

Nov. 22, 1960

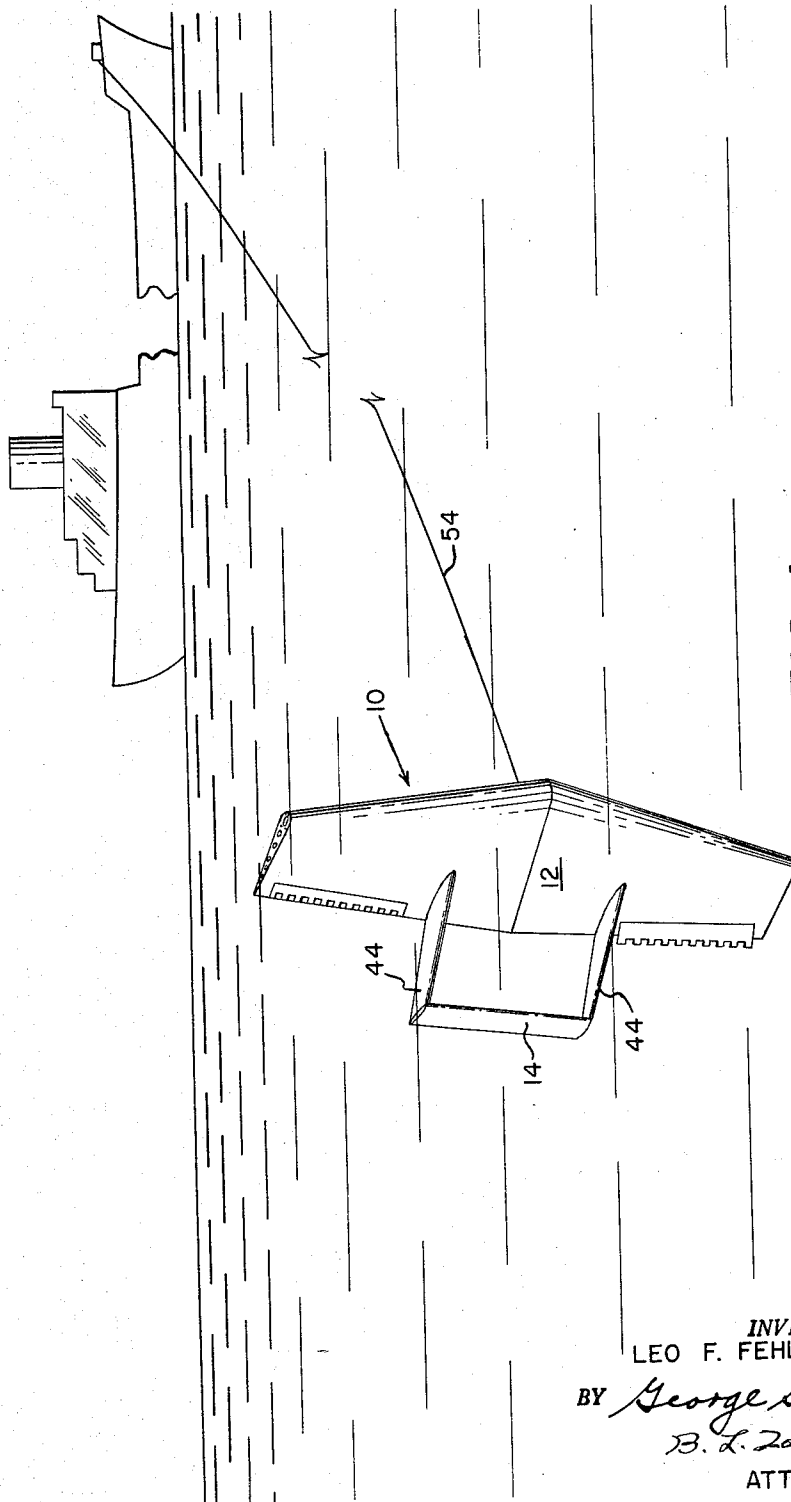
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2,960,960

