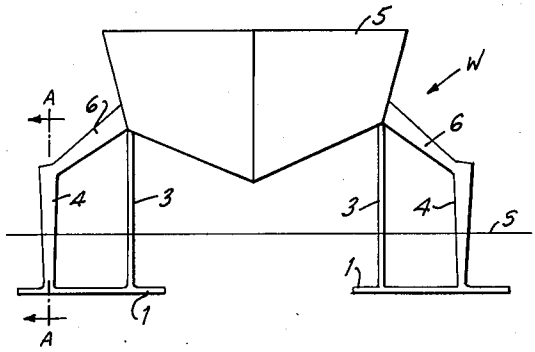
Sept. 10, 1963 H. VON SCHERTEL 3,103,197

AUTOMATIC HYDROFOIL CONTROL SYSTEM FOR WATERCRAFT

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FIG. 1



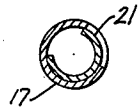


FIG. 4a

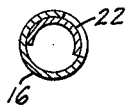
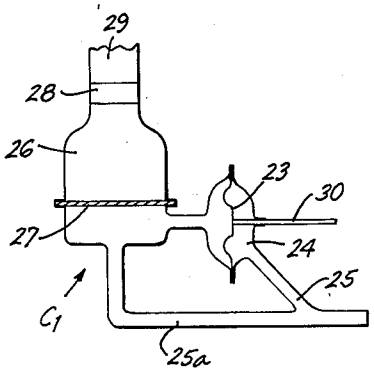


FIG. 4b

FIG. 5



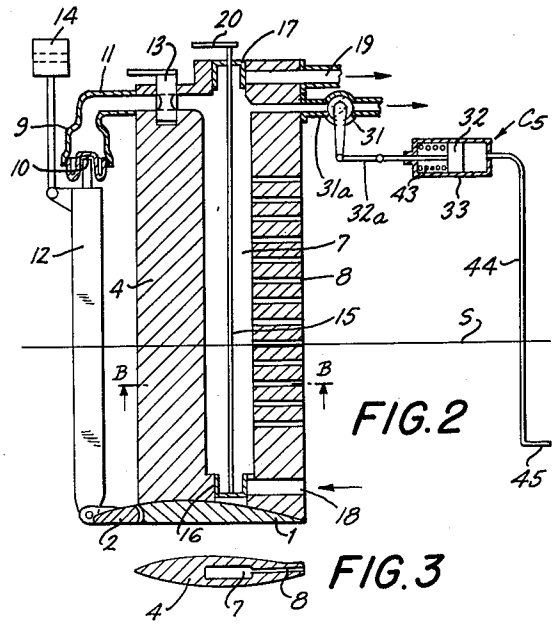


FIG. 2

FIG. 6

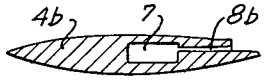


FIG. 3

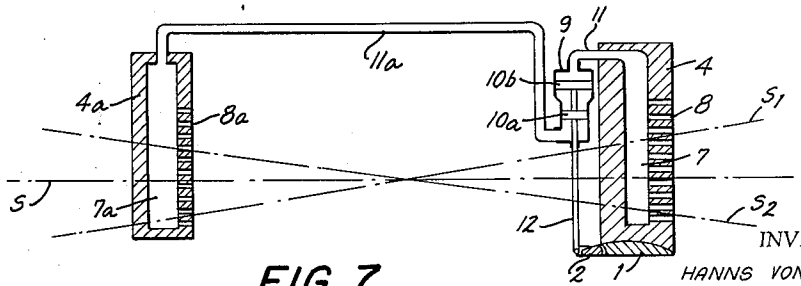


FIG. 7

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AUTOMATIC HYDROFOIL CONTROL SYSTEM FOR WATERCRAFT

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FIG. 8

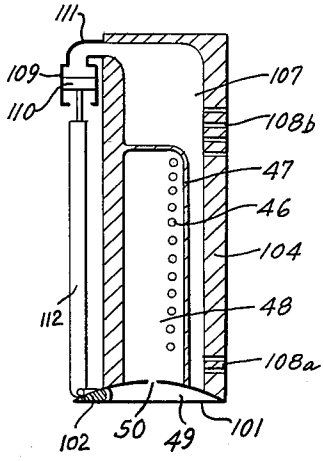


FIG. 9

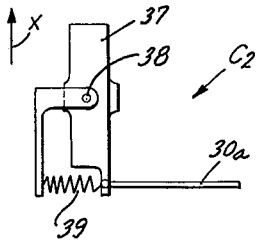


FIG. 10

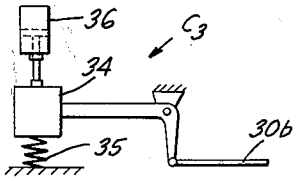
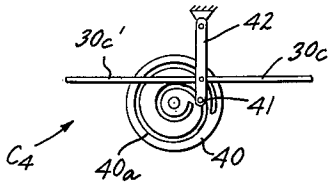


FIG. 11



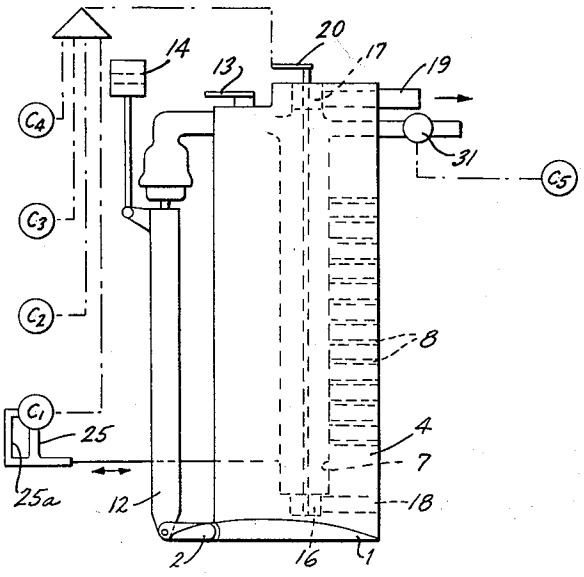


FIG. 12

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United States Patent Office 3,103,197 Patented Sept. 10, 1963

3,103,197

AUTOMATIC HYDROFOIL CONTROL SYSTEM FOR WATERCRAFT

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Filed Oct. 25, 1960, Ser. No. 64,947
11 Claims. (Cl. 114—66.5)

The present invention relates to improvements in watercraft of the type comprising one or more preferably fully submerged foils extending transversely of the hull, and more particularly to an automatic control system which regulates the extent to which the foil or foils are submerged when the watercraft is in motion, and which also improves the seaworthiness of such watercraft. Still more particularly, the invention relates to an automatic control system for watercraft of the type whose at least partly but preferably fully submerged foil or foils are provided with flaps hinged to their trailing edges so that a change in the inclination of the flaps brings about a change in the distance of the foils from the water surface.

As is known, fully submerged foils for the watercraft of the above outlined character do not possess sufficient stability to retain a given position with respect to the water surface and, therefore, such foils must be combined with special control systems which regulate the extent to which the foils may sink by imparting a lifting force to the foils whenever they descend too far below the water surface. The presently known control systems are satisfactory in relatively calm water, i.e. when the wave formation is rather negligible, but they cannot properly control the foils in turbulent waters. In the latter instance, the control system must be capable of responding to certain other factors, such as the speed at which the foils change their position with respect to the water surface, the vertical acceleration of the foils (i.e. the first and second differentiation of submersion against time), and also the listing, pitching, heeling or trim of the watercraft from its normal position. The above factors become very important and must be given full consideration when the foil-supported watercraft is used in heavy seas, and the control system utilized in such circumstances must be capable of transmitting corresponding signals to the foils so that the latter will react in time and will either change or retain their distance from the water surface as the conditions might require in dependency on one or more of the above factors.

