

[54] **FLUID CUSHION MACHINES**

[72] Inventor: **Dominique Etienne Louis Pont**, Garches, France

[73] Assignee: **Societe D'Etudes et De Developpement Des Aeroglisseurs Marius Terrestres et Amphibies S.E.D.A.M.**, Paris, France

[22] Filed: **Oct. 15, 1970**

[21] Appl. No.: **81,050**

[30] **Foreign Application Priority Data**

Oct. 17, 1969 France6935675

[52] U.S. Cl.114/66.5 H

[51] Int. Cl.B63b 1/28, B63b 1/38

[58] Field of Search114/67 A, 66.5 H

[56] **References Cited**

UNITED STATES PATENTS

2,696,796 12/1954 Amster114/66.5 H

3,179,077 4/1965 Wai Po Loo114/66.5 H

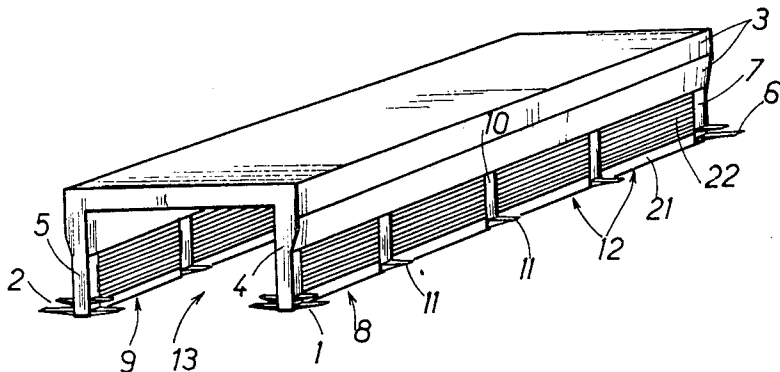
Primary Examiner—Andrew H. Farrell

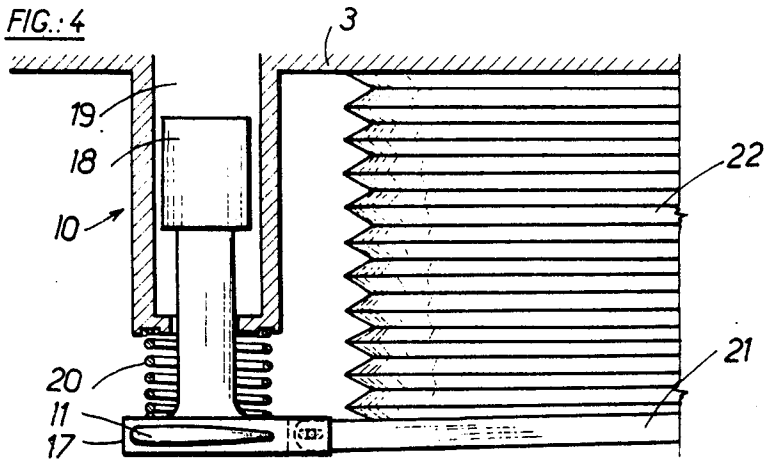
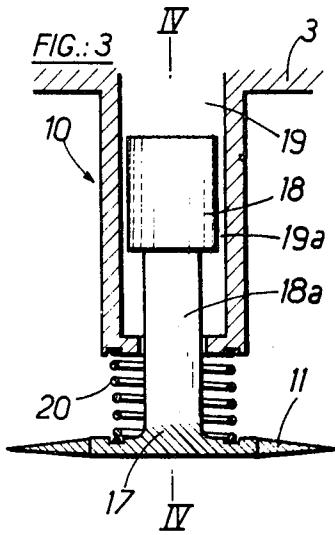
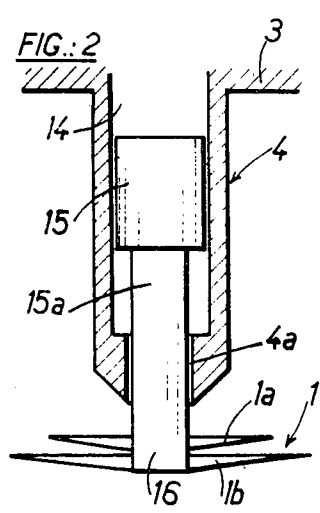
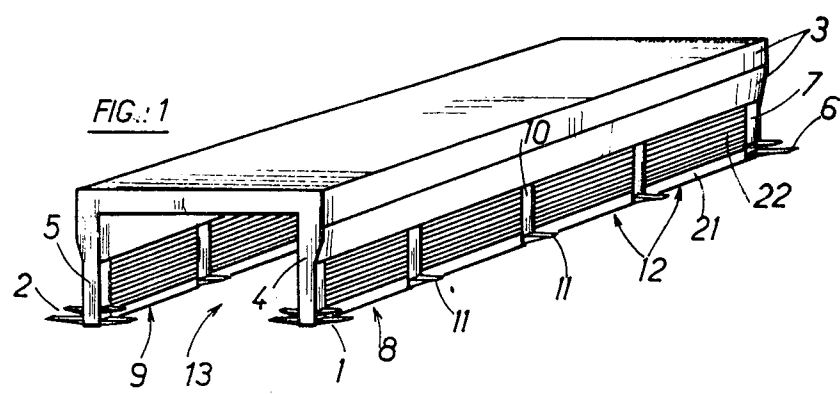
Attorney—Brufsky, Staas, Breiner & Halsey