PARAVANE

Filed July 27, 1954

4 Sheets-Sheet 1



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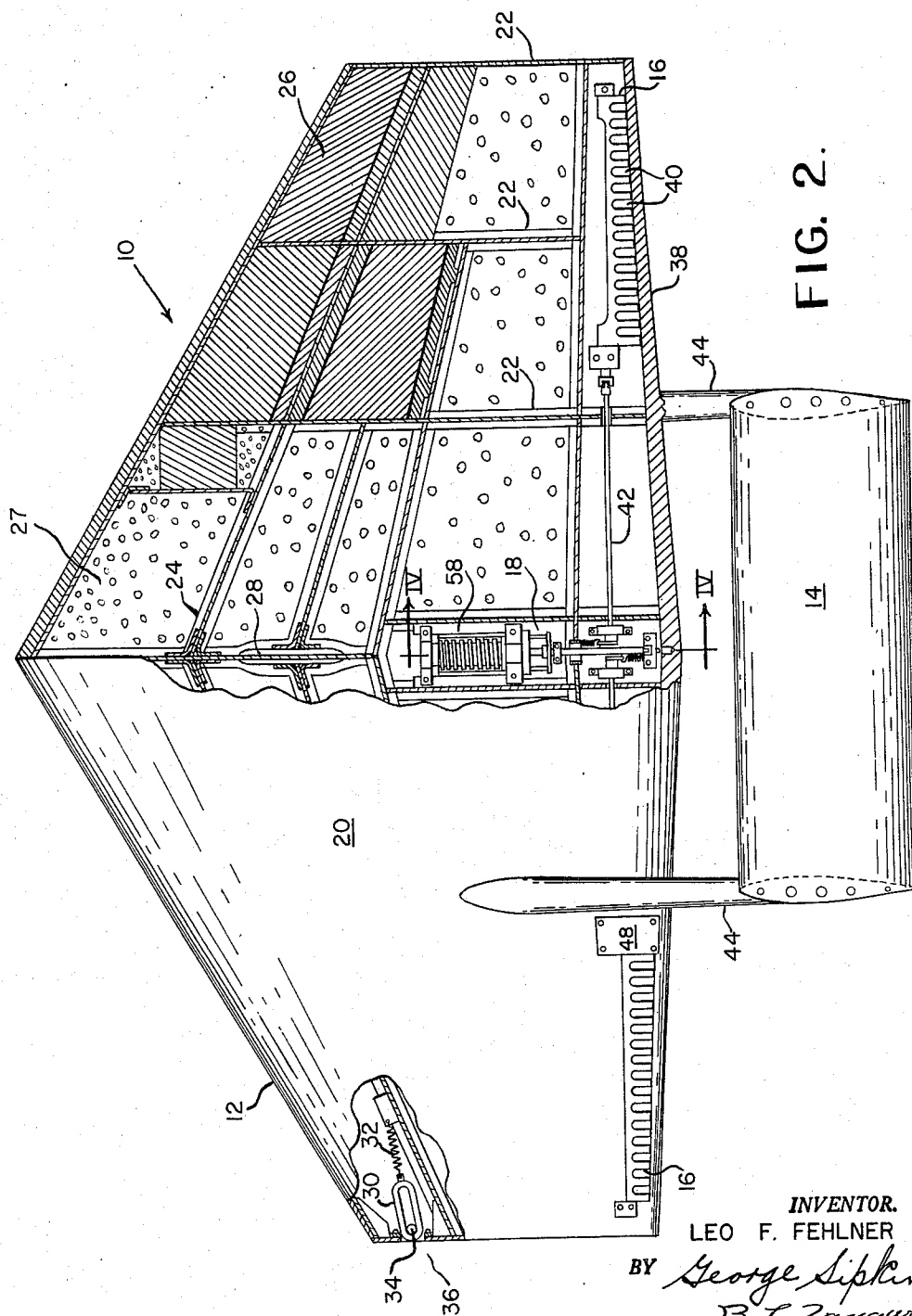
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PARAVANE