In certain presently known control systems for such purposes, the depth (i.e. the distance from the water surface) of the foils is adjusted by utilizing rockable or swingable foils or by providing hingedly connected flaps at the trailing edges of the foils and by adjusting the position of the foils or flaps by an arrangement comprising depth-sensitive mechanical or electrical command elements. According to one prior proposal, scanning elements are mounted on comparatively long forwardly extending arms in such a way as to slide on the water surface and to bring about a change in the inclination of the foils or of their flaps whenever the foils change their distance from the water surface. Such control systems are rather bulky and too delicate for use in turbulent water; therefore, they did not find broad acceptance by the manufacturers of foil-supported watercraft. According to another known proposal, scanning elements provided with electrical contacts are used, the contacts

completing an electric circuit whenever the scanning elements are submerged in water to thereby transmit a control signal to the foils or to the flaps. It was further proposed to utilize a sonic altimeter which records the depth of the foils and transmits corresponding signals to the foil adjusting mechanism. Such electronic control systems must include an amplifier and two sources of electrical energy which not only increases the cost but also leads to frequent malfunctions and reduces the reliability of the control system resulting in reduced stability of the watercraft.

An important object of the present invention is to provide a very simple and highly reliable control system for the foils of foil-supported watercraft which is particularly suited for use in turbulent water.

Another object of the invention is to provide a control system of the just outlined characteristics which is capable of taking into consideration all factors which arise in actual use of the foil-supported watercraft in calm and/or turbulent waters.

A further object of the instant invention is to provide a control system for the foils of foil-supported watercraft which is constructed and assembled in such a way that it cannot be damaged by driftwood or by other partly or fully submerged objects.

An additional object of my invention is to provide a control system of the above described type which takes into full consideration all factors that might influence the stability of a foil-supported watercraft and which need not be provided with a separate source of energy but is operated by the dynamic pressure of water and eventually air as soon as the watercraft is brought into motion.

A concomitant object of the invention is to provide a control system of the above outlined characteristics which may be readily installed in all or nearly all types of foil-supported watercraft without requiring any or by requiring only minor modifications in the design of such conveyances.

Still another object of the present invention is to provide a control system which may be readily adjusted so as to be equally effective in calmer as well as in comparatively turbulent waters.

An additional object of my invention is to provide a control system whose main component part at the same time performs another function by constituting a connecting element between the hull of a watercraft and the foil or foils, or by constituting a support for the foil or foils.

With the above objects in view, the invention resides in the provision of a control system for watercraft of the type supported on one or more transversely extending preferably but not necessarily fully submerged hydrofoils which are connected by means of struts with the hull of the watercraft, the control system comprising one or more adjustable flaps which are hinged to the trailing edge of at least one foil and whose purpose is to vary the lifting force with which the water acts upon the foil, and at least one normally streamlined control member preferably constituting a supporting strut for the foil. The leading edge or a zone close to the leading edge of the control member is formed with orifices normally located partially above and partially below the normal water level and leading into an internal space formed in the control member. The dynamic pressure

of water in the internal space of the control member depends on the ratio of the combined cross-sectional area of the immersed orifices to the combined cross-sectional area of the exposed orifices, and the internal space communicates with a motion transmitting arrangement which is connected with the flap or flaps in such a way as to adjust the flaps in response to changes in water pressure prevailing in the internal space of the control member. The motion transmitting arrangement preferably comprises a cylinder and a rigid or diaphragm like piston which is connected with the flap or flaps by means of a rod-like element so that an increased dynamic water pressure in the internal space of the control member causes a pivotal movement of the flap or flaps about the trailing edge of the foil in such direction as to maintain the distance of the foil from the water surface at an optimum magnitude best suited to insure full stability of the watercraft. According to another feature of my invention, the control member is provided with water intake and discharge openings each of which is controlled by a regulating valve so that the position of the flaps may also be controlled by factors other than the dynamic pressure of water entering through the orifices provided in or close to the leading edge of the control member. For example, the regulating valves may be adjusted by devices responsive to changes in the direction, inclination and/or forward, downward or upward acceleration of the watercraft so that all factors affecting the stability of the watercraft in actual operation may selectively or cumulatively influence the angular position of the flaps and hence the distance between the foils and the water surface.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following detailed description of certain specific embodiments when read in connection with the accompanying drawings, in which:

FIG. 1 is a schematic end elevational view of a watercraft supported on two spaced transversely extending fully submerged foils each of which is provided with one or more flaps controlled by a system embodying one form of my invention;

FIG. 2 is an enlarged central vertical section through a control member and a transverse section through the associated foil, the section being taken along the line A—A of FIG. 1, as seen in the direction of arrows;

FIG. 3 is a transverse section through the control member as seen in the direction of the arrows from the line B—B of FIG. 2;

FIG. 4*a* is an enlarged schematic transverse section through a regulating valve mounted in the control member of FIG. 2;

FIG. 4*b* is a similar transverse section through another regulating valve which is installed in the control member of FIG. 2;

FIG. 5 is a schematic section through a control device which is responsive to the speed at which the foil moves toward or away from the water surface and which is adapted to adjust the position of the regulating valves and hence of the flaps in response to such speed;

FIG. 6 is a transverse section through a modified control member whose water intake and discharge orifices are somewhat offset rearwardly from and are located at the outer side of the leading edge;

FIG. 7 is a transverse section through two operatively connected control members which add to the stability of the watercraft in turbulent waters;

FIG. 8 illustrates a further modification of the control system which is utilized in connection with hollow foils;

FIG. 9 is a schematic representation of a control device which is responsive to a listing of the watercraft and which is connected with the regulating valves of the control member to influence the position of the flaps when the watercraft is caused to list about its longitudinal symmetry axis;

FIG. 10 illustrates a control device which is responsive to vertical acceleration of the watercraft and which is also connected with the regulating valves;

FIG. 11 illustrates a control device which regulates the flaps in response to changes in the course of the watercraft; and

FIG. 12 is a schematic diagram showing the manner in which five control devices regulate the position of a flap.

Referring now in greater detail to the drawings, and first to FIG. 1, there is shown a watercraft W which comprises a hull 5 supported by two spaced transversely extending hydrofoils 1. As is shown in FIG. 2, the trailing edge of each foil 1 is hingedly connected with a flap 2, the latter serving as a means for controlling the distance between the foils 1 and the water surface S. The means for connecting each of the foils 1 with the hull 5 comprises an upright strut 3 which is directly secured to the hull and a second strut 4 whose upper end is connected to an auxiliary wing or outrigger 6 extending laterally from the hull 5. In the embodiment of FIG. 1, the foils 1 are disposed in a common horizontal plane at the opposite sides of the watercraft; however, it is equally possible to support the watercraft on a single transversely extending foil which may be inclined from a horizontal plane or which may be shaped in the form of the letter V.