[57] **ABSTRACT**

An air cushion vehicle adapted to move on the surface of water and comprising in combination stabilizing hydrofoils transmitting to the vehicle structure hydrodynamic lift forces co-operating with one or more fluid cushions to lift and stabilize the vehicle, and further hydrofoils which maintain the bottom edge of the lateral boundary walls for the fluid cushion near the water surface.

18 Claims, 9 Drawing Figures





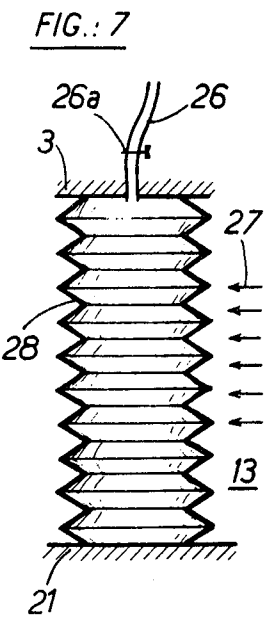
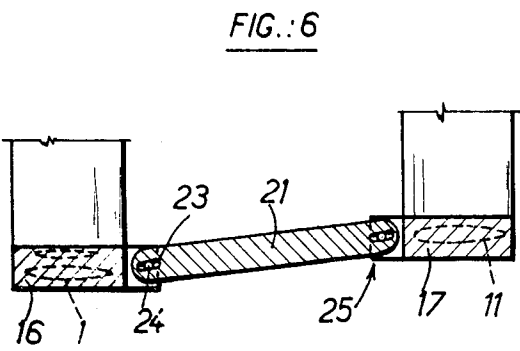
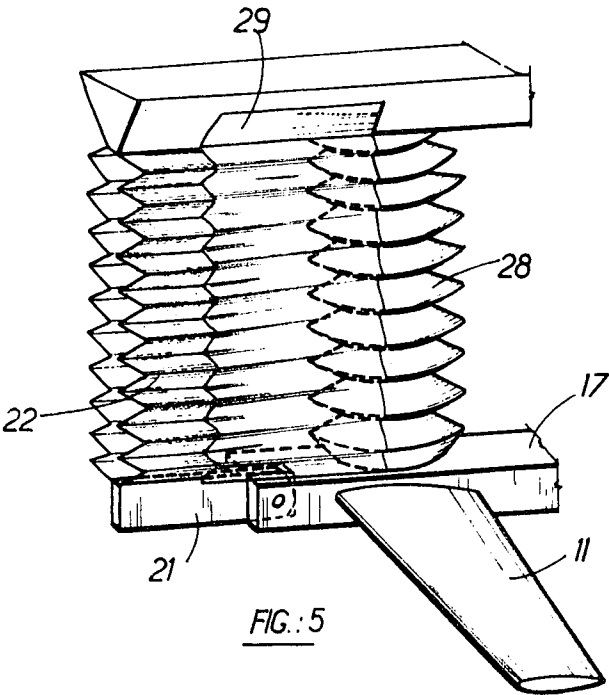