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4 Sheets-Sheet 3

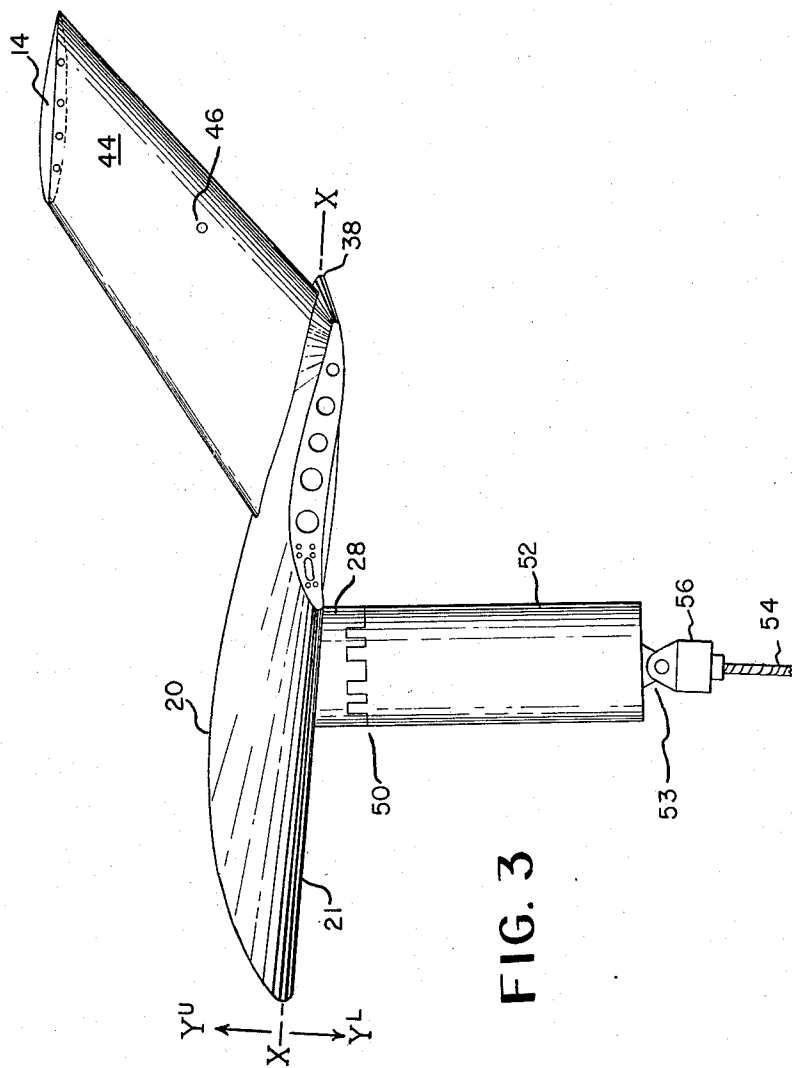


FIG. 3

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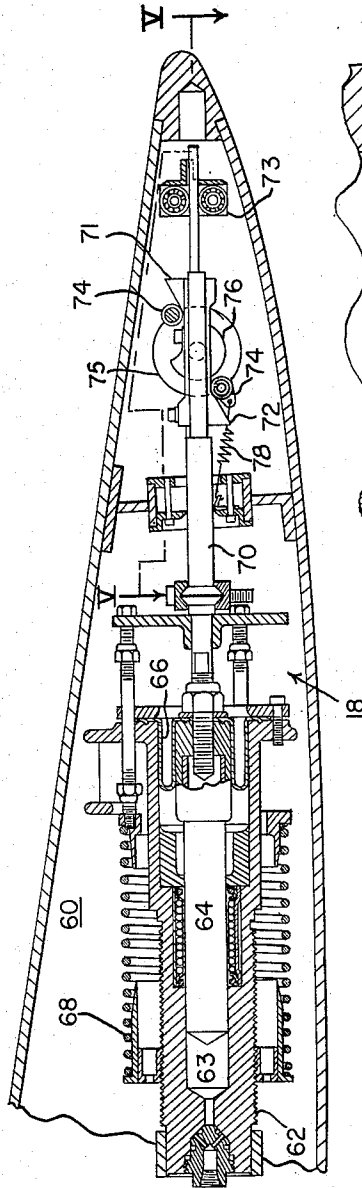


FIG. 4.

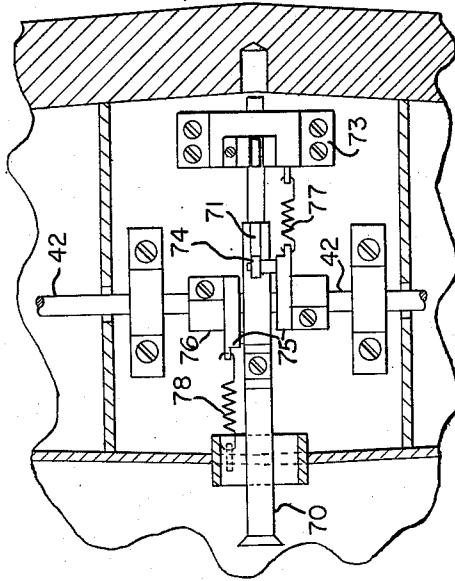


FIG. 5

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PARAVANE

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7 Claims. (Cl. 114—235)

(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to improvements in paravanes and more particularly to paravanes having cambered hydrofoils with high lift-to-drag and lift-to-weight ratios, and which maintain an accurate operational depth.