Each outer strut 4, hereinafter called control member, forms part of the control system for the respective foil 1, this control system also including the aforementioned flap 2 at the trailing edge of each foil. As is best shown in FIG. 3, the control members 4 are of streamlined shape and are formed with internal spaces 7 which, as illustrated in FIG. 2, extend vertically in their longitudinal directions. The leading edge of each control member 4 is formed with a plurality of substantially horizontal vertically spaced orifices 8 which communicate with the internal space 7 and which are located partly above and partly below the normal water surface or level S when the watercraft W is in motion. Owing to its dynamic pressure, water enters the internal space 7 through the submerged lower orifices 8 and is discharged through the upper orifices 8 which are momentarily located above the water surface S whereby the pressure prevailing in the space 7 is lower than the dynamic pressure of water. The pressure in the space 7 depends on the ratio of the total cross-sectional area of submerged orifices 8 to the combined cross-sectional area of the exposed orifices, i.e. the pressure in the space 7 is a function of the extent to which the control member 4 and the foil 1 are submerged in water. Though the water jets discharged in forward direction through the exposed orifices 8 cause a rather insignificant increase in the resistance to a forward movement of the watercraft, such jets perform a very useful function by deflecting from the leading edge of the control member 4 driftwood or any other floating objects which are met by the control member when the watercraft is in motion.

The control member 4 operates a motion transmitting arrangement which latter, in turn, controls the position of the flap 2. As is best shown in FIG. 2, the motion transmitting arrangement comprises a conduit 11 which communicates with the internal space 7 and also with a cylinder 9, the latter receiving a piston 10 which is connected with one end of a rod 12. The lower end of this rod is articulately connected with the flap 2 so that any changes in pressure prevailing in the space 7 and in the parts 9, 11 of the motion transmitting arrangement will cause the rod 12 to pivot the flap 2 about the trailing edge of the foil 1 whereby the change of lift will cause the foil to rise closer toward or will permit the foil to descend further away from the water surface S. In other words, the upper side of the piston 10 is always subjected to a pressure which is identical with the pressure momen-

tarily prevailing in the internal space 7 so that the movements performed by the flap 2 are also a function of the distance of the foil 1 from the water surface S and a function of the extent to which the control member 4 is submerged in water. The rod 12 counteracts the natural tendency of the flap 2 to pivot in clockwise direction, as viewed in FIG. 2. Since the moment of the flap 2 varies with changes in its angular position, each momentary force transmitted to the rod 12 by the piston 10 corresponds to a given angular position of the flap 2 and hence to a given lifting force acting upon the foil 1. The effective surface of the piston 10 is selected in such a way that, under normal operating conditions, the flap 2 assumes an angular position which corresponds to the desired extent to which the foil 1 should descend below the water surface S, i.e. the angular position of the flap 2 then corresponds to a predetermined extent to which the control member is submerged in water to expose only a selected number of its orifices 8. Such state of equilibrium is independent from the forward speed of the watercraft because the force of the piston 10 as well as the moment of the flap are proportional with the second power of the forward speed and because the piston force counteracts the moment of the flap.

In its preferred form, the piston 10 of the motion transmitting arrangement 9–12 assumes the form of a flexible diaphragm which completely seals the open end of the cylinder 9 and which, therefore, prevents the entry of foreign matter into the space 7. However, it will be readily understood that the diaphragm 10 may be replaced by a rigid piston of the type shown in FIG. 8 which has a tight sliding fit in its cylinder.

The operation of the control system is extremely simple and will be readily understood on the basis of the following detailed explanation. Thus, and assuming that the foil 1 changes its position by descending further below the water surface S, the pressure in the internal space 7 of the control member 4 increases accordingly to increase the shifting force of the piston 10 so that the latter causes an anticlockwise pivotal movement of the flap 2, as viewed in FIG. 2, in order to increase the lifting force. The foil 1 then automatically returns to a position closer to the water surface. On the other hand, if the foil moves closer to the water surface than desired, the pressure in the internal space 7 and in the cylinder 9 drops accordingly, and the piston 10 urges the rod 12 with a lesser force in a direction toward the flap 2 so that the latter can yield to the dynamic water forces and assumes a position of lesser inclination with respect to the plane of the foil 1. The foil then descends until the state of equilibrium is reestablished in a fully automatic way.

In choppy or turbulent waters, the control system preferably operates the foil 1 in such a way that the latter tends to follow the movement of the waves. However, the inertia of the movable components of the control system and of the water masses, as well as the friction between the movable and stationary components of the control system is too large and prevents the foil from reacting in response to very short waves. In addition, the speed at which the control system reacts to uneven configuration of the water surface may be varied by throttling the flow of water from the internal space 7 to the interior of the cylinder 9. As is shown in FIG. 2, the throttling means comprises a valve 13 which is mounted in the conduit 11 and which is adjustable in such a way as to reduce the sensitivity of the control system, i.e. to reduce the tendency of the foil 1 to rapidly follow the contours of the water surface. In other words, the throttle valve 13 serves as a means for eliminating the effect of short waves on the control system. This valve may be adjusted from the pilot stand of the watercraft by remote control means of any known design, not shown, for example by a so-called teleball system, by Bowden wires, or in any other suitable way.

Though it has been found that the inertia, friction and the throttle valve 13 insure satisfactory damping of the control system, i.e. that they eliminate the influence of short waves, additional damping means in the form of a dashpot 14 may be provided. In the embodiment of FIG. 2, the dashpot 14 is articulately connected with the rod 12 and its purpose is to reduce the speed at which the piston 10 and the rod 12 react to changes in pressures prevailing in the cylinder 9.

The above described control system regulates the position of the flap 2 solely in dependency on the extent to which the foil 1 is submerged below the water surface S. In order to enable the flap 2 to respond to certain other factors which arise during the actual use of foil-supported watercraft, the control system preferably comprises two regulating valves 16, 17 which are connected to each other by a shaft 15 and which are mounted in the control member 4 in a manner best shown in FIG. 2. The regulating valve 16 is provided in the lower part of the control member 4 and regulates the inflow of water through an intake opening 18 leading to the internal space 7, while the upper valve 17 regulates the escape of water through a discharge opening 19 provided at the upper end of the control member 4. In the illustrated embodiment, the regulating valves 16, 17 assume the form of rotary slide valves and are simultaneously controllable by an actuating means in the form of a handgrip member 20 or the like which is secured to the upper end of the connecting shaft 15. When the lower regulating valve 16 at least partially exposes the discharge end of the intake opening 18, additional water is permitted to enter the space 7 to vary the pressure acting upon the piston 10 and to thereby adjust the angular position of the flap 2. The upper regulating valve 17 can bring about a reduction in the pressure prevailing in the space 7 independently of the orifices 8.

In FIGS. 4*a*, 4*b*, the regulating valves 17, 16 are respectively shown in their neutral positions, i.e. the openings 19, 18 are completely sealed and the pressure prevailing in the space 7 is determined solely by the ratio of the combined cross-sectional area of the exposed orifices 8 to the combined cross-sectional area of the submerged orifices. When the handgrip member 20 and the shaft 15 are turned in clockwise direction, the valve member 21 of the upper regulating valve 17 exposes the opening 19 and permits additional discharge of water from the space 7 so as to reduce the pressure of water acting on the piston 10. By being turned in anticlockwise direction, the valve member 22 of the lower regulating valve 16 at least partially exposes the opening 18 and causes an increase in the dynamic water pressure prevailing in the space 7. It will be readily understood that the regulating valves 16, 17 may assume any other suitable form, e.g. that they may control the openings 18, 19 by axial rather than angular movements of the connecting shaft 15, if desired.

