air through, and
- an opening and closing device (42) arranged with same axis (43) as the first plate (40), provided with arms (44) and plates (45) adapted to the holes (41), which opening and closing  
30 device (42) is arranged for rotation and therethrough alternating opening and closing of the holes (41).

13. Air-driven vessel according to claim 12, **characterized in** that the device for increasing the effect of propulsion by alternating opening and closing for pulsating blowout of the air for

propulsion further includes a plate (46) which exhibits openings/cuts (47) around the periphery which allows air passing through the plate (46).

14. Air-driven vessel according to claim 12, **characterized in** that the device for increasing the effect of propulsion by alternating opening and closing for pulsating blowout of the air for propulsion includes a motor (50) for rotating the opening and closing device (42) and at the same time adjusting the pulsation frequency.

15. Air-driven vessel according to claim 12, **characterized in** that the device for increasing the effect of propulsion by alternating opening and closing for pulsating blowout of the air for propulsion for rotating the opening and closing device (42) includes a bent duct (51) arranged between two circular plates which by means of air supply in the duct (14, 23) can rotate and at the same time rotating the opening and closing device with it.

16. Air-driven vessel according to claim 15, **characterized in** that the device for increasing the effect of propulsion by alternating opening and closing of the air for propulsion further includes a valve (53) controlling the air outlet amount and at the same time adjusts the pulsation frequency.

17. Air-driven vessel according to claim 7, **characterized in** that the device for increasing the effect of propulsion by alternating opening and closing for pulsating blowout of the air for propulsion is arranged in the air channels or ducts (14, 23) and is formed of:

- a cylindrical body (70) provided with holes (71),
- a rotating opening and closing device (72) arranged in or outside the cylindrical body (70),

which device (72) is provided with means (74) for alternating opening and closing of the holes (71).

25

18. Air-driven vessel according to claim 12, **characterized in** that it in connection with the opening and closing device (42) is arranged bearing means (48) so that it rotates steady and with minimal distance from the plate (40).

19. Air-driven vessel according to claim 5, **characterized in** that the walls (111, 112) of the hull parts (101) are provided with air openings (113) for accommodating air trapped under the hull by the hull construction (20) into a limited part (114) of the hull parts (101), and openings (115) for conveying this air out in the open channels (102) of the hull parts again for providing an air cushion between the hull and the sea.

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20. Air-driven vessel according to claim 19, **characterized in** that it in connection with the openings (115) are arranged covers (116) for guiding the air backwards in the open channels (102) along the entire vessel.
- 5     21. Air-driven vessel according to claim 19, **characterized in** that it in connection with the openings (115) is arranged a closing device (130) provided with openings (131) arranged for adjusting the air amount which is let out in the open channels (102) through the openings (115).
- 10    22. Air-driven vessel according to claim 5, **characterized in** that it includes a mainly vertically extending air channel (117) arranged in the bow of the vessel, which extends from the bottom and up along the bow and follows the bow a distance under the water surface, which air channel (117) is arranged for letting out air captured by the hull construction (20) in the front of the bow for providing an air cushion between the bow and the sea.
- 15    23. Air-driven vessel according to claim 19, **characterized in** that it in connection with the air openings (113) are arranged means (150, 160) for opening and closing the air supply to the open channels (102).