FIG. 8

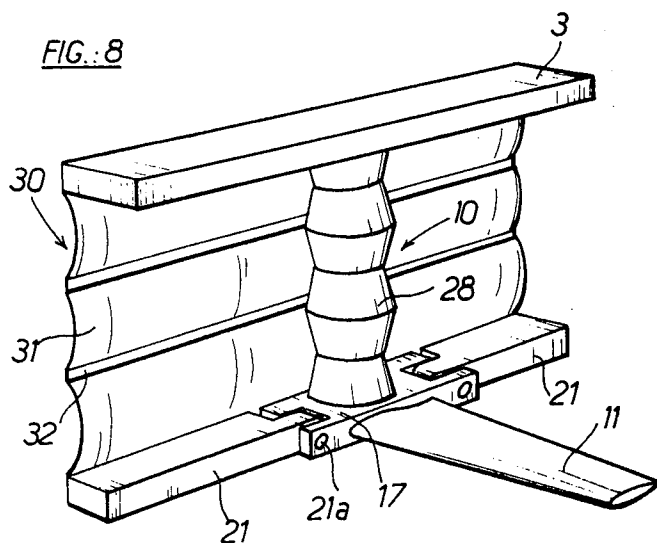
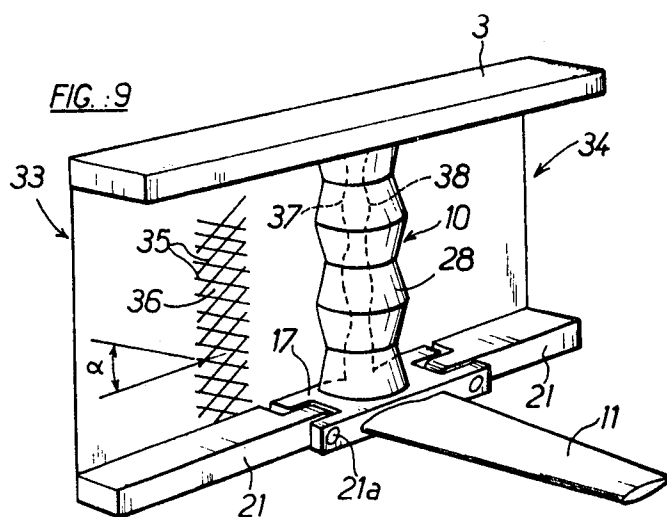


FIG. 9



FLUID CUSHION MACHINES

This invention relates to machines adapted to move over the surface of water and borne on one or more cushions of air or other pressure fluids, of the kind often called air cushion vehicles (ACVs) or ground effect machines. The invention applies more particularly to ACVs having lateral keels — i.e., of the kind in which the or each fluid cushion is bounded laterally by rigid or substantially rigid walls. However, the invention is also of use in flexible-skirt ACVs where the or each cushion is bounded laterally by flexible walls.

In lateral-keel type ACVs, some of the lift or buoyancy is derived from the hydrostatic and/or hydrodynamic forces acting on the keels, the bottom part of which dips some distance into the water. Such forces help or may help to stabilize the trim of the vehicle to the extent that any inclination thereof produces a restoring torque which opposes the torque causing the inclination.

Keel buoyancy is usually less economic than the buoyancy or lift provided by one or more fluid cushions — i.e., keel lift is offset by relatively heavy drag, the drag increasing in proportion as the surface of the water becomes rougher. Keel lift should therefore be the minimum compatible with satisfactory vehicle behavior, and the commonest practice is for keel lift to amount to 10 percent of total weight.

To reduce the drag of lateral keels in the water, it has already been suggested that ACVs be stabilized by foils similar to those used for bearing hydropters. Foils of this kind are slightly or partly immersed lift surfaces; their incidence can be controlled by known means and they can be given "dihedral" — i.e., they can be V-shaped — or they can be placed one above another ladder-fashion with some immersed and others not immersed — i.e., two or more such foils can be placed one above another so that when the keel goes lower in the water, the number of foils immersed increases and the lift or bearing surface therefore increases.