Though the regulating valves 16, 17 may be adjusted in a manner similar to that described in connection with the adjustments of the throttle valve 13, i.e. from the pilot stand of the watercraft, it is preferred to operatively connect these valves with at least one but preferably more control devices which are automatically responsive to certain other factors such as usually develop when the watercraft is in actual use. Referring to FIG. 5, there is shown a control device C_1 which is automatically responsive to the immersion speed and emersion speed of the foil 1 and which is connected with the shaft 15 of the regulating valves 16, 17 by means of an actuating member 30 in order to adjust the position of the regulating valves in dependency on such immersion speed and emersion speed. The control device C_1 insures that, when the watercraft W is used in turbulent water, i.e. when the waves are rather high and long, the flap 2 will react more rapidly in order to insure that the foil 1 will follow the the contours of the water surface S. In other words, when the control member 4 emerges from a wave trough and rapidly enters a wave crest, the distance between the water

surface and the foil 1 is changed very rapidly, and the control device C_1 then insures that the foil will rapidly adjust its position with respect to the water surface. Thus, tha control device of FIG. 5 actually constitutes a supplemental control means which imparts a strong additional impulse to the flap 2 supplementary to the impulse generated by the dynamic water pressure transmitted through selected orifices 8. Such supplemental control impulses in response to rapid changes in the distance of the foil from the water surface contribute greatly to the seaworthiness of the foil-supported watercraft.

The control device C_1 of FIG. 5 comprises a diaphragm 23 which is mounted in a closed housing 24 and which divides the interior of this housing into two airtightly separated compartments. The right-hand compartment of the housing 24 is directly connected with the internal space 7 by means of a conduit 25. The other or left-hand compartment of the housing 24 also communicates with the space 7 but the water flowing between the left-hand compartment of the housing 24 and the space 7 must pass along the elastic diaphragm 27 of an air chamber 26 which contains a predetermined quantity of a compressible gas, e.g., air. The air in the chamber 26 is entrapped at that side of the elastic diaphragm 27 which is turned away from the flexible diaphragm 23, and the pressure of this entrapped air is adjustable by a piston 28 which is reciprocable in a cylinder 29. The actuating member 30 is connected with the diaphragm 23 and controls the angular position of the connecting shaft 15 in a manner shown schematically in FIG. 12. The volume of the space between the elastic diaphragm 27 and the piston 28, i.e. the pressure of air entrapped in the housing 26, is variable by axial displacements of the piston 28 in its cylinder 29.

The control device C_1 of FIG. 5 operates as follows:

When the control member 4 is rapidly immersed into water, the pressure in the space 7 increases very rapidly, and such increased pressure is immediately communicated to the right-hand side of the flexible diaphragm 23 by water flowing through the conduit 25. Such increased pressure is communicated to the left-hand side of the diaphragm 23 with some delay because the water flowing through the branch conduit 25*a* will first deform the elastic diaphragm 27 to compress the air entrapped in the chamber 26 between the diaphragm 27 and the piston 28 before deforming the flexible diaphragm 23. Thus, in the first step, the diaphragm 23 is deflected to the left whereby the actuating member 30 causes an anticlockwise movement of the handgrip member 20 so that the valve member 22 of the lower regulating valve 16 at least partially exposes the water intake opening 18 and permits the entry of additional water into the space 7. The increased pressure in the cylinder 9 then causes the flap 2 to pivot in anticlockwise direction, as viewed in FIG. 2, and to cause a rapid ascent of the foil 1 toward the water surface.

When the control member 4 emerges from a wave crest and enters a wave trough so that the pressure in the space 7 drops suddenly owing to the exposure of a large number of orifices 8, the pressure in the right-hand compartment of the housing 24 drops very rapidly and the expanding elastic diaphragm 27 causes the water contained in the left-hand compartment of the housing 24 to deflect the flexible diaphragm 23 and to move the actuating member 30 in a direction to the right which results in a clockwise rotation of the shaft 15 so that the upper regulating valve 17 at least partially exposes the discharge opening 19. In other words, the air entrapped in the chamber 26 prevents the pressure of water at the left-hand side of the diaphragm 23 from dropping at the same speed as the pressure at the right-hand side of the diaphragm 23 so that the pressure difference brings about an oppositely directed movement of this diaphragm and of the actuating member 30.

Referring now to FIG. 9, there is shown a control device C_2 which is connected with the regulating valves 16, 17 so as to change in a fully automatic way the position of the flap 2 in response to rolling speed of the watercraft about the latter's longitudinal axis of symmetry. This control device comprises a rate gyroscope which is mounted in a housing 37, the latter being swingable about a vertical axis 38 and being normally maintained in a neutral position by a resilient element here shown as a coil spring 39. When the gyroscope is subjected to angular speed during a rolling movement of the watercraft, the housing 37 performs precession angular movements about the vertical axis 38 and shifts the actuating member 30*a* which is operatively connected with the shaft 15 of the regulating valves 16, 17, see FIG. 12. The arrangement is such that, and assuming that the control device C_2 of FIG. 9 is associated with the regulating valves 16, 17 in the control member 4 for the righthand foil 1 shown in FIG. 1, the actuating member 30*a* rotates the shaft 15 in clockwise direction when the right-hand side of the hull 5 is lifted away from the water surface so that the upper valve 17 permits the escape of water from the internal space 7 of the right-hand control member 4 whereby the right-hand foil is caused to sink deeper below the water surface. On the other hand, when the right-hand side of the hull 5 lists in a direction to cause a deeper penetration of the right-hand foil 1, the actuating member 30*a* turns the shaft 15 in anticlockwise direction so that additional water is admitted through the opening 18 and the right-hand flap 2 is pivoted in anticlockwise direction, as seen in FIG. 2, so as to bring about a lifting action and to return the watercraft into a position of equilibrium. The gyroscope assembly 37 may be combined with a hydraulic or electric amplifier of any known design so as to insure sufficient forces for adjusting the valves 16 and 17. The same control device C_2 is used for the flap of the left-hand foil 1 shown in FIG. 1. Pitching of the watercraft about an axis which is perpendicular to the longitudinal axis of the hull 5 is reduced by a second gyroscope which is turned through 90 degrees with respect to the gyroscope assembly 37. The direction of forward movement of the watercraft is indicated in FIG. 9 by the arrow X. Though it is considered that the stabilization of a foil-supported watercraft is normally insured by making the flaps responsive to the angular speed, it is equally possible to use a so-called gyroscopic horizon which responds to all inclinations of the watercraft; in such instances, a single gyroscope-containing control device is sufficient to reduce listing and pitching movements in turbulent water.

The regulating valves 16, 17 may be caused to respond to vertical acceleration of the watercraft by utilizing a control device C_3 of the type shown in FIG. 10. This control device comprises a substantially vertically movable mass or weight 34 which is maintained in a start of equilibrium by a resilient element 35 and which is connected with a damping means in the form of a dashpot 36. The actuating member 30*b* is connected with the shaft 15 of the valves 16, 17 (see FIG. 12) and, when the watercraft is accelerated in downward direction, the actuating member 30*b* causes the regulating valve 16 to expose the water intake opening 18 in order to bring about a displacement of the flap 2 in a sense to lift the foil 1 toward the water surface. On the other hand, when the watercraft is accelerated in upward direction, the actuating member 30*b* turns the shaft 15 in clockwise direction whereby the valve member 21 of the regulating valve 17 exposes the water discharge opening 19 and thereby brings about a descent of the foil 1 away from the water surface. An important advantage of the control device C_3 is that the actuating member 30*b* may be coupled directly with the valves 16, 17 without any amplifiers therebetween. This is possible because the forces necessary for adjusting the position of the regulating valves 16, 17 are extremely

small so that they respond even to minimal displacements of the control devices.