Generally, paravanes have been towed by a towing vessel at a substantial angle rearward from the towpoint on the ship by a cable attached to the paravane body since presently used paravanes have a high inherent drag which causes the paravane to lag appreciably rearward of the towing point. Further, paravanes are usually equipped with a depth control device sensitive to static pressure changes to position the paravane at a specific operational depth. Some of these depth control devices in combination with the conventional paravane construction have caused the paravane to excessively oscillate or "hunt" in the water in finding an equilibrium towing position. This hunting action of the paravane produces dynamic loads which result in undesirable repeated stress on the towing cable, and in an erratic and inefficient manner of towing the device.

The present invention embodies a buoyant or non-buoyant paravane capable of carrying a cable quickly away from the ship and to be towed therefrom. The paravane utilizes a cambered hydrofoil, hereinafter called a paravane wing. The paravane wing is similar to an aircraft wing and is equipped with horizontal and lateral stabilizing surfaces. The cooperation of the aerodynamically designed, cambered paravane wing with the stabilizing surfaces causes the paravane to operate nearly abeam of the tow point on the ship, while the depth of the paravane is determined by controlling the attitude of the paravane relative to its direction of travel.

The cambered paravane wing operates in a similar manner as an aircraft wing in a banked attitude, wherein the inclination of the wing may be changed by varying the lift forces over the paravane's cambered surfaces through an induced change in the relative fluid flow pattern thereon through the use of control surfaces, such as flaps, ailerons, elevators, or the like. In conjunction with the paravane wing, a depth control mechanism responsive to hydrostatic pressure is utilized for motivating the action of the control surfaces for differentially varying the fluid flow pattern and, consequently, the lift forces over the wing. The variation of the lift loading on the paravane wing, in response to changes in hydrostatic pressure, will produce corresponding variations in the attitude of the wing which will result in a corresponding change in the depth position of the paravane.

Further, the present invention embodies a paravane wherein the pulling force exerted by the towing vessel of the paravane, through the towline, will not be greatly affected by the drag forces of the paravane, and wherein the normal towing position will accordingly be substantially abeam of the vessel's towing point. The high re-

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sultant lift force inherent in the cambered design of the paravane wing will cause said wing to quickly tow-out, instead of being merely dragged along, and to assume the desired operational position at the end of a substantially taut cable.

The paravane wing is attached to the towline through a suitable coupling which enable the paravane wing to pivot continuously about an axis concentric with the towline and to roll freely about a horizontal axis and pitch freely about an axis perpendicular to both the roll axis and the tow cable, which axes are fixed by operational requirements. Accordingly, the paravane wing will be operative free of any interfering action from the towline and will tend to remain substantially in its chosen equilibrium position, for independent reaction to changes in hydrostatic pressure. The paravane wing is provided with suitable stability surfaces to furnish a dampening and stabilizing effect which will substantially retard any oscillatory movement of said wing about its vertical or horizontal axis. The paravane wing will quickly tend to return to its equilibrium position of operation after any change in its attitude since it is solely responsive to changes in hydrostatic pressure and not to forces transmitted thereto through the attached towline other than tension.

The paravane wing of the immediate invention is provided with longitudinal stability about its towpoint through the provision of the suitable surface contour, or camber, wherein the resultant of all the hydrodynamic forces acting on said wing will pass through its towing point to substantially eliminate any undesirable unbalancing of said wing from its operative attitude and wherein deviations from this attitude result in moments which tend to restore the paravane to its operative attitude. By isolating the paravane wing in the manner heretofore discussed from an deleterious effects of unbalanced loads arising from the interaction of the hydrodynamic forces and the towline loads, the wing will be free to assume its equilibrium position and will be responsive to small changes in hydrostatic pressures. These hydrostatic pressure changes will be translated through a simple mechanism into movement of suitable control surfaces regulating the depth of the paravane.

Hence, a broad object of the present invention is to provide a paravane constructed with suitable cambered hydrofoil sections having a high lift-to-drag ratio.

A further object is the provision of a pressure sensitive device highly responsive to small changes in hydrostatic pressure and having simple translating mechanism for actuating control surfaces which determine the attitude of the paravane in the water through suitable modification of the fluid flow over the paravane's surface.

Another object of the present invention is the provision of a paravane which when towed on the end of a cable assumes an equilibrium position of tow substantially abeam of the towing vessel at a specified depth and continues to remain in this position over a specified speed range.

A further object of the invention is the provision of a paravane having an airplane-type wing and movable control surfaces for controlling the depth of the paravane.