The use of bearing hydrofoils or foils has also been suggested for stabilizing flexible skirt type ACVs.

This invention is for improvements for providing optimum trim of the vehicle very economically at all speeds and for improving vehicle performances in rough sea conditions by reducing very considerably the wetted area of the lateral boundary walls of the or each fluid cushion without impairing the satisfactory sealing thereof.

According to the invention, stabilizing hydrofoils are used in combination with lateral boundary walls, at least the bottom edge of which comprises a number of longitudinal elements articulated so as to be able to move up and down and rotate around transverse axes, the elements being associated with bearing surfaces, called follower foils, which maintain them very near the water surface. These moving elements are connected to the vehicle structure by wall portions which allow them to move but provide continuous bounding.

The follower foils maintain the moving elements which form the bottom part of the lateral boundary walls in contact with the water or very slightly immersed therein. The follower foils are therefore not themselves required to provide hydrodynamic lift and are preferably thin-walled.

The stabilizing foils can be relatively long and be disposed on depending support members which are rigidly secured to the machine structure. They can be either stationary or vertically reciprocable and mounted on hydraulic actuators, enabling the pilot to adjust vehicle height and trim, and/or on springs which are, with advantage, associated with dampers to reduce the restoring torques which occur in rolling and pitching. Preferably, the stabilizing foils are disposed at the front and rear ends of the lateral boundary walls of the or each fluid cushion.

Preferably too, the follower foils are disposed on depending support members rigidly secured to the machine structure, with the interposition of a spring facility and, if required, of damping means. In their downwards and upwards movements, therefore, the follower foils move the elements of the bottom part of the boundary walls, which part therefore intimately fol-

lows the shape of the swell in an advantageous manner, rather as the wheels of a motor vehicle follow unevennesses of the road. The follower foils, since they have to withstand only reduced loads, are small. They can be very elongated and therefore be very satisfactory hydrodynamically.

The drag of the hydrofoils and follower foils is less than the drag of an ordinary rigid side wall and is little affected by the state of the sea. The vehicle experiences reduced accelerations and comfort is improved.

According to a first feature, the wall portions connecting the vehicle structure to the articulated elements forming the boundary wall bottom edge are bellows which are preferably inflated to a fluid pressure slightly above the cushion pressure.

According to a second feature, such wall portions are ordinary pieces of cloth secured to the vehicle structure, to the longitudinal articulated elements and possibly to the depending support members on which the follower foils or further hydrofoils are disposed. The elements of each fluid cushion boundary wall can take the form either of a single cloth which is continuous along the whole length of such wall, or of interrupted pieces of cloth secured to each depending support members.

Advantageously, the cloth or each piece of cloth has different elastic extensions vertically and horizontally, since increased vertical elasticity permits large movements for a moderate variation in cloth tension. However, horizontal elongation is not necessary. The cloth can be inter alia of the kind described in U.S. Pat. application to Faure et al. Ser. No. 870,543 of June 10, 1968 comprising a mattress of crossing filaments or cables each forming an angle of less than about 35.4° with the horizontal, and a covering to seal and protect the cloth, such covering being either rigidly secured to or just fitted to the mattress. The cloth can also be of the kind described in U.S. Pat. application to Delamare Ser. No. 822,595 of May 7, 1969 with an impervious flexible diaphragm and a number of spaced flexible ferrules or hoops or bands or the like disposed in horizontal planes.

The inflated bellows of the first embodiment have inherent suspension characteristics (stiffness, damping) which combine with the suspension characteristics of the further hydrofoils to form a kind of coupling which may in some cases impair the quality of vehicle suspension. One of the advantages of the second embodiment is to reduce the inevitable coupling between the suspension characteristics of the further or follower hydrofoils and the suspension characteristics of the remainder of the wall.

The following description, taken together with the accompanying exemplary non-limitative drawings, will show clearly how the invention can be carried into effect.