The regulating valves **16**, **17** are equally useful to insure a heeling or lateral inclination of the watercraft when the latter is caused to travel in an arcuate path. Thus, to prevent an overturning of the conveyance in a sharp curve, the foil or foil portion at the inner side of the hull is caused to submerge more than the outer foil or foil portion. This is attained by a control device C_4 shown in FIG. 11 which is operatively connected with the steering or directional control mechanism of the watercraft so that it automatically adjusts the regulating valves **16**, **17** whenever the craft travels in an arcuate path. The control device of FIG. 11 comprises a rotary drum or disc **40** which forms part of or is connected with the steering mechanism and which is provided with a helical cam groove **40***a* receiving a follower **41** secured to one end of a lever **42** whose other end is pivotable about a stationary axis by being secured to a stationary component part of the watercraft. The lever **42** is articulately connected with the ends of two actuating members **30***c*, **30***c*'. The actuating member **30***c* is connected to the shaft **15** of the right-hand control member **4**, see FIG. 12, and the actuating member **30***c*' is connected with the shaft **15** of the left-hand control member **4**. The configuration of the cam groove **40***a* in the drum or disc **40** is such that the actuating member **30***c* turns the associated shaft **15** in a direction to admit additional water into the internal space of the right-hand control member **4** when the latter is located at the outer side of a curve so that the outer foil or foil portion is caused to rise closer to the water surface, whereas the left-hand control member and its foil (assumed to be at the inner side of the curve), are permitted to descend deeper into water. By suitable changes in the configuration of the cam groove **40***a*, any desired transmission ratio between the rotary movement of the member **40** and the rotary movement of the shaft **15** may be achieved. It is preferred to provide adjustable connections between the lever **42** and the actuating members **30***c*, **30***c*' which also enables an operator to adjust the extent to which the one or the other foil will be submerged in a curve.

It will be readily understood that, if desired, each of the control devices shown in FIGS. 5, 9, 10 and 11 may control a separate set of regulating valves **16**, **17** in the control member or members of the control system for a foil-supported watercraft, or that all such control devices may be operatively connected with a single set of regulating valves. In the latter instance, the connection between the various control devices and the single set of regulating valves **16**, **17** comprises suitable mechanical or hydraulic mixer elements which insure that only a selected control device will affect the position of the regulating valves in a given situation, i.e. that say the control device C_4 of FIG. 11 will adjust the valves **16**, **17** when the watercraft is guided in an arcuate path while the other control devices do not affect the position of the regulating valves unless there is a simultaneous pitching, listing or other undesirable fringe movement of the watercraft.

According to another feature of my invention, a relief valve may be adjusted by a control device which prevents the foils **1** from ascending closer to the water surface when the forward speed of the watercraft is increased. Such undesirable lifting of the foils is normally observable in watercraft of the type to which my present invention pertains. The control device C_5 which prevents the lifting of foils in response to higher forward speed of the watercraft is shown in FIG. 2. It comprises a relief valve **31** which is mounted in a discharge pipe **31***a* in communication with the internal space **7** of the control member **4**. The relief valve **31** is responsive to changes in forward speed of the watercraft and is adjustable by a piston **32** which is reciprocably received in a cylinder **33** and is permanently biased to an end position by a resilient element in the form of a helical spring **43** which latter is mounted in the cylinder **33** and counteracts the water pressure acting against the right-hand side of the piston **32**. The cylinder **33** communicates with a conduit **44** whose intake end is provided with a submerged intake nozzle **45** so that the pressure of water entering the conduit **44** through the nozzle **45** acts upon the right-hand side of the piston **32** and tends to shift the latter in the cylinder **33** against the bias of the spring **43**. The connection between the piston **32** and the relief valve **31** comprises an actuating means in the form of a link train **32***a*. As the forward speed of the watercraft increases, the pressure against the right-hand side of the piston **32** also increases and the latter adjusts the position of the relief valve **31** so that more water may be discharged through the conduit **31***a* whereby the position of the flap **2** is changed in a sense to bring about a reduced lifting action. In the position as shown in FIG. 2, the piston **32** moves in a direction to the left whenever the forward speed of the watercraft is increased.

Should one, two or all control devices become damaged or ineffective, the basic control system as shown in FIG. 2 by itself is sufficient to control the position of the foils in calmer or turbulent waters. The control devices are constructed in such a way that, in the event of malfunction or when rendered inoperative for any other reason, they assume a neutral position so that they cannot affect the operation of the basic control sytsem.

In certain instances, it is desirable to provide two or more control members for each foil **1**, i.e. to control the movements of the flap **2** by a motion transmitting arrangement which is responsive to the pressures prevailing in two or more separate control members. Such control system is shown in FIG. 7 and comprises two control members **4**, **4***a* one of which is preferably disposed rearwardly of the other. The internal space **7***a* of the rear control member **4***a* is connected with one end of the cylinder **9** of the motion transmitting arrangement by a conduit **11***a* so that the dynamic pressure of water entering the space **7***a* through the momentarily exposed orifices **8***a* is transmitted to the underside of a second piston **10***a* which is also reciprocably received in the cylinder **9**. The diameter of the piston **10***a* is smaller than the diameter of a piston **10***b* which latter is responsive to pressures prevailing in the space **7** of the forward control member **4**. The piston **10***b* is adjacent to that end of the cylinder **9** which communicates wtih the conduit **11** and hence with the internal space **7**. Such control system insures that the flap **2** is adjusted at a rate which is proportional to the ratio of combined cross-sectional area of immersed orifices **8** and **8***a* to the combined cross-sectional area of the exposed orifices **8** and **8***a*, i.e. at a rate which is proportional with the pressures prevailing in the internal spaces **7**, **7***a* of both control members. The control system of FIG. 7 is responsive to the slope of the waves. As is shown in FIG. 7, the pressure prevailing in the internal space **7** of the forward control member **4** acts upon the larger-diameter piston **10***b* and tends to move this piston in downward direction to counteract the moment of the flap **2**, i.e. it tends to prevent the flap from assuming a position which would cause a descent of the foil **1** away from the water surface. On the other hand, the pressure prevailing in the internal space **7***a* of the rear control member **4***a* is transmitted to the smaller-diameter piston **10***a* in a sense to assist the moment of the flap **2**. When the watercraft has a forward trim or when the watercraft passes a wave which is inclined in the direction indicated by the line S_1, the pressure against the larger-diameter piston **10***b* is increased because a larger number of orifices **8** is immersed in water, while the pressure against the underside of the smaller-diameter piston **10***a* drops because the rear control member **4***a* exposes a larger number of its orifices **8***a*. The inclina-

tion of the flap 2 is then increased so that the foil 1 retains its median distance from the ideal water level S. When the watercraft has a rearward trim or when it passes along a forwardly inclined water surface S_2, the action of the pistons 10*b*, 10*a* is reversed, i.e. the pressure upon the piston 10*b* is reduced and the pressure upon the smaller-diameter piston 10*a* increases so that the inclination of the flap 2 is reduced and the foil 1 again retains its median distance from the ideal water level S.

FIG. 6 illustrates a modified control member 4*b* whose orifices 8*b* are slightly offset from its leading edge, i.e. the intake ends of these orifices are disposed at the outer side and rearwardly of the leading edge. Such construction protects the orifices 8*a* from driftwood or other floating objects and, in addition, when the watercraft is moved in an arcuate path, the pressure of water entering through the orifices 8*b* of the outer control member is greater thant he pressure of water entering the orifice in the control member momentarily located at the inner side of the curve. In other words, such arrangement of the orifices 8*b* brings about an effect which is similar to the effect of the control device C_4 shown in FIG. 11. It is equally possible to provide a suitably inclined protecting rail in front of the orifices 8, 8*a* or 8*b* in order to shield the orifices against the impact by floating objects.

The above outlined control system may be readily combined with a control system of the type disclosed in my copending application Serial No. 67,189 for "Automatic Hydrofoil Control System for Watercraft" according to which the position of the foils is controllable by predetermined quantities of air discharged at their suction sides, i.e. at the upper side of one or more foils. The exact quantity of air discharged at the suction side of a foil depends on the momentary position of the foil with respect to the water surface. The foil must be hollow and its internal space communicates with the internal space of a control member which is formed with air intake apertures, these apertures being partially submerged and partially exposed, depending on the extent to which the control member is submerged in water.

A modified control system of the just outlined characteristics is shown somewhat schematically in FIG. 8. The control member 104 is formed with a lower set of orifices 108*a* and with a second or upper set of orifices 108*b*, the latter being normally exposed and the former being normally submerged in water when the watercraft is in motion. The orifices 108*a*, 108*b* communicates with the internal space 107 which, in turn, communicates with the cylinder 109 of the motion transmitting arrangement through a conduit 111. The motion transmitting arrangement further comprises a piston 110 which is reciprocable in the cylinder 109, and a rod 112 which is articulately connected with the flap 102, the latter being hinged to the trailing edge of an at least partially hollow foil 101. A separate control member 47 defines therewithin a second internal space or compartment 48, the latter communicating with the atmosphere through a series of vertically spaced air intake apertures 46 which are disposed at a level between the orifices 108*a*, 108*b*. The compartment 48 communicates with the internal space 49 of the hollow foil 101, and the latter's upper or suction side is formed with discharge apertures 50. The column of air intake apertures 46 is provided in the central area of one side wall of the streamlined control member 104 along which a sub-pressure develops during travel when the control member 104 is partially submerged below the water level. Thus, some of the air intake apertures 46 are located above and some of these apertures are located below the water level during travel and, since the latter apertures are in the sub-pressure area of the control member, water does not penetrate from the outside into the compartment 48. Since, on the other hand, a sub-pressure develops during travel along the upper surface of the hydrofoil 101 in the area of its apertures 50, air is drawn from the outside of the control member 104 into the compartment 48 of the member 47 and therefrom through the space 49 of the hydrofoil 101 into the apertures 50 to escape to the upper surface of the hydrofoil. Thus, in accordance with the rate at which air is permitted to escape from the space 49, the lift of the hydrofoil 101 and hence its submersion depth is varied in dependency on the number of exposed air intake apertures 46. This number varies when the water level rises or falls relative to the control member 104. As described in connection with the orifices 8 and the space 7 of the control member 4 shown in FIG. 2 whose operation is totally different from the operation of the member 47, during travel the space 107 is filled with water which penetrates through the orifices 108*a* disposed in the area of the ram pressure of the control member 104. As long as the orifices 108*b* are above the water level, water escapes from the space 107 of the control member 104 by flowing through the orifices 108*b*. The two control systems operate in the following manner:

The lower orifices 108*a* are normally immersed in water so that the flap 102 is subjected to an unvarying pressure generated by water acting against the upper side of the piston 110 in the cylinder 109 as long as the extent of submersion of the foil 101 is controlled by air entering the space 49 and escaping through the apertures 50. However, and assuming that the watercraft moves in turbulent waters and that the foil 101 is immersed to such a depth that all air intake apertures 46 are submerged below the water surface and that, as a result of such submersion, the air control system is rendered inoperative, water will also enter through one or more of the upper orifices 108*b* and the increased pressure in the space 107 will cause the rod 112 to rock the flap 102 in anticlockwise direction in order to bring about a lifting action upon the foil 101. On the other hand, when the foil 101 is moved into such close proximity of the water surface that not only the apertures 49 but also some or all orifices 108*a* are lifted above the water surface, a pressure drop develops in the space 107 and in the cylinder 109 so that the flap 102 is automatically adjusted in clockwise direction and permits the foil to descend further below the water surface.

It will be noted that, in the control system of FIG. 8, any regulating action in response to dynamic water pressure is observable only in the two end positions of the foil 101 while the intermediate positions of the foil are controlled by the air drawn through the apertures 46 and discharged through the apertures 50. The advantage of the system shown in FIG. 8 is that it broadens the control range for the foil 101 beyond that which is attainable with the system utilizing solely air, i.e. that it extends the upper and the lower limit of the control range so that the watercraft equipped with such a combined control system is particularly suited for use in turbulent waters.

It will be understood that the control systems described hereinabove are equally useful in watercraft whose less stable foil or foils are inclined in transverse direction of the hull so that they project to a certain extent above the water surface when the watercraft is in motion.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can, by applying current knowledge, readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic and specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. In a watercraft of the type in which the hull is supported by at least one at least partially submerged foil extending substantially transversely to the longitudinal

axis of the hull, an automatic system for controlling the distance between the foil and the water surface, said system comprising, in combination, at least one flap hinged to the trailing edge of the foil; at least one control member having a leading edge and formed with vertically spaced orifices adjacent to said leading edge, said orifices disposed partially below and partially above the normal level of the water surface and communicating with an internal space formed in said control member, said control member further formed with normally submerged water intake opening means and with normally exposed water discharge opening means, said opening means adjacent to said leading edge and communicating with said space; a pressure-responsive motion transmitting arrangement operatively connected with said flap and with said control member for pivoting the same about the trailing edge of said foil in response to changes in water pressure in said space, the changes in water pressure taking place when the ratio of the combined cross-sectional area of the orifices below the water surface to the combined cross-sectional area of orifices above the water surface is changed; and first and second regulating valve means mounted in said control member for respectively controlling the entry of water through said intake opening means and the escape of water through said discharge opening means and for thereby regulating the water pressure in said space independently of said orifices.

2. In a watercraft of the type in which the hull is supported by at least one at least partially submerged foil extending substantially transversely to the longitudinal axis of the hull, an automatic system for controlling the distance between the foil and the water surface, said system comprising, in combination, at least one flap hinged to the trailing edge of the foil; at least one control member having a leading edge and formed with vertically spaced orifices adjacent to said leading edge, said orifices disposed partially above and partially below the normal level of the water surface and communicating with an internal space formed in said control member, said control member further formed with normally submerged water intake opening means and with normally exposed water discharge opening means, each of said opening means adjacent to said leading edge and each communicating with said space; first and second interconnected regulating valve means mounted in said control member for respectively controlling the entry of water through said intake opening means and the escape of water through said discharge opening means; a pressure-responsive motion transmitting arrangement operatively connected with said control member and with said flap for pivoting the flap about the trailing edge of said foil in response to changes in water pressure in said space, the changes in water pressure taking place when the ratio of the combined cross-sectional area of the orifices below the water surface to the combined cross-sectional area of orifices above the water surface is changed and when the position of said regulating valve means is changed; and a control device automatically responsive to immersion speed and emersion speed of said foil for changing the position of said regulating valve means, said control device comprising a housing, flexible diaphragm means mounted in and dividing said housing into a first and a second compartment, first and second conduit means for communicatively connecting said first and second compartment with said space, air chamber means including elastic diaphragm means adjacent to the path of water through one of said conduit means, and actuating means for connecting said flexible diaphragm means with said regulating valve means whereby the position of said regulating valve means is changed by said actuating means in response to pressure differences developing at the opposite sides of said flexible diaphragm means when the water pressure in said spaced is changed, said actuating means adjusting said regulating valve means in a sense to admit water through said intake opening means when the foil descends further away from the water surface and to permit escape of water through said discharge opening means when the foil rises toward the water surface.

3. In a watercraft of the type in which the hull is supported by at least one at least partially submerged foil extending substantially transversely to the longitudinal axis of the hull, an automatic system for controlling the distance between the foil and the water surface, said system comprising, in combination, at least one flap hinged to the trailing edge of the foil; at least one control member having a leading edge and formed with vertically spaced orifices adjacent to said leading edge, said orifices disposed partially above and partially below the normal level of the water surface and communicating with an internal space formed in said control member, said control member further formed with normally submerged water intake opening means and with normally exposed water discharge opening means, each of said opening means adjacent to said leading edge and each communicating with said space; first and second interconnected regulating valve means mounted in said control member for respectively controlling the entry of water through said intake opening means and the escape of water through said discharge opening means; a pressure-responsive motion transmitting arrangement operatively connected with said control member and with said flap for pivoting the flap about the trailing edge of said foil in response to changes in water pressure in said space, the changes in water pressure taking place when the ratio of the combined cross-sectional area of the orifices below the water surface to the combined cross-sectional area of orifices above the water surface is changed and when the position of said regulating valve means is changed; and a control device automatically responsive to immersion speed and emersion speed of said foil for changing the position of said regulating valve means, said control device comprising a housing, flexible diaphragm means mounted in and dividing said housing into a first and a second compartment, first and second conduit means for communicatively connecting said first and second compartment with said space, air chamber means including elastic diaphragm means adjacent to the path of water through one of said conduit means, means for varying the volume of said air chamber means, and actuating means for connecting said flexible diaphragm means with said regulating valve means whereby the position of said regulating valve means is changed by said actuating means in response to pressure differences developing at the opposite sides of said flexible diaphragm means when the water pressure in said space is changed, said actuating means adjusting said regulating valve means in a sense to admit water through said intake opening means when the foil descends further away from the water surface and to permit escape of water through said discharge opening means when the foil rises toward the water surface.

4. In a watercraft of the type in which the hull is supported by at least one at least partially submerged foil extending substantially transversely to the longitudinal axis of the hull, an automatic system for controlling the distance between the foil and the water surface, said system comprising, in combination, at least one flap hinged to the trailing edge of the foil; a forward and a rear control member each having a leading edge and each formed with vertically spaced orifices adjacent to its leading edge, the orifices of each control member disposed partially above and partially below the normal level of the water surface when the watercraft is in motion and communicating with an internal space formed in the respective control member; and a pressure-responsive motion transmitting arrangement operatively connected with said control members and with said flap for pivoting the flap about the trailing edge of said foil in response to changes in water pressure in the spaces of said

control members, the changes in water pressure taking place when the ratio of the combined cross-sectional area of orifices below the water surface to the combined cross-sectional area of orifices above the water surface is changed in at least one of said control members, said motion transmitting arrangement comprising cylinder means having a first end communicating with the space of said forward control member and a second end communicating with the space of said rear control member, first piston means reciprocably received in and adjacent to the first end of said cylinder means, smaller-diameter second piston means received in and adjacent to the second end of said cylinder means, and means for connecting said pistons with each other and with said flap, the water pressure prevailing in the space of said forward control member acting against said first piston in a sense to pivot the flap in a direction which causes the foil to rise toward the water surface, and the water pressure prevailing in the space of said rear control member acting against said second piston in a sense to pivot the flap in a direction to cause a descent of said foil away from the water surface.

5. In a watercraft of the type in which the hull is supported by at least one at least partially submerged foil extending substantially transversely to the longitudinal axis of the hull, in combination, at least one foil having a trailing edge and a suction side and formed with an internal space, said foil having air discharge aperture means leading from said internal space to said suction side; and an automatic system for controlling the distance between the foil and the water surface, said system comprising at least one flap hinged to the trailing edge of said foil, at least one first control member having a leading edge and formed with vertically spaced upper and lower sets of orifices adjacent to said leading edge, the upper set of said orifices disposed above the normal level of the water surface and the lower set of said orifices disposed below the normal level of the water surface, said orifices communicating with an internal space formed in said control member, at least one second control member defining an internal compartment and formed with a plurality of vertically spaced air intake aperture means communicating with said compartment and disposed between the upper and lower sets of said orifices, said compartment communicating with the internal space of said foil so that air drawn through said intake aperture means may be conveyed to said discharge aperture means, and a pressure-responsive motion transmitting arrangement operatively connected with the internal space of said first control member and with said flap for pivoting the flap about the trailing edge of said foil in response to changes in water pressure in the internal space of said first control member, the changes in water pressure taking place when the ratio of combined cross-sectional area of orifices below the water surface to the combined cross-sectional area of orifices above the water surface is changed.

6. In a watercraft of the type in which the hull is supported by at least one at least partially submerged foil extending substantially transversely to the longitudinal axis of the hull, an automatic system for controlling the distance between the foil and the water surface, said system comprising, in combination, at least one flap hinged to the trailing edge of the foil; at least one control member having a leading edge and formed with vertically spaced orifices adjacent to said leading edge, said orifices disposed partially above and partially below the normal level of the water surface and communicating with an internal space formed in said control member, said control member further formed with normally submerged water intake opening means and with normally exposed water discharge opening means, each of said opening means adjacent to said leading edge and each communicating with said space; interconnected first and second regulating valve means mounted in said control member for respectively controlling the entry of water through said intake opening means and the escape of water through said discharge opening means; pressure-responsive motion transmitting means operatively connected with said control member and with said flap for pivoting the flap about the trailing edge of said foil in response to changes in water pressure in said space, the changes in water pressure taking place when the ratio of the combined cross-sectional area of orifices below the water surface to the combined cross-sectional area of orifices above the water surface is changed and when the position of said regulating valve means is changed; and a control device automatically responsive to vertical accelerations of the watercraft for changing the position of said regulating valve means, said control device comprising a substantially vertically movable mass, actuating means for connecting said mass with said regulating valve means, and resilient means for maintaining said mass in a state of equilibrium, said control device operating in such a manner that, upon downward acceleration of the watercraft said actuating means adjusts said regulating valve means in a sense to admit water through said intake opening means and, upon upward acceleration of the watercraft said actuating means adjusts said regulating valve means in a sense to permit escape of water through said discharge opening means.

7. In a watercraft of the type in which the hull is supported by at least one at least partially submerged foil extending substantially transversely to the longitudinal axis of the hull, an automatic system for controlling the distance between the foil and the water surface, said system comprising, in combination, at least one flap hinged to the trailing edge of the foil; at least one control member having a leading edge and formed with vertically spaced orifices adjacent to said leading edge, said orifices disposed partially above and partially below the normal level of the water surface and communicating with an internal space formed in said control member, said control member further formed with normally submerged water intake opening means and with normally exposed water discharge opening means, each of said opening means adjacent to said leading edge and each communicating with said space; interconnected first and second regulating valve means mounted in said control member for respectively controlling the entry of water through said intake opening means and the escape of water through said discharge opening means; pressure-responsive motion transmitting means operatively connected with said control member and with said flap for pivoting the flap about the trailing edge of said foil in response to changes in water pressure in said space, the changes in water pressure taking place when the ratio of the combined cross-sectional area of orifices below the water surface to the combined cross-sectional area of orifices above the water surface is changed and when the position of said regulating valve means is changed; and a control device automatically responsive to vertical accelerations of the watercraft for changing the position of said regulating valve means, said control device comprising a substantially vertically movable mass, actuating means for connecting said mass with said regulating valve means, resilient means for maintaining said mass in a state of equilibrium, and means for damping the movements of said mass, said control device operating in such a manner that, upon downward acceleration of the watercraft said actuating means adjusts said regulating valve means in a sense to admit water through said intake opening means and, upon upward acceleration of the watercraft said actuating means adjusts said regulating valve means in a sense to permit escape of water through said discharge opening means.

8. In a watercraft of the type having a directional control mechanism and in which the hull is supported by at least one at least partially submerged foil extending substantially transversely to the longitudinal axis of the hull, an automatic system for controlling the distance between the foil and the water surface, said system comprising, in combination, at least one flap hinged to the trailing edge

of the foil; at least one substantially vertical control member located laterally of the hull and having a leading edge and formed with vertically spaced orifices adjacent to said leading edge, said orifices disposed partially above and partially below the normal level of the water surface and communicating with an internal space formed in said control member, said control member further formed with normally submerged water intake opening means and with normally exposed water discharge opening means, each of said opening means adjacent to said leading edge and each communicating with said space; interconnected first and second regulating valve means mounted in said control member for respectively controlling the entry of water through said intake opening means and the escape of water through said discharge opening means; pressure-responsive motion transmitting means operatively connected with said control member and with said flap for pivoting the flap about the trailing edge of said foil in response to changes in water pressure in said space, the changes in water pressure taking place when the ratio of the combined cross-sectional area of orifices below the water surface to the combined cross-sectional area of orifices above the water surface is changed and when the position of said regulating valve means is changed; and a control device operatively connected with said directional control mechanism and with said valve means, said control device automatically responsive to changes in the direction in which the watercraft is steered by said directional control mechanism for thereby changing the position of said valve means in a sense to admit more water into said space when the control member is located at the outer side of a curve described by the watercraft and to discharge more water from said space when the control member is located at the inner side of a curve described by the watercraft.

9. In a watercraft of the type having a directional control mechanism and in which the hull is supported by at least one at least partially submerged foil extending substantially transversely to the longitudinal axis of the hull, an automatic system for controlling the distance between the foil and the water surface, said system comprising, in combination, at least one flap hinged to the trailing edge of the foil; at least one substantially vertical control member located laterally of the hull and having a leading edge and formed with vertically spaced orifices adjacent to said leading edge, said orifices disposed partially above and partially below the normal level of the water surface and communicating with an internal space formed in said control member, said control member further formed with normally submerged water intake opening means and with normally exposed water discharge opening means, each of said opening means adjacent to said leading edge and each communicating with said space; interconnected first and second regulating valve means mounted in said control member for respectively controlling the entry of water through said intake opening means and the escape of water through said discharge opening means; pressure-responsive motion transmitting means operatively connected with said control member and with said flap for pivoting the flap about the trailing edge of said foil in response to changes in water pressure in said space, the changes in water pressure taking place when the ratio of the combined cross-sectional area of orifices below the water surface to the combined cross-sectional area of orifices above the water surface is changed and when the position of said regulating valve means is changed; and a control device automatically responsive to changes in the direction in which the watercraft is steered by said directional control mechanism for thereby changing the position of said valve means in a sense to admit more water into said space when the control member is located at the outer side of a curve described by the watercraft and to discharge more water from said space when the control member is located at the inner side of a curve described by the watercraft, said control device comprising rotary means connected with the directional control mechanism and rotatable in response to changes in the position of said mechanism, said rotary means formed with substantially helical cam groove means, lever means pivotable about a fixed axis, follower means fixed to said lever means and received in said cam groove means, and actuating means operatively connected with said lever means and with said valve means.

10. In a watercraft of the type in which the hull is supported by at least one at least partially submerged foil extending substantially transversely to the longitudinal axis of the hull, an automatic system for controlling the distance between the foil and the water surface, said system comprising, in combination, at least one flap hinged to the trailing edge of the foil; at least one control member having a leading edge and formed with vertically spaced orifices adjacent to said leading edge, said orifices disposed partially above and partially below the normal level of the water surface and communicating with an internal space formed in said control member, said control member further formed with normally submerged water intake opening means and with normally exposed water discharge opening means, each of said opening means adjacent to said leading edge and each communicating with said space; interconnected first and second regulating valve means mounted in said control member for respectively controlling the entry of water through said intake opening means and the escape of water through said discharge opening means; pressure-responsive motion transmitting means operatively connected with said control member and with said flap for pivoting the flap about the trailing edge of said foil in response to changes in water pressure in said space, the changes in water pressure taking place when the ratio of the combined cross-sectional area of orifices below the water surface to the combined cross-sectional area of orifices above the water surface is changed and when the position of said regulating valve means is changed; and a control device automatically responsive to forward acceleration of the watercraft, said control device comprising discharge pipe means disposed above the water surface and communicating with said internal space, relief valve means for controlling the flow of water through said pipe means, and means for adjusting the position of said relief valve means, said adjusting means comprising cylinder means, piston means reciprocably received in said cylinder means, resilient means for biasing said piston means in a given direction, actuating means connected with said piston means and with said relief valve means, and conduit means comprising submerged intake nozzle means for delivering water under dynamic pressure to said cylinder means so that the water pressure counteracts the bias of said resilient means, said piston means and said actuating means adjusting said relief valve means in a sense to permit the discharge of water through said pipe means in response to increasing water pressure against said piston means.

11. In a watercraft of the type in which the hull is supported by at least one at least partially submerged foil extending substantially transversely to the longitudinal axis of the hull, an automatic system for controlling the distance between the foil and the water surface, said system comprising, in combination, at least one flap hinged to the trailing edge of the foil; at least one substantially vertical control member located laterally of the hull, having a leading edge and formed with vertically spaced orifices adjacent to said leading edge, said orifices disposed partially above and partially below the normal level of the water surface and communicating with an internal space formed in said control member, said control member further formed with normally submerged water intake opening means and with normally exposed water discharge opening means, each of said opening means adjacent to said leading edge and each communicating with said space; interconnected first and second regulat-

ing valve means mounted in said control member for respectively controlling the entry of water through said intake opening means and the escape of water through said discharge opening means; pressure-responsive motion transmitting means operatively connected with said control member and with said flap for pivoting the flap about the trailing edge of said foil in response to changes in water pressure taking place when the ratio of the combined cross-sectional area of orifices below the water surface to the combined cross-sectional area of orifices above the water surface is changed and when the position of said regulating valve means is changed; and a control device automatically responsive to inclinations of the watercraft for changing the position of said regulating valve means in a sense to admit water to said space when the foil descends further from the water surface and to permit escape of water through said discharge opening means when the foil rises toward the water surface, said control device comprising rate gyroscope means and an operative connection between said gyroscope means and said valve means.

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