Still another object is to provide a paravane having a high lift-to-weight ratio.

Another object is the provision of a paravane wherein the depth of the paravane during towing is a function of the attitude of the hydrofoil relative to its direction of movement.

An object of the present invention is the provision of a paravane that during towing will have longitudinal stability about its towline attachment point.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same

becomes better understood by reference to the following detailed description when considered in connection with the accompanied drawings in which like reference numerals designate like parts throughout the figures thereof and wherein:

Figure 1 is a perspective view of a preferred embodiment of the invention, in an exaggerated scale for purposes of clarity, showing an airplane-type paravane wing in towing position relative to a towing vessel;

Figure 2 is a plan view, partly in section, of the preferred embodiment of the invention showing the airplane-type paravane wing;

Figure 3 is a side elevation view of the paravane shown in Figure 2;

Figure 4 is a sectional view of the device, taken on a line IV—IV of Figure 2, looking in the direction of the arrows, showing the hydrostatic pressure actuated mechanism for controlling the depth of the paravane; and

Figure 5 is a sectional plan view of the device taken on a line V—V of Figure 4 looking in the direction of the arrows.

Referring now to the drawings, there is shown in Figure 1 a preferred embodiment 10 of the invention comprising a cambered hydrofoil or paravane wing 12, as referred to hereinafter, with a stability surface 14 and flaps 16 integral with the wing. The flaps 16 are alternately actuated by a depth controlled mechanism 18 (Fig. 2) mounted within the paravane wing 12 and exposed to the static pressure of the fluid in which it is immersed in a manner herein disclosed.

The paravane wing 12 may be formed in any suitable geometric shape; however, in the preferred embodiment said wing is constructed with a uniform sweepback about its longitudinal axis and with a top and bottom cambered surface 20 and 21, respectively, as viewed in Fig. 3. The cambered surface of the paravane wing 12 is constructed of chordwise cross-sections which are determined by the following dimensionless coordinates, or of characteristically similar coordinates, to provide a high lift-to-drag ratio and longitudinal stability over the operational speeds:

X/Chord	Y _u /Chord	Y _l /Chord
0	0	0
.001	.00464	.00382
.003	.00856	.00608
.005	.01148	.00740
.007	.01400	.00830
.009	.01628	.00898
.01	.01736	.00926
.02	.02663	.01079
.03	.03441	.01115
.04	.04131	.01099
.05	.04759	.01053
.06	.05338	.00990
.07	.05874	.00918
.08	.06375	.00841
.09	.06842	.00762
.10	.07281	.00683
.125	.08259	.00501
.150	.09089	.00345
.175	.09785	.00227
.200	.10363	.00147
.225	.10829	.00109
.250	.11194	.00110
.275	.11465	.00151
.300	.11648	.00228
.325	.11750	.00338
.350	.11775	.00479
.375	.11730	.00646
.400	.11619	.00837
.425	.11449	.01047
.450	.11221	.01273
.475	.10942	.01508
.500	.10617	.01749
.525	.10247	.01993
.550	.09841	.02233
.575	.09400	.02466
.600	.08930	.02688
.625	.08434	.02894
.650	.07918	.03078
.675	.07386	.03238
.700	.06844	.03368
.725	.06293	.03465
.750	.05739	.03523
.775	.05187	.03539
.800	.04643	.03507
.825	.04107	.03425
.850	.03587	.03285
.875	.03086	.03086

X/Chord	Y _u /Chord	Y _l /Chord
.900	.02607	.02819
.910	.02420	.02692
.920	.02235	.02549
.930	.02052	.02392
.940	.01878	.02216
.950	.01681	.02019
.960	.01488	.01796
.970	.01281	.01543
.980	.01047	.01241
.990	.00749	.00855
.991	.00711	.00809
.993	.00531	.00709
.995	.00337	.00593
.997	.00420	.00454
.999	.01246	.00258
1.000	0	0

In Figure 3, it will be seen that X indicates a position on the chord (the distance from the leading edge to the trailing edge 38 of any cross-section of the paravane wing 12), while the corresponding Y_u and Y_l indicate a percentage of the chord in the indicated direction from the X-axis. Accordingly, for any chordwise cross-section of the paravane wing 12, the upper and lower camber may be determined for any position X along the chord.

Referring now to Fig. 2, the frame of the paravane wing 12 consists of spaced longitudinal rib members 22 interconnected with lateral spar members 24 to form an integral and rigid structural assembly to provide the paravane wing 12 with a simple internal construction. Ballast weights 26 are provided suitably secured to one of the sides of the structural assembly to give the proper operational attitude of the paravane. The side of the paravane to be ballasted is determined by the position to be operationally assumed relative to the towing vessel.

The internal structural assembly of the paravane wing is provided with a suitable non-absorbent buoyant material 27 located between the rib members 22 and spar members 24 to occupy the void space therebetween. The buoyancy of the paravane is determined by the amount of ballast weights and buoyant material utilized depending on the operational buoyancy desired. A tow bar 28 (Fig. 3) is integrally secured to the structural assembly at the middle of the wing span at the same fore and aft position as the center of gravity of the paravane wing 12 and in such position as to be consistent with the requirements for longitudinal stability.

As shown in Fig. 2, the paravane is provided with a hoisting hook 30 retractably positioned on the wing tip laterally opposite the weights 26 for lowering or raising the paravane from the deck of the towing vessel through any conventional hoisting apparatus located thereon. The hoisting hook 30 is retractably mounted within the paravane wing, so that a biasing spring 32 maintains the hook within the paravane wing 12. The hoisting hook 30 is prevented from completely retracting within the hydrofoil wing tip by a pin 34 suitably secured to the paravane wing so as to intersect the hoisting hook for maintaining the hook accessible through an opening 36 in the paravane wing tip.

As shown in Fig. 2, the flaps 16 are pivotally mounted in a recess provided on the top surface 20 of the paravane wing adjacent the trailing edge 38. The flaps 16 are formed with a plurality of edge spoiler slots 40 so as to increase the drag of the deflected flap and thus produce a favorable yawing moment. The paravane may be compared to an airplane in near vertical bank, in which lift is controlled by flattening the bank through control of one wing flap or the other. The flaps 16 are connected to the depth control mechanism 18 (Fig. 2) through flap shafts 42, and operatively actuated thereby in a manner hereinafter discussed.

The longitudinal stability surface 14 is spaced from the hydrofoil 12 and supported in a fixed relation thereto by supporting struts 44, to thereby remove said sur-

face from the deleterious effect of the slipstream of the fluid flow over the paravane wing so as to provide a measure of longitudinal stability in excess of that provided by the wing 12. The struts 44 are shaped so as to form lateral stability surfaces which provide lateral stability and damping and are hollow in construction and filled with the buoyant material 27 with the exception of conduits for communicating the hydrostatic pressure from pressure taps 46 (Fig. 3), provided on its surface, to the depth control mechanism 18. The stability surface 14, also filled with the buoyant material 27, and its supporting struts 44 are formed with suitable streamlined contours so as to present an efficient hydrodynamic shape to the fluid flow about the paravane wing 12, and to thus minimize any possible interference with the flow over said paravane wing and to minimize the drag. To facilitate maintenance, the paravane's top surface 20 (Fig. 2) is provided with a number of conventionally constructed accessible well covers 48 to provide the means for periodical inspections of the flap shafts 42 and the depth control mechanism 18.

Referring to Fig. 3, the tow bar 28 is mechanically coupled through a roll pivot hinge 50 to a tow staff 52, which is coupled to a towing cable 54 through a pitch pivot hinge 53 and a tow line swivel 56. The towing cable 54 is suitably connected to the towing vessel in any of a number of conventional methods not shown herein. The depth control mechanism 18 is mounted within the paravane wing 12, and positioned about its longitudinal axis in a chamber 58 (Fig. 2), provided in the internal structural assembly of the wing, which is opened to the pressure taps 46 for communicating the hydrostatic pressure of the surrounding fluid therefrom as heretofore mentioned.

The depth control mechanism 18, as shown in Figure 4, is provided with a pressure responsive motor 60 having a casing 62, suitably fixed to the internal structural assembly of the paravane wing, and a slidable shaft 64 coaxial therewith. The fixed casing 62 and the slidable shaft 64 are operatively coupled through bellows 66 and a spring 68, coaxial therewith which tends to bias the slidable shaft 64 away from the fixed casing 62. The spring 68 is set at a specific preload corresponding to the hydrostatic pressure of the predetermined operational depth of the paravane.

Thus, the static pressure operates the bellows 66 to slidably move shaft 64 relative to the casing 62. Shaft 64 is coaxially coupled to a control shaft 70 having suitably secured thereon a pair of diametrically opposite triangular cam surfaces 71 and 72, as shown in Figure 4. The control shaft 70 is slidably journaled in a ball bearing unit 73 fixed to the paravane wing 12 to thereby maintain shafts 64 and 70 slidably positioned relative to casing 62 and to flap shafts 42 (Fig. 5).

The inner ends of flap shafts 42 are each provided with a circular plate 75 suitably secured thereon through set screw coupling devices 76, with each plate having an integral pin 74 mounted perpendicularly and eccentrically thereon. A spring 77 is provided to angularly bias one of the pins 74 against cam surface 71 and a spring 78 to angularly bias the other of the pins 74 against cam surface 72. The springs 77 and 78 are respectively secured to a suitable fixed portion of the paravane wing 12 adjacent the control shaft 70.

In the operation of the preferred embodiment 10, the paravane wing 12 is adjusted to operate at a specific depth within certain design limits by the suitable adjustment of the preload of the spring 68. The paravane wing is coupled to the tow line 54 (Figs. 1 and 3) by the connection of the tow bar 28 to the tow staff 52 through the roll pivot hinge 50 and the pitch pivot hinge 53, and by the connection to the tow line swivel 56. The paravane wing is placed in a suitable launcher so that the stability surface 14 is facing away from the tow-

ing vessel when launched in its operative position in the water.

In launching the preferred embodiment, the paravane wing 12 is jettisoned or dropped from the towing vessel into the water as far away from the side of the vessel as possible to insure that the paravane does not hit the vessel's side and to give the paravane an initial attitude on leaving the launcher which causes the paravane to enter the surface of the water and quickly tow out into normal operative position.

In the normal operative towed position, the depth of the paravane is determined by controlling the vertical attitude of the paravane wing 12 relative to its direction of travel. The attitude of the wing is controlled by the variation from a predetermined pressure, set by the spring 68, of the hydrostatic pressure of the water adjacent the pressure taps 46, which is received by the pressure responsive motor 60 of the depth control mechanism 18, to independently and alternately actuate the flaps 16 adjacent the trailing edge 38 of said wing 12 and in addition for large changes in operative depth by a relocation of the roll pivot hinge. The hydrostatic pressure is received through the pressure taps 46, located at a suitable distance from the fluid flow over the paravane wing to escape any pressure disturbances created therefrom, and communicated through passageways provided in the buoyant material 27 within struts 44 to the chamber 58 and to the bellows 66.

Thus, any variation in hydrostatic pressure caused by the rising or falling of the paravane from the predetermined depth of operation as determined by the specific tension set in the spring 68, will cause the bellows 66 to slidably actuate the shaft 64 and the control shaft 70 axially connected thereto. Longitudinal actuation of the shaft 70 will move either the cam surface 71 or cam surface 72 to angularly displace its associated eccentrically mounted pin 74.

The angular movement of either eccentric pin 74 by its associated cam surface will cause its respective flap shaft 42 to rotate accordingly. The rotation of either one of the flap shafts 42 will cause the corresponding flap 16 to be angularly actuated with respect to the upper cambered surface of the paravane. The movement of either flap 16 will cause the paravane wing 12 to bank according to the amount of change in the hydrostatic pressure communicated to the pressure responsive cylinder 60. Thus, any change in hydrostatic pressure will cause the paravane to react thereto by a relative change in the banking characteristics of the paravane through a variation in the lift forces over the surface of the paravane wing 12. The variation in lift is produced through a change in the fluid flow pattern over a portion of the paravane wing 12 due to the action of the actuated flap 16 on the path of the fluid flow to reduce the lift and increase the drag over said portion of the paravane wing.

In accordance with the present invention, a paravane is provided that is towed by a cable from a towing vessel, which in operation quickly assumes an equilibrium position of tow substantially abeam of the vessel's towing point, at a specified depth and continues to remain in this position over a specified speed range. Accordingly, a much more stable device for maintaining a cable substantially abeam of the towing ship is provided through the action of the depth control mechanism which prevents hunting, and through the high lift-to-drag design of the paravane wing which is formed with cambered surfaces to provide longitudinal stability about the paravane's tow point.

In the instant application and in divisional applications Serial Nos. 854,991 and 854,992, filed October 22, 1959, aerodynamic principles are employed to obtain a high lift paravane wing with an inherent low drag and with a high lift-to-weight ratio for providing a very efficient paravane, which will maintain a towline substantially abeam of the vessel's tow point. The embodiments of

the present invention utilize cambered paravane wing surfaces designed according to the non-dimensional coordinates presented herein, and utilize a depth control mechanism responsive to changes in hydrostatic pressure for actuating a mechanism operatively coupled to control surfaces associated with the paravane wing. Suitable actuation of the control surfaces produces a modification of the fluid flow pattern about the paravane which results in a variation of the paravane's lift and drag components which determine its attitude in the water and, consequently, its depth.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood, that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A paravane comprising a cambered paravane wing adapted to be towed with its ends in a vertical plane having adjustable fluid controlling surfaces adjacent its trailing edge, a hydrostatic responsive device secured within said paravane wing, and means for connecting said hydrostatic responsive device to said controlling surfaces for adjusting said surfaces, stabilizing means connected to said wing, a plurality of parallel fin means securing said stabilizing means to a surface of said paravane wing and spaced therefrom, hydrostatic conduit means connected to said paravane wing for communicating hydrostatic pressure changes to said hydrostatic responsive device.

2. A paravane adapted to be towed by a cable substantially abeam of a towing vessel, comprising a paravane wing having cambered surfaces, tow line connecting means secured to said paravane wing adapted for coupling the cable thereto, stabilizing means secured to said paravane wing for maintaining longitudinal and lateral stability of said paravane wing, flap means pivotally mounted on the trailing edge of said paravane wing, hydrostatic pressure responsive means secured within said paravane wing and operatively connected to said flap means for controlling the banking attitude of the paravane.

3. A paravane adapted to be towed substantially abeam of a vessel's towing point by a cable, comprising a paravane wing having a first and second cambered surface and a swept back leading edge, a stabilizing surface spaced from and parallel to said paravane wing, a plurality of hollow struts connecting said paravane wing and said stabilizing surfaces and having hydrostatic pressure communicating apertures thereon, a pair of flaps pivotally attached to said paravane wing adapted to be angularly actuated away from said second cambered surface, a depth control device within said paravane wing, conduit means connecting said pressure hydrostatic communicating apertures with said depth control device for transmitting hydrostatic pressure changes thereto, tow line securing means fixed to said paravane wing and projecting from said first cambered surface adapted to secure the cable thereon, weight means integral with said paravane wing and mounted on one side thereof to thereby maintain said paravane wing in a vertical operating attitude in the water.

4. The invention as defined in claim 3 but further characterized by said depth control device comprising a fixed casing secured to said paravane wing and having a shaft chamber concentric therewith, an axially slidable

shaft slidably mounted within said shaft chamber, a bellows coupling said slidable shaft and said fixed casing adapted to react to hydrostatic pressure changes, spring means concentric with said fixed casing and said slidable shaft adapted to maintain said slidable shaft at a predetermined position relative to said fixed casing, a control shaft, axially secured to said slidable shaft and having thereon a pair of diametrically opposed cam surfaces, a pair of spoiler shafts rotatably mounted within said paravane wing perpendicular to said control shaft and juxtaposed to said cam surfaces, each of said spoiler shafts having one end operatively secured to one of said flaps and having a circular plate integrally secured to the other end, an eccentric pin fixed perpendicular to the face of each of said circular plates adjacent its perimeter and adapted to operatively coact with one of said cam surfaces to angularly displace said spoiler shaft, and spring means continuously biasing said eccentric pins toward said respective cam surface.

5. A paravane for carrying a cable substantially abeam from a towing vessel, said paravane comprising a hydrofoil having major surfaces thereof cambered according to given non-dimensional coordinates in a manner as to produce inherently low drag and relatively high lift-to-weight ratio when towed in a normal substantially vertical operative position to thereby maintain the cable substantially abeam of the towing vessel, a tow bar secured to the paravane on the longitudinal axis thereof and at substantially the same fore and aft position as the center of gravity of the paravane, means including a roll, pitch and swivel connection connecting the tow bar to the cable, movable control surfaces connected to the hydrofoil for modifying fluid flow patterns about the cambered surfaces thereof, and depth control mechanism responsive to changes in hydrostatic pressure on the hydrofoil and operatively coupled to the control surfaces for moving such surfaces relative to the hydrofoil to thereby modify the fluid pattern about the cambered surfaces of the hydrofoil resulting in a variation in lift and drag components and corresponding changes in attitude and depth of the paravane.

6. A paravane as set forth in claim 5 wherein the depth control mechanism includes a hydraulic motor provided with a pressure tap having an inlet exposed to ambient fluid and an outlet at the motor and wherein the inlet is so located relative to the hydrofoil as to be substantially free of pressure disturbances created by the hydrofoil.

7. A paravane as set forth in claim 5 which includes stabilizing means secured to the hydrofoil and having surfaces thereof spaced from the hydrofoil in a manner as to maintain longitudinal and lateral stability of the hydrofoil.

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