In the drawings:

FIG. 1 is a diagrammatic perspective view to a reduced scale showing an ACV having an improvement according to the invention;

FIG. 2 is a partial diagrammatic view in cross-section showing a system of stabilizing hydrofoils and the bottom part of the depending support member to which such system is fitted;

FIG. 3 is a partial diagrammatic view in cross-section showing a follower or further hydrofoil and the bottom part of the depending support member on which such hydrofoil is disposed;

FIG. 4 is a diagrammatic view in partial section on the line IV—IV of FIG. 3 showing a first embodiment of the wall portions;

FIG. 5 is a detail view in perspective showing how sealing-tightness is achieved between a wall portion of FIG. 4 and a depending support member for a follower hydrofoil;

FIG. 6 is a view in section showing the connection between a bottom wall portion element and the adjacent follower foils;

FIG. 7 is a view in cross-section of bellows used for the embodiment shown in FIG. 4;

FIG. 8 is a detail perspective view, similar to FIG. 5, showing a second embodiment of the wall portions, and

FIG. 9 is a view similar to FIG. 8 showing modifications.

FIG. 1 is a diagrammatic view of an air cushion vehicle (ACV) of which only the structure, the stabilizing foils (hydrofoils) and the support air cushion bounded laterally by walls having follower foils (further hydrofoils) are shown. The propulsion facilities and the facilities for supplying the air cushion and bounding the same at front and rear are not shown; they are familiar and it therefore do not need to be illustrated and described in detail.

Two stabilizing hydrofoil systems 1, 2 are borne at the front of structure 3 by two depending support members 4, 5 respectively. Two other stabilizing hydrofoil systems, as 6, are borne at the rear of structure 3 by two depending support members, as 7. Other depending support members each bearing follower foils (further hydrofoils) 11 subdivide each of lateral walls 8, 9 into a number of sections 12. A space 13 below structure 3 is bounded laterally by the walls 8, 9 and at the front and rear by walls which are not shown and is supplied with compressed air by the cushion energization facility (not shown), so that when the ACV moves over water the air cushion produced in space or chamber 13 provides most of the lift for the vehicle. As will be described hereinafter, the foils provide the remainder of the lift hydrodynamically, help in stabilization and maintain the bottom edge of the side walls 8, 9 very near the water surface.

FIG. 2 is a view in greater detail of the hydrofoil system 1 and its arrangement on member 4. In member 4 is an actuator cylinder 14 and, movable therein, a piston 15 whose rod 15a has at its end a widened part 16 bearing the foils 1a, 1b. As FIG. 2 shows, the integers 1a, 1b are disposed ladder-fashion.

FIG. 3 is a diagrammatic view showing how a follower foil 11 is disposed on its depending support member 10. Foil 11 is mounted on a widened part 17 at the end of rod 18a of a damping piston 18 movable in a damping cylinder 19 contrived in member 10. A compression spring 20 is interposed between member 17 and the end of member 10. This damped resilient suspension is shown diagrammatically, the damping function being represented by a clearance 19a between the piston 18 and the oil-filled cylinder 19. The resilient suspension can of course be embodied by any appropriate means.

The actuator 14, 15, 15a is diagrammatically shown in FIG. 2, the inset end 4a of member 4 serving to guide the piston rod 15a. Means (not shown) are provided to distribute pressure fluid to the cylinders 15 of the members 4, 5, 7 so that the pilot can vary the distance between the structure 3 and the stabilizing foil systems 1, 2, 6 and thus, as will be described hereinafter, adjust the trim of the vehicle.

Instead of being rigidly secured to rod 15a, the member 16 could be connected thereto by a resilient suspension with or without damping. No such suspension is shown but it could be something like what is diagrammatically shown in FIG. 3.

Each wall section 12 has a moving bottom element 21 which is connected to structure 3 by a wall portion 22 to be described hereinafter. Each element 21 is articulated at front and rear to the two members 16 or 16 and 17 bearing the adjacent foils. FIG. 4 shows an element 21 articulated at the front to a member 17, FIG. 5 shows an element 21 articulated at the rear to a member 17, and FIG. 6 shows an element 21 articulated at the front to the member 16 bearing the hydrofoils 1 and at the rear to the member 17 bearing the adjacent follower foils 11.