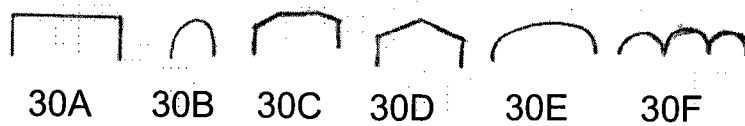
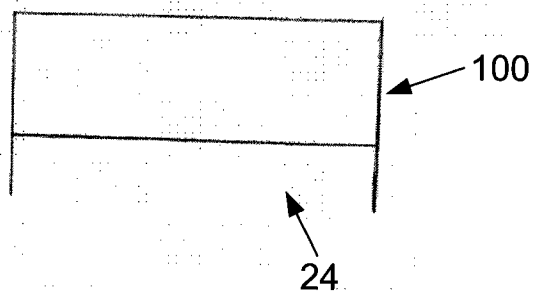
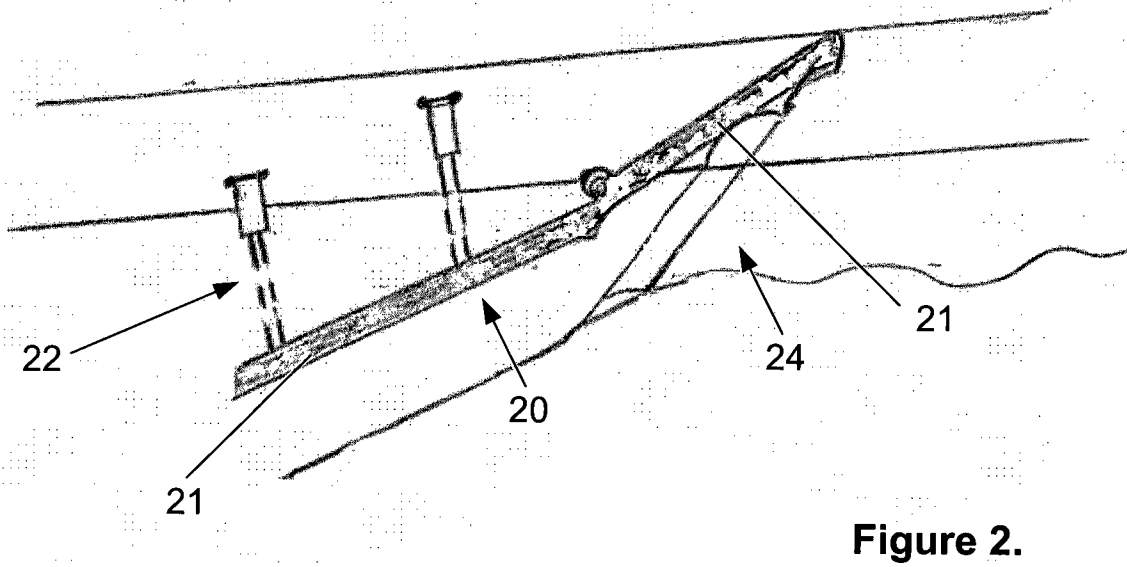
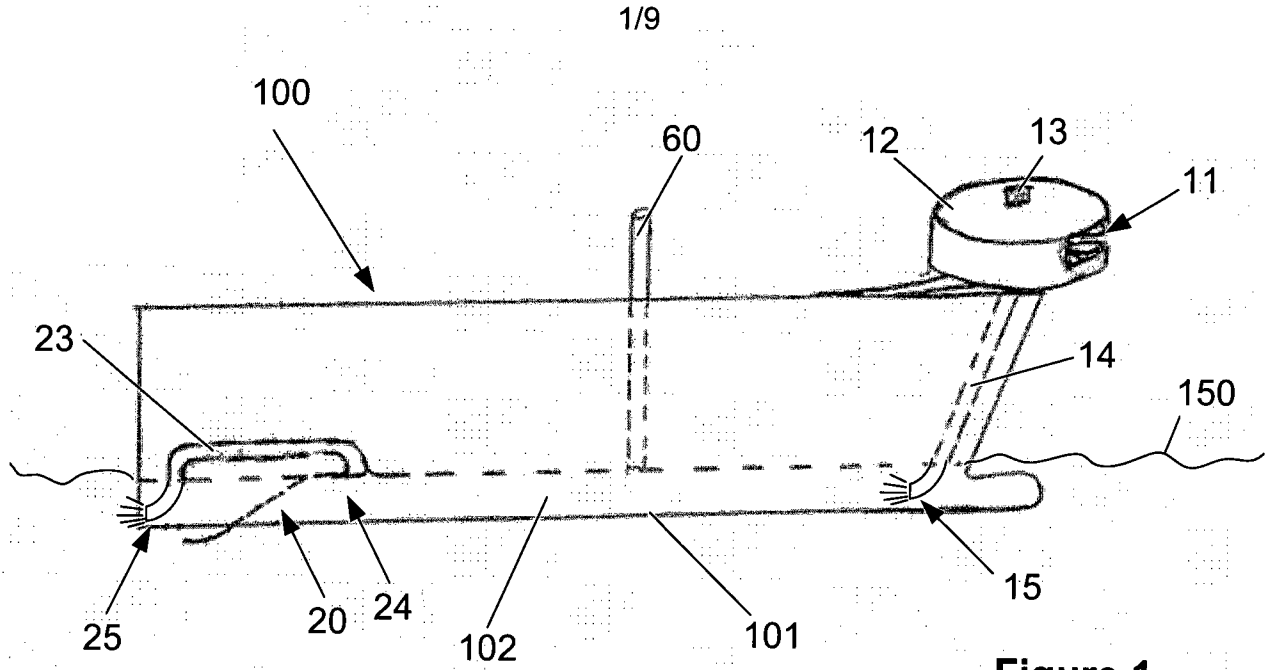


Figure 3.

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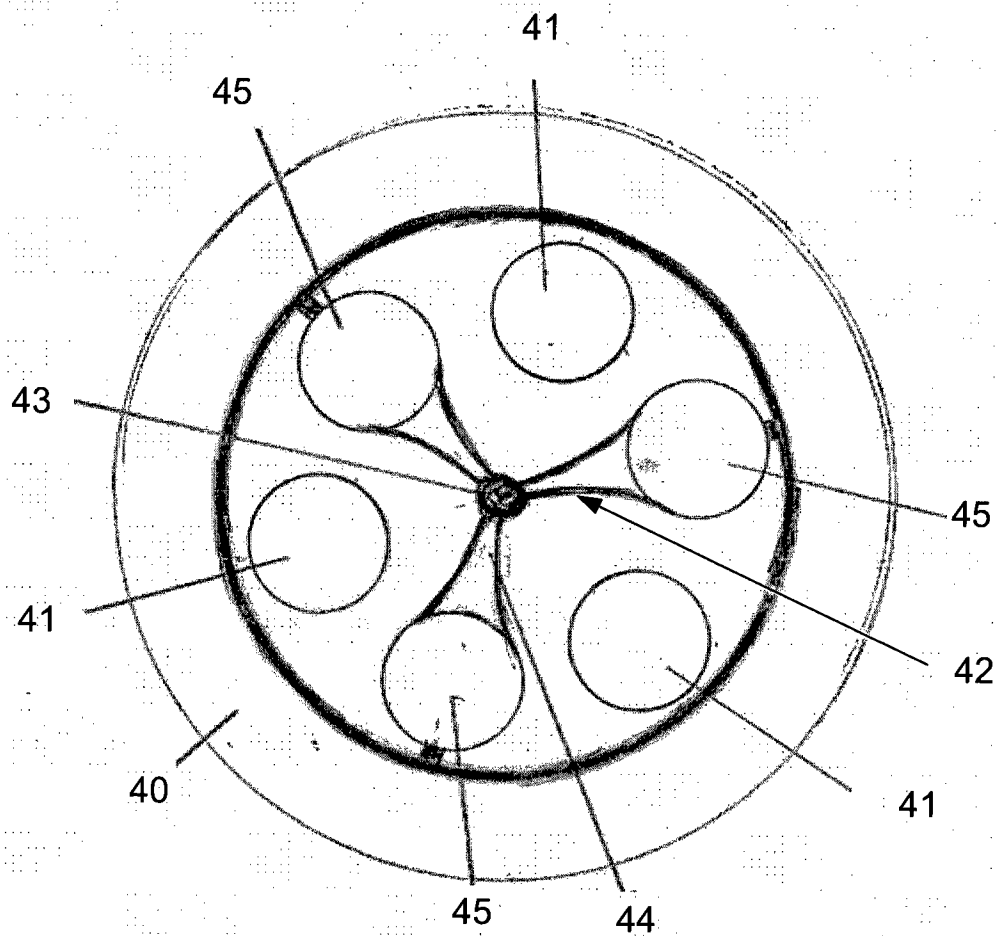


Figure 4A.

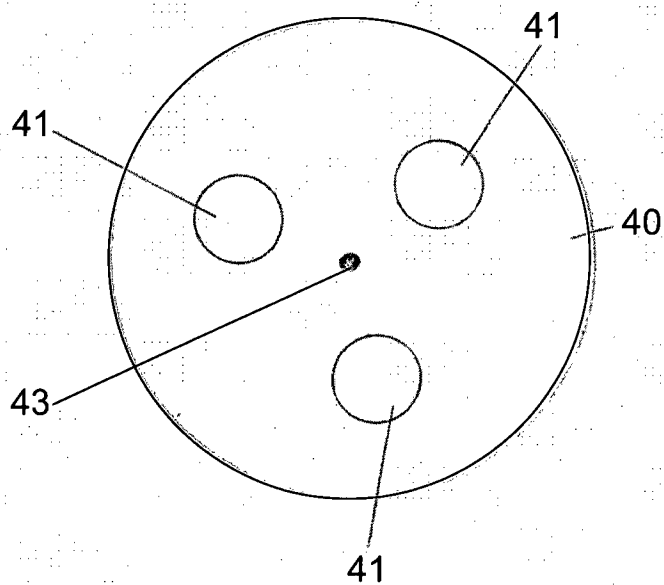


Figure 4B.

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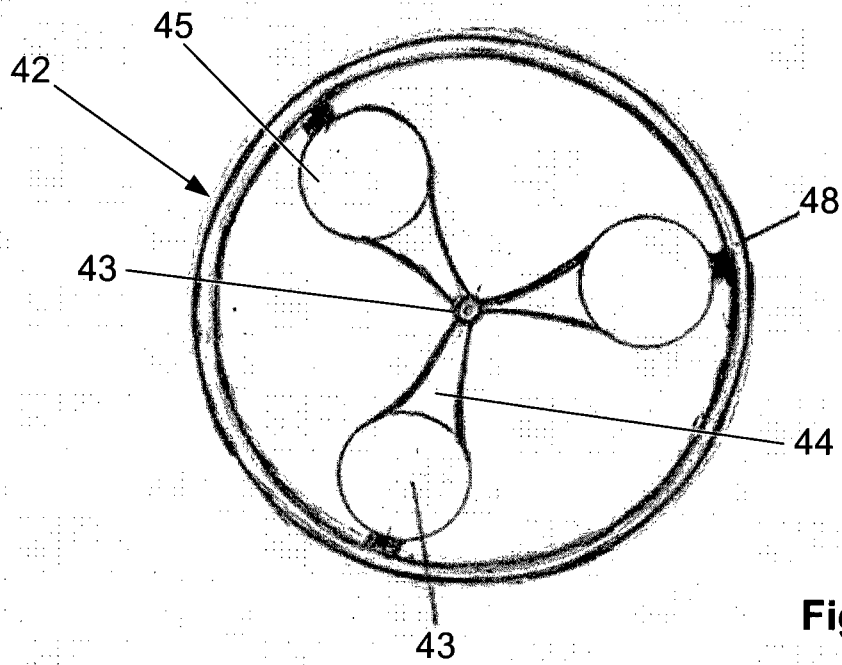


Figure 4C.

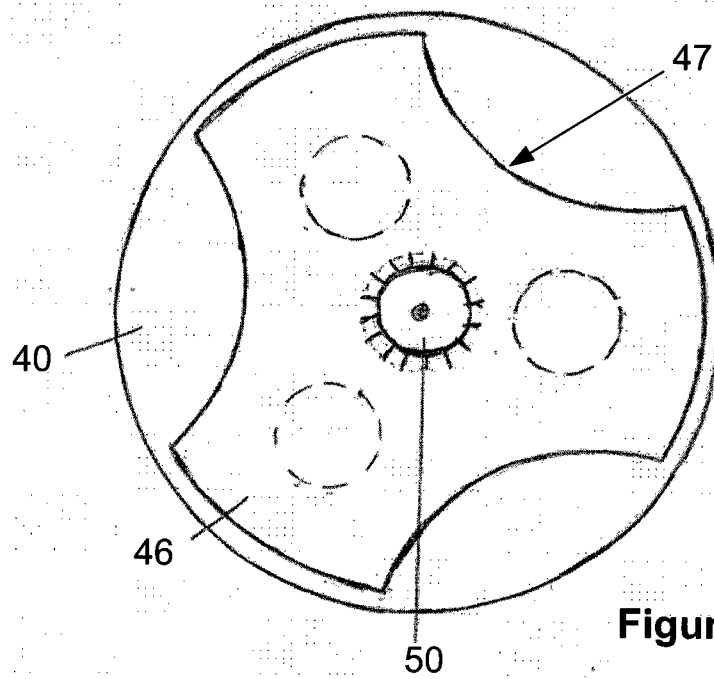


Figure 4D.

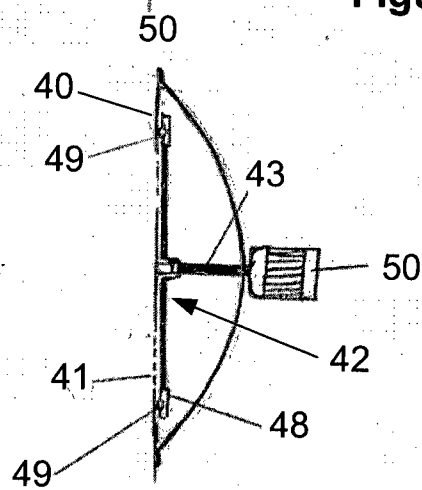
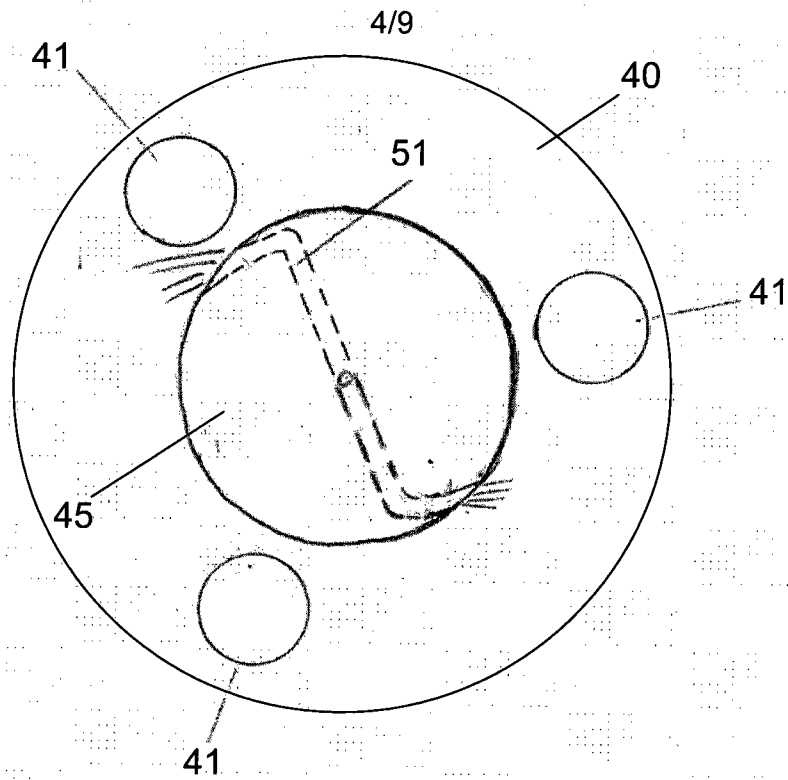
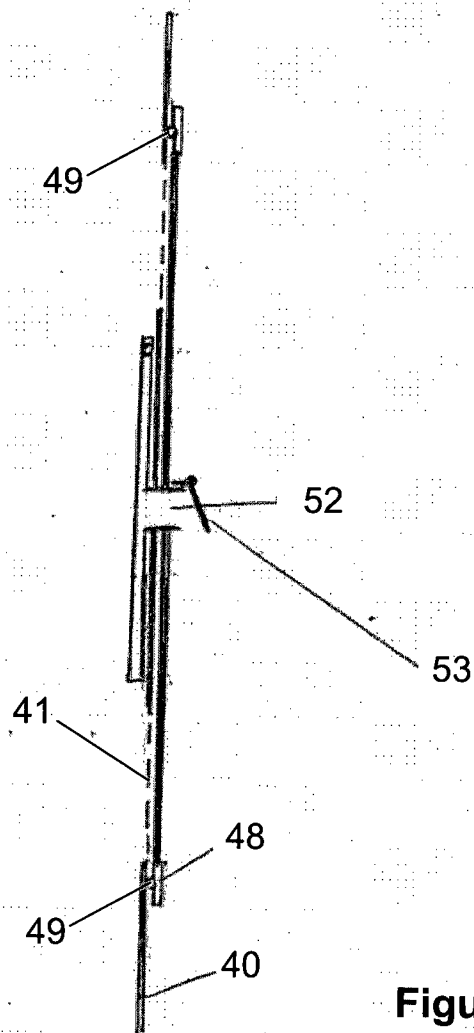


Figure 4E.

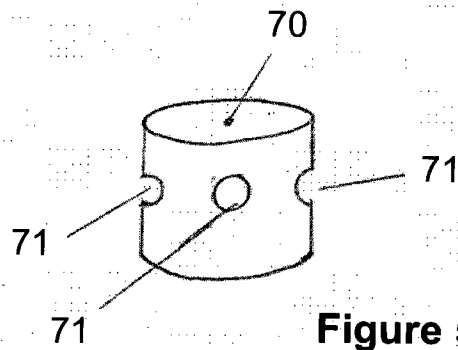


**Figure 4F.**

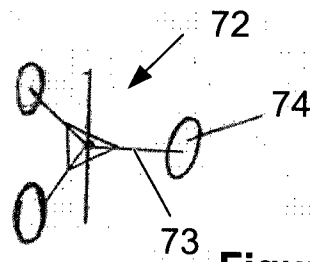


**Figure 4G.**

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**Figure 5A.**



**Figure 5B.**

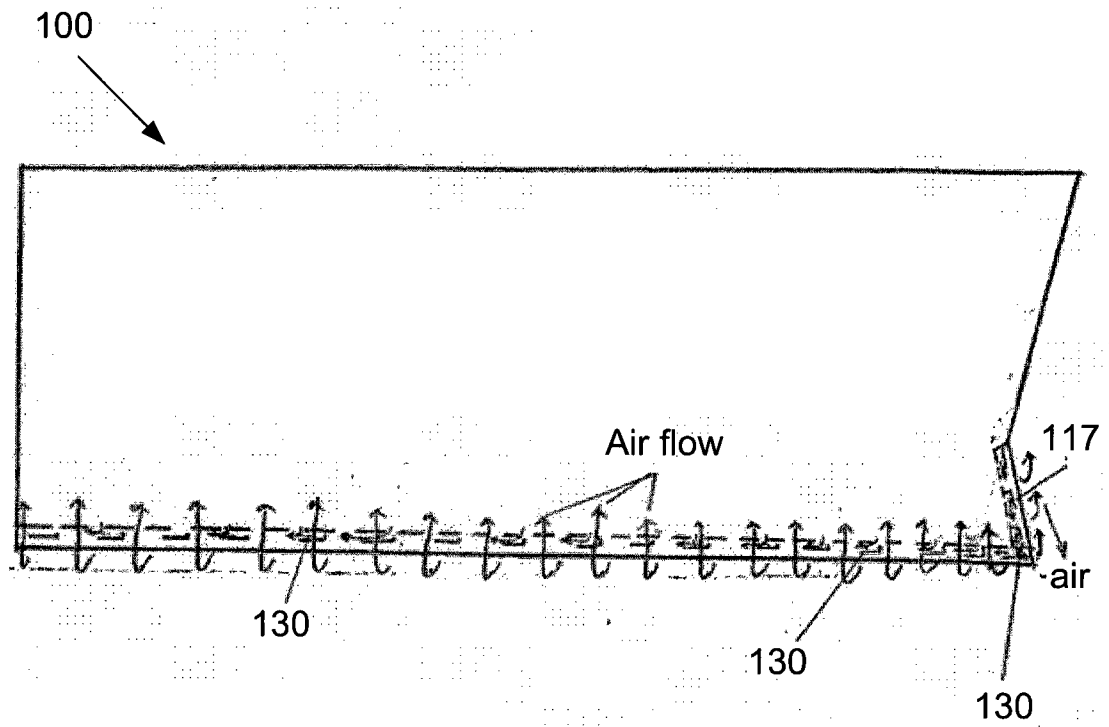


Figure 6A.

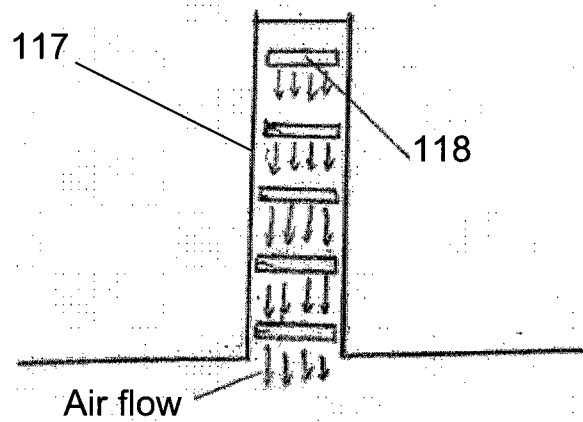


Figure 6B.

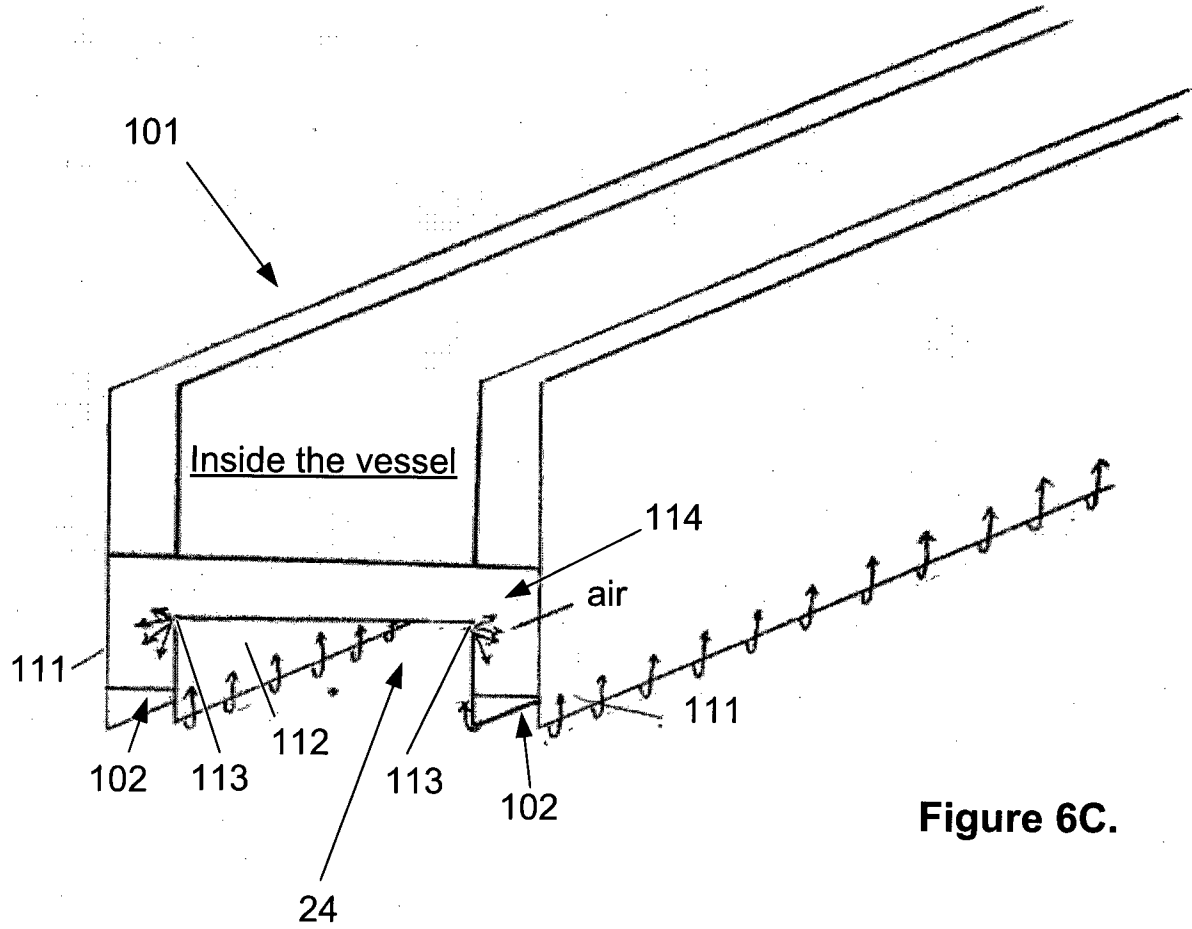


Figure 6C.

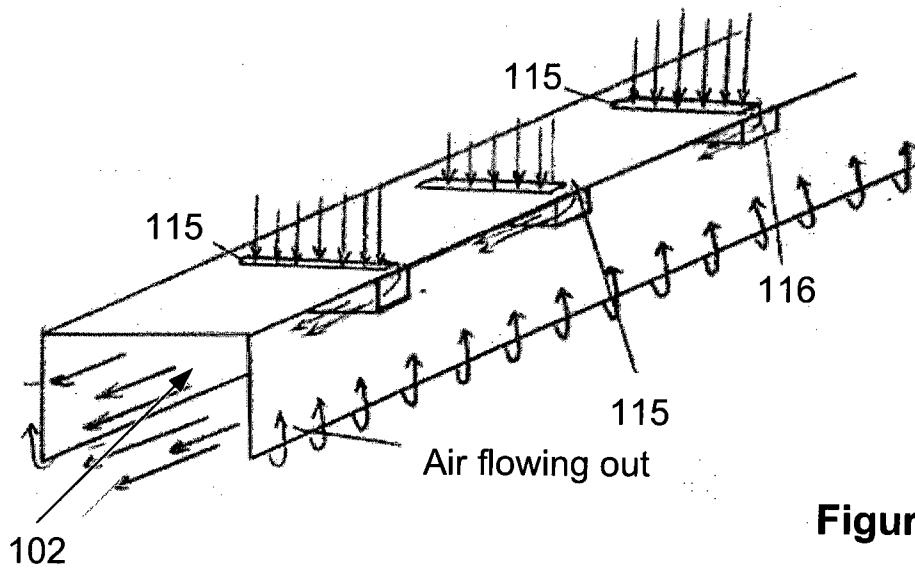


Figure 6D.

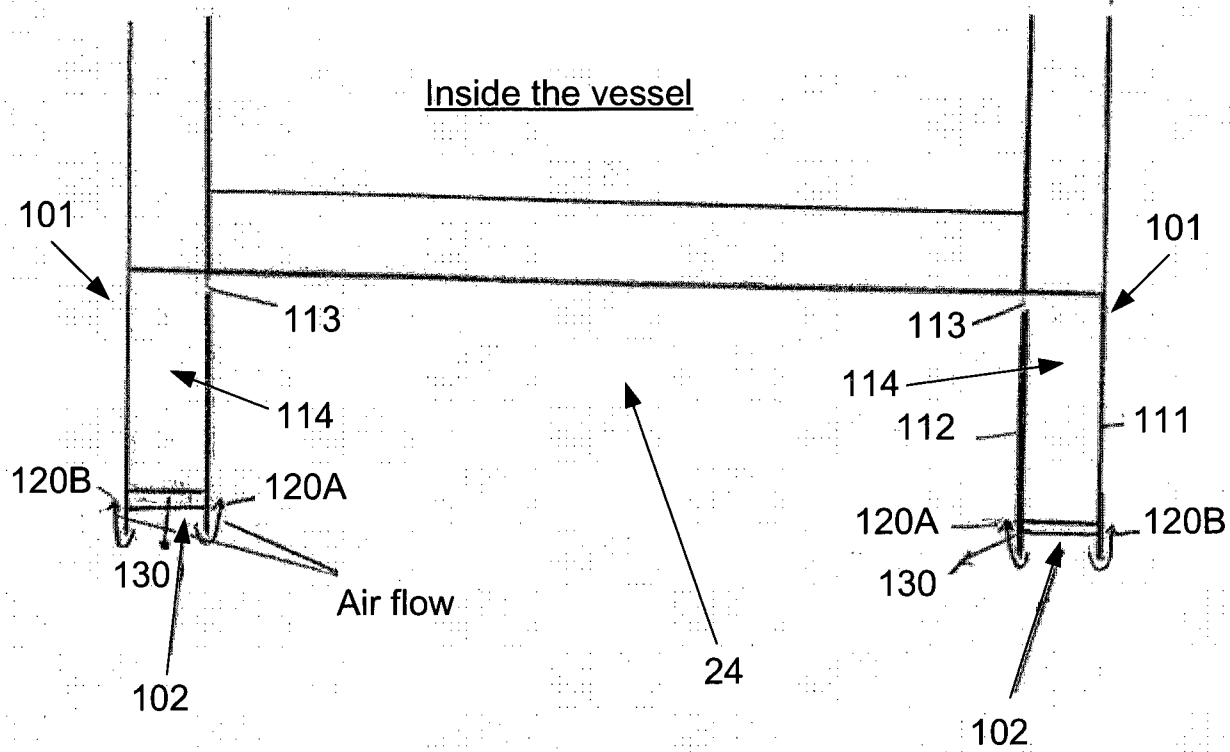


Figure 6E.

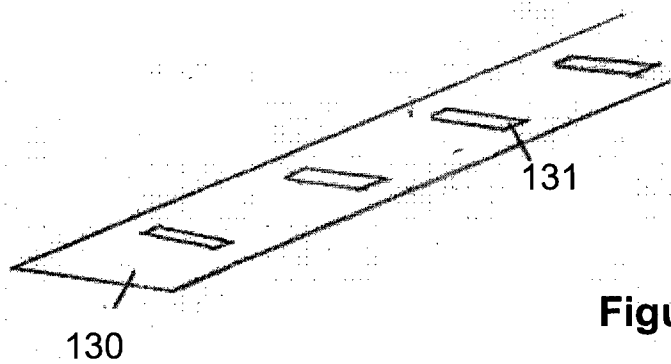


Figure 6F.

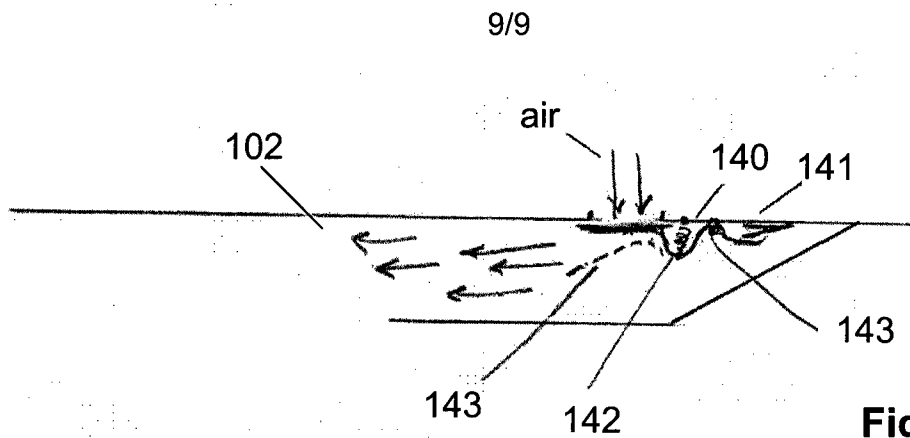


Figure 7.

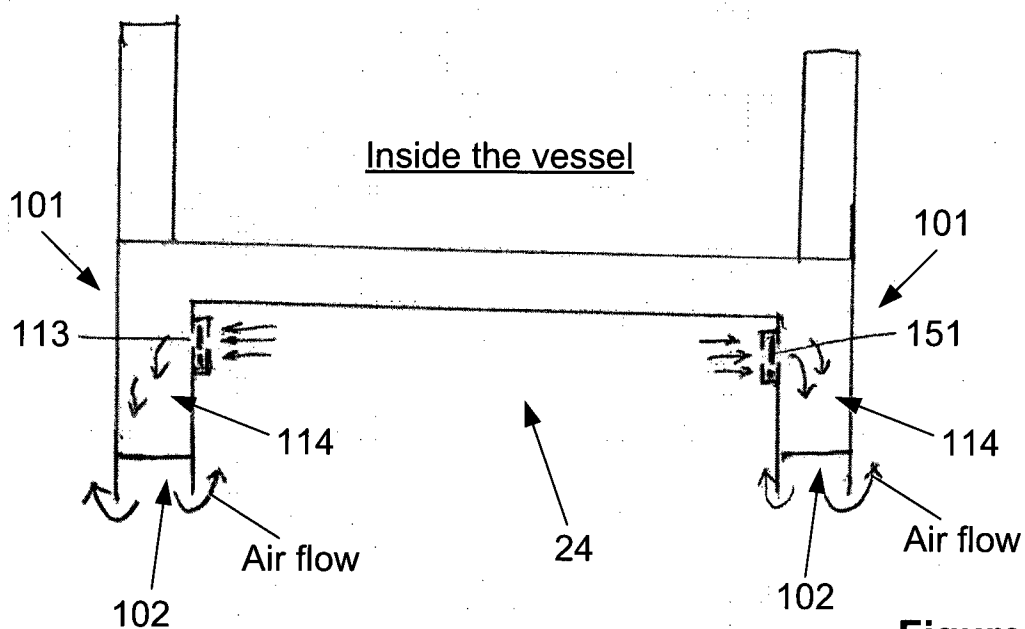


Figure 8A.

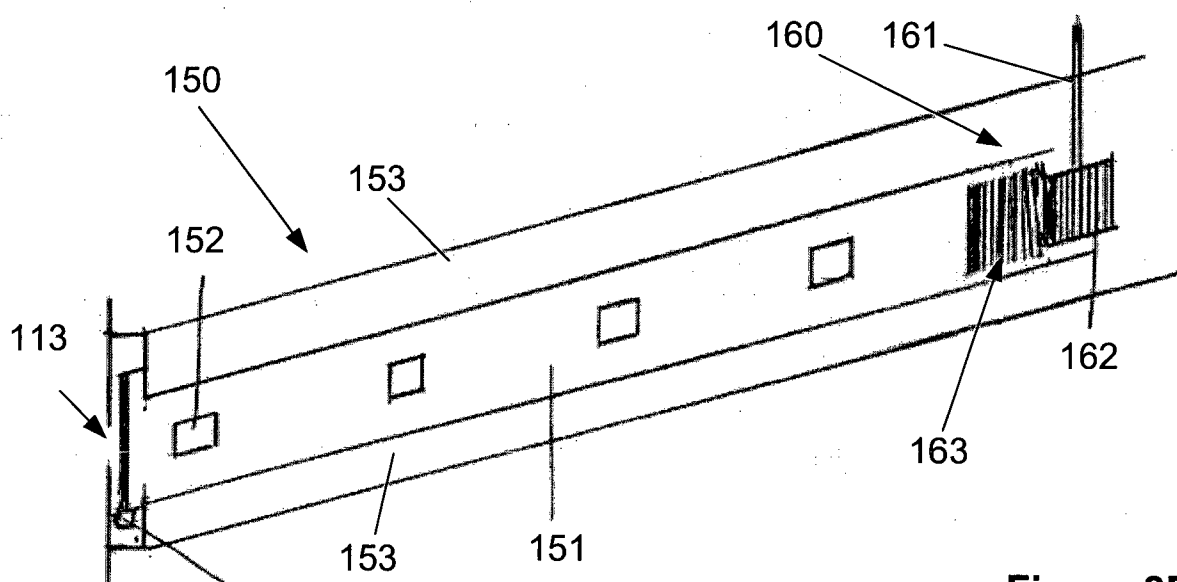


Figure 8B.

## INTERNATIONAL SEARCH REPORT

 International application No.  
 PCT/NO2013/050100

## A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: B60V, B63B, B63H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE, DK, FI, NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, PAJ, WPI data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                       | Relevant to claim No. |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| X         | US 608757 A (CULBERTSON, ANDREW J), 9 August 1898 (1898-08-09); page 1, line 46 - page 2, line 54; figures 1-4<br>--                     | 1, 4, 5, 8, 9         |
| A         | FR 1328413 A (CIRAUD, M PIERRE ALFRED), 31 May 1963 (1963-05-31); whole document<br>--                                                   | 1-23                  |
| A         | JP H068881 A (NISHIYAMA AKIRA), 18 January 1994 (1994-01-18); (abstract) Retrieved from: PAJ database; Original document: figure 1<br>-- | 1-23                  |
| A         | US 3198274 A (COCKSEGE GEORGE T), 3 August 1965 (1965-08-03); column 5, line 74 - line 44; figure 2<br>--                                | 1-23                  |



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&amp;" document member of the same patent family

Date of the actual completion of the international search

02-10-2013

Date of mailing of the international search report

03-10-2013

Name and mailing address of the ISA/SE

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## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/NO2013/050100

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                                                                         | Relevant to claim No. |
|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
| A         | US 5967071 A (WIPPER DANIEL J), 19 October 1999 (1999-10-19); abstract; column 11, line 17 - line 50; figures 1,3,15A,15B<br>--                            | 1-23                  |
| A         | US 5415120 A (BURG DONALD E), 16 May 1995 (1995-05-16); abstract; column 15, line 14 - column 16, line 32; figures 5,6<br>--                               | 1-23                  |
| A         | CN 101602361 A (NINGSHENG WANG), 16 December 2009 (2009-12-16); (abstract) Retrieved from: WPI database; Original document: figures 2,3,7,8<br>--<br>----- | 1-23                  |

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/NO2013/050100

## Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
2. ☐ Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
  
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

The following separate inventions were identified:

1: Claims 1, 2, 4-6, 8-11, 19-21 and 23 directed to a method for pneumatically propelling a vessel and a pneumatically propelled vessel where the air used to propel the vessel is recovered.

2: Claims 3, 7, 12-18, 22 directed to a method for increasing the effect of the pneumatic propulsion of a vessel and a vessel provided with means for increasing the effect of the pneumatic propulsion.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☒ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
  
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

### Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

**Continuation of:** second sheet**International Patent Classification (IPC)*****B63H 11/12*** (2006.01)***B63B 1/38*** (2006.01)

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/NO2013/050100

|    |             |            |      |              |            |
|----|-------------|------------|------|--------------|------------|
| US | 608757 A    | 09/08/1898 | NONE |              |            |
| FR | 1328413 A   | 31/05/1963 | NONE |              |            |
| JP | H068881 A   | 18/01/1994 | NONE |              |            |
| US | 3198274 A   | 03/08/1965 | NONE |              |            |
| US | 5967071 A   | 19/10/1999 | AU   | 745813 B2    | 11/04/2002 |
|    |             |            | AU   | 1616899 A    | 16/06/1999 |
|    |             |            | BR   | 9815163 A    | 03/10/2000 |
|    |             |            | CA   | 2310430 A1   | 10/06/1999 |
|    |             |            | CN   | 1280540 A    | 17/01/2001 |
|    |             |            | EP   | 1042161 A4   | 18/09/2002 |
|    |             |            | JP   | 2001524421 A | 04/12/2001 |
|    |             |            | NO   | 20002807 A   | 01/08/2000 |
|    |             |            | WO   | 9928180 A1   | 10/06/1999 |
| US | 5415120 A   | 16/05/1995 | NONE |              |            |
| CN | 101602361 A | 16/12/2009 | NONE |              |            |