As these figures show, the elements 21 are thin-walled — i.e., they are narrower than the members 16, 17, which must be strong enough to bear the foils. The reason for this is that the only function of the elements 21 is to form the bottom edge of the wall portions 12 which, as will be described hereinafter, is maintained very near the water surface by the foils 11. Each element 21 is formed at front and rear with an oval aperture 23 receiving a spindle 24 borne by a yoke 25 of the adjacent member 16 or 17. Each element 21 can therefore follow the upwards and downwards movements of the adjacent members 16 or 16 and 17 by rising or descending and/or rotating around instantaneous axes of rotation which extend transversely of the vehicle.

In FIGS. 4, 5 and 7 the wall parts 22 are embodied by bellows. The bellows are each connected to an on-board compressed air source (not shown) by means represented diagrammatically in FIG. 7 by a hose 26 having a valve 26a. An air pressure slightly above the pressure of the air cushion 13 can therefore be maintained in the bellows 22. The bellows are therefore not excessively distorted by the pressure applied to them by the air cushion — the latter pressure being indicated diagrammatically by arrows 27 — but there is no hampering of the movement of the elements 21.

FIG. 5 also shows how sealing-tightness can be achieved between the ends of the bellows 22 and the depending support members 4, 5, 7, 10. Each member 4, 5, 7, 10 has around it circular-section bellows 28 connecting the member 16 or 17 to structure 3, and sealing-tightness is achieved by means of an accordion-pleated sheet 29 stuck or sewn to a wall of the bellows 22 and 28. Another similar sheet can be provided on the other surface.

When the vehicle moves over water most of its lift is provided by the air cushion 13, and the movement of the foils 1, 2, 6 in the water produces hydrodynamic lift at the front and rear of the vehicle. The pilot can therefore control the machine height and trim by means of the actuators 14, 15. The follower foils 11 also experience lift forces by hydrodynamic effect and so follow the shape of the swell, rising and falling relatively to the members 10. However, their rises and falls are damped by the suspensions 18–20 which transmit the lift forces to the structure 3; the follower foils 11 therefore contribute towards vehicle lift but only slightly since they are very small in relation to the lift provided by the air cushion and the stabilizers. The elements 21 follow the movement of the foils 11 and the bellows 22 deform to allow the elements 21 to move, so that the bottom edges of the wall sections 12 also follow the swell "profile." Excellent bounding of the air cushion is therefore achieved without entailing considerably variations, which would cause drag, of the immersion of the side walls.

The embodiment described is of course only one example and can be modified, inter alia by the use of technical equivalents, without for that reason departing from the scope of the invention as defined in the claims. More particularly, the bellows-like wall portions 22 forming a kind of lateral keel which is not free of any transverse movement could be replaced by a more complex skirt system interconnecting the depending support members and the follower foils. They can also be replaced by ordinary cloths, for instance, on the basis of one of the features now to be described with reference to FIGS. 8 and 9.

Referring to FIG. 8, the lateral wall or partition is embodied between its top edge 3 and its bottom edge 17, 21 by a cloth 30 whose top edge is secured to the structure 3, whose bottom edge is secured to the elements 21 and whose front and rear edges are secured to the depending support members which bear the hydrofoils. Along the lines of the disclosure in U.S. Pat. application to Delamare Ser. No. 822,595 of May 7, 1969, the cloth 30 has a diaphragm 31 and flexible straps 32 disposed horizontally on the diaphragm outside surface.

In the embodiment shown in FIG. 9, the flexible part of the lateral partition between the top edge 3 and the bottom edge 17, 21 comprises a number of cloth pieces, as 33, 34, each devised as disclosed by U.S. Pat. application to Faure et al. Ser. No. 870,543 of June 10, 1968, with a mattress 35 of crossed filaments forming angles α of less than about 35.4° with the horizontal, and a sealing covering or protection in the form of a flexible diaphragm 36. So as to simplify the drawing, the mattress is shown for only some of the cloth. Each piece of cloth is secured at the top to the structure 3 and at the bottom to an element 21 and its vertical edges are secured at places 37 and 38 to the bellows 28 which extend around the depending support members.

Nor would the scope of the invention be exceeded if the follower foils and the moving or deformable wall sections were to be associated with stationary non-vertically-adjustable

hydrofoils or with hydrofoils connected to the vehicle structure by a simple resilient suspension or by a damped resilient suspension.

I claim:

1. An air cushion vehicle (ACV) or like ground effect machine adapted to move over the surface of water and comprising : (1) a substantially horizontal structure ; (2) stabilizing hydrofoils connected to the structure to transmit thereto hydrodynamic lift forces adapted to contribute to lift and stabilize the ACV ; (3) means for producing and bounding fluid cushions, including lateral boundary walls each comprising : (a) a number of elongated elements forming a bottom edge ; (b) articulation means between the elongated elements such that the same can move substantially vertically up and down and can rotate around axes transverse of the structure ; and (c) wall portions connecting the structure to the elongated elements to make the bounding means continuous, such wall portions being adapted to allow the elongated elements to move ; and (4) further hydrofoils associated with the elongated elements to transmit hydrodynamic lift forces thereto so as to maintain the elongated elements near the water surface.

2. An ACV according to claim 1 wherein the elongated elements are relatively thin and the further hydrofoils are secured to relatively thick members articulated to the elongated elements.

3. An ACV according to claim 1 comprising depending support members rigidly secured to the structure, and means for securing the stabilizing hydrofoils to the depending support members in vertically adjustable manner.

4. An ACV according to claim 1 comprising resilient suspension means for the resilient suspension of the stabilizing hydrofoils on the structure.

5. An ACV according to claim 4 wherein the resilient suspension means comprise damping means.

6. An ACV according to claim 1 comprising depending support members rigidly secured to the structure and resilient suspension means for the resilient suspension of the further hydrofoils on the depending support members.

7. An ACV according to claim 6 wherein the resilient suspension means comprise damping means.

8. An ACV according to claim 1 wherein the further hydrofoils are rigidly secured to members adapted to move vertically relatively to the structure, comprising pivot spindles engaging in oval apertures for the articulation of the elongated elements to the last-mentioned vertically movable members.

9. An ACV according to claim 8 wherein the stabilizing hydrofoils are rigidly secured to other members adapted to move vertically relatively to the structure, comprising pivot spindles engaging in oval apertures to articulate the elongated elements to the said other members adapted to move vertically.

10. An ACV according to claim 1 wherein the wall portions comprise bellows.

11. An ACV according to claim 10 comprising means for inflating the bellows to a fluid pressure slightly above the pressure of the fluid cushion.

12. An ACV according to claim 10 comprising depending support members for bearing the hydrofoils, further bellows extending around the depending support members, and accordion-pleated sheets to provide a sealing-tight connection of the bellows to the said other or further bellows.

13. An ACV according to claim 1 wherein the wall portions are simple cloths.

14. An ACV according to claim 13 wherein the elements of each side wall are made of a cloth which is continuous right along such wall.

15. An ACV according to claim 13 comprising depending support members for bearing the hydrofoils, wherein the wall elements are pieces of cloth secured to two adjacent depending support members.

16. An ACV according to claim 13 wherein the cloths have different elastic extension vertically and horizontally.

17. An ACV according to claim 16 wherein the cloths have a mattress of crossed filaments or cables each forming an angle of less than about 35.4° with the horizontal, plus a hermetic covering or protection or the like.

18. An ACV according to claim 16 wherein the cloths have an impervious flexible diaphragm and a number of spaced flexible hoops or bands or ferrules or the like disposed in horizontal planes.

* * * * *

45

50

55

60

65

70

75

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,661,110 Dated May 9, 1972

Inventor(s) Dominique Etienne Louis PONT

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the heading, [73] Assignee, "Marius" should read -- Marins --.
Column 4, line 36, "considerably" should read -- considerable --.

Signed and sealed this 5th day of March 1974.

(SEAL)

Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents