April 4, 1939. E. B WILFORD 2,152,984

WATERCRAFT

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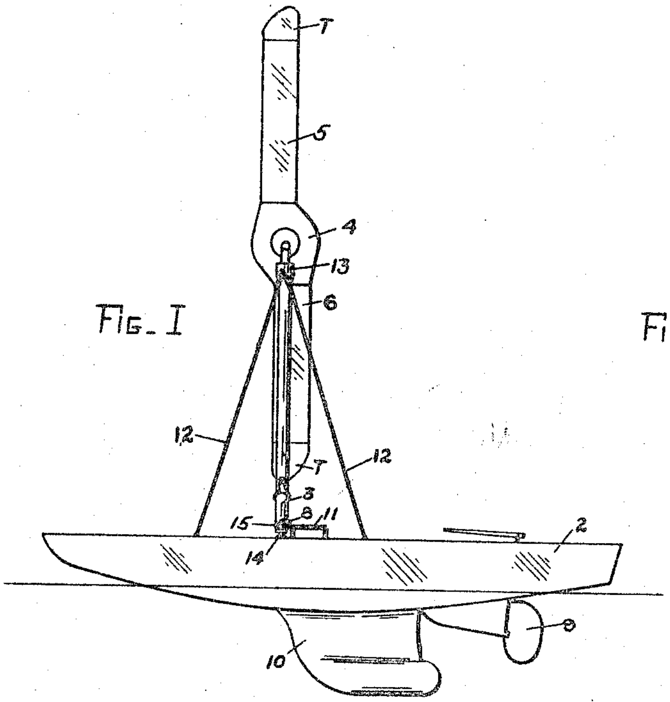
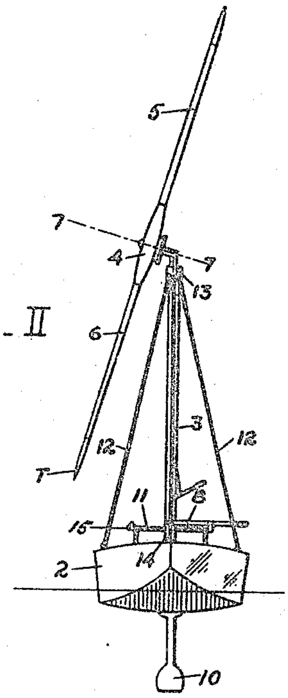
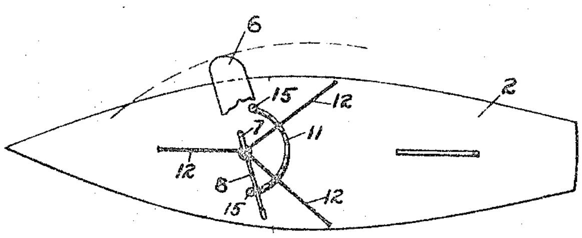


FIG_I



FIG_II



FIG_III

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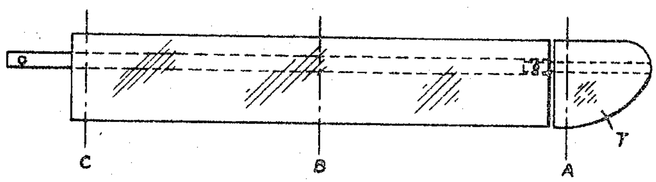

FIG. IV

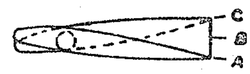

FIG. V

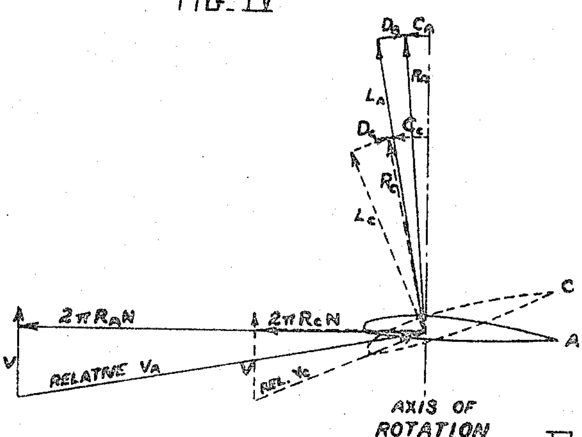

FIG. VI

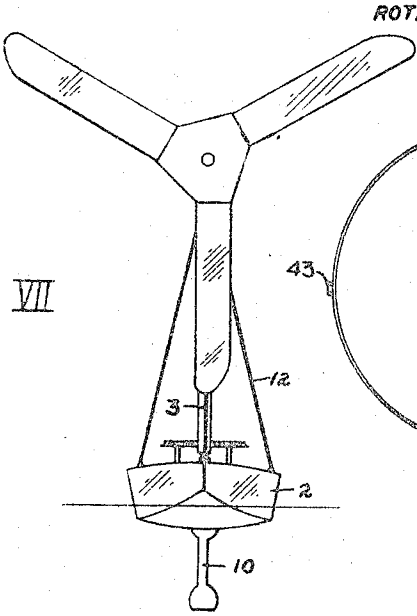

FIG. VII

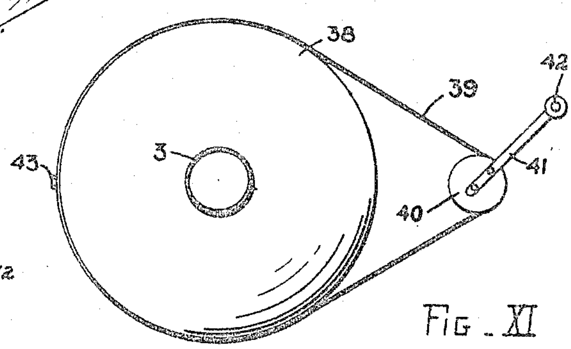

FIG. XI

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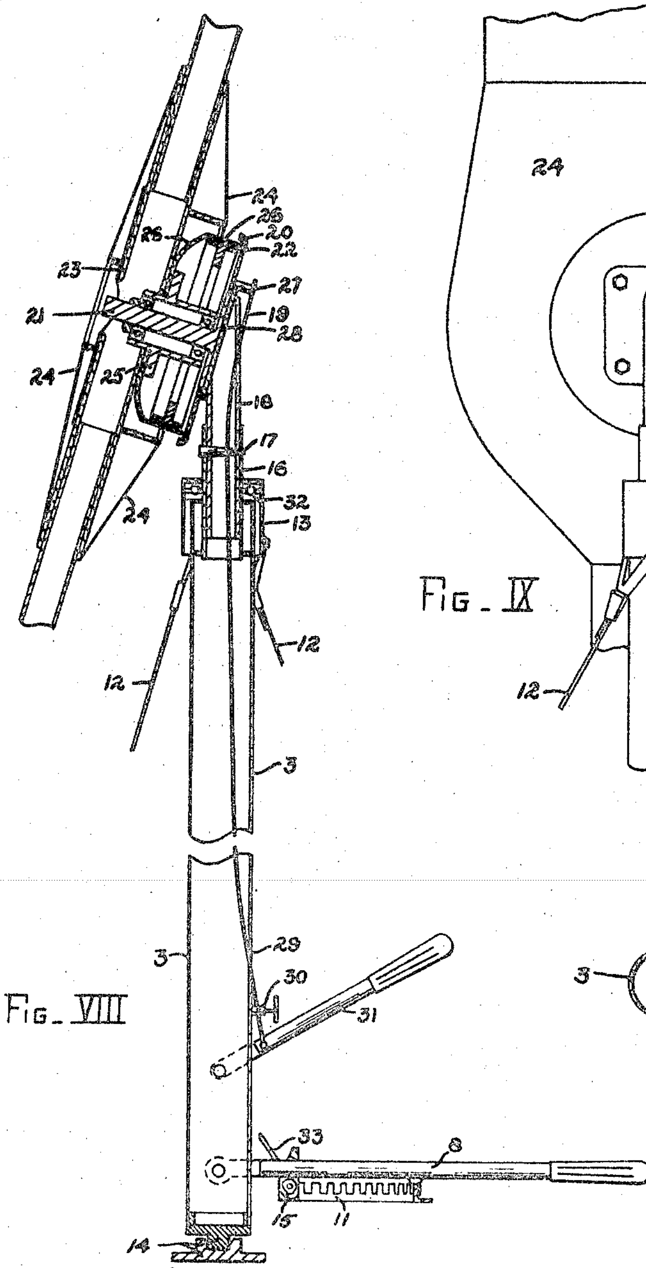
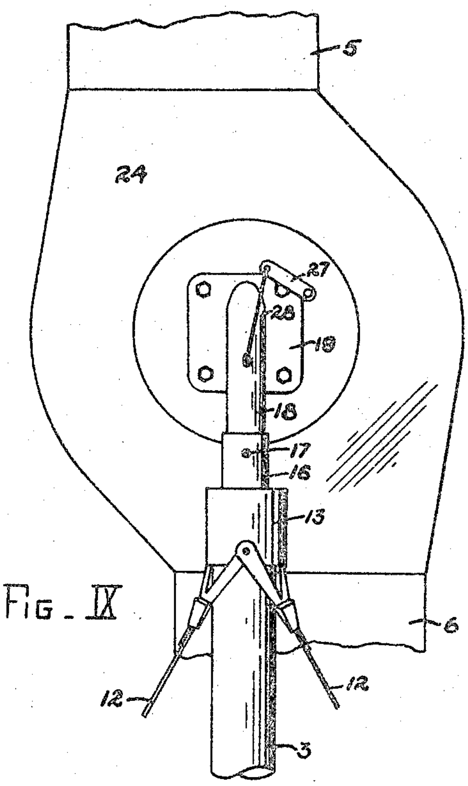
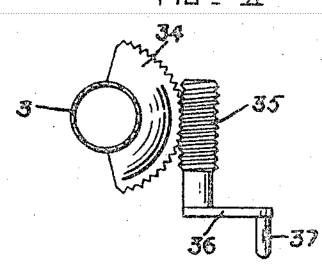


FIG_VIII



FIG_IX

FIG_X



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Patented Apr. 4, 1939 2,152,984

UNITED STATES PATENT OFFICE

2,152,984

WATERCRAFT

Edward Burke Wilford, Merion, Pa.

Application August 17, 1936, Serial No. 96,344

12 Claims. (Cl. 114—39)

This invention relates to a watercraft and more particularly to a craft having a rotor thereon supported and secured externally of the hull.

It is an object of my invention to provide a watercraft wherein stabilization is effected by a rotating rotor supported externally of the hull in such manner that the stabilizing forces available from the rotor are distributed over a substantial area of the hull and to spaced points, avoiding the imposition of severe localized stresses. It is a further object of my invention to provide means whereby wind energy is effectively utilized for the propulsion of a watercraft by means of a rotor, and to provide means whereby the craft embodying such rotor adequately supports the same without interference. It is a further object of my invention to provide in a wind propelled craft a rotor capable of auto-rotation so supported that its plane of rotation may be changed with respect to the craft in accordance with the desires of the operator and without interference with the supporting structure. Additionally, my invention contemplates a craft so coordinated that the operators and passengers are protected from the rotating rotor irrespective of the angle to which the plane of rotation of the rotor is adjusted with respect to the craft.

These and other objects and the advantages incident to my invention will become more apparent from the following description and drawings illustrating the present preferred embodiment of my invention in which,

Figure I is a side elevation of a boat embodying my invention;

Figure II is a front elevation of the craft shown in Figure I;

Figure III is a top plan view of the craft shown in Figures I and II;

Figure IV is a plan view of a preferred rotor blade;

Figure V is an end elevation of the blade shown in Figure IV;

Figure VI is a simple kinematic diagram of the motions and forces involved in the phenomenon of auto-rotation;

Figure VII is a front elevation of a craft similar to that shown in Figure I but embodying a different rotor;

Figure VIII is a sectional side view of a rotor hub, support therefor, and associated control mechanism;

Figure IX is a back view of a portion of the assembly shown in Figure VIII; and

Figures X and XI diagrammatically illustrate control mechanisms.

Referring first to Figures I and II, there is shown a watercraft having a body 2, a mast 3, supported thereby, a rotor 4 comprising a plurality of blades 5 and 6 adapted for auto-rotation about an axis generally indicated at 7—7, fixed to the mast 3, and a handle 8 for turning the mast 3 about its longtudinal axis to select a desired angle for the plane of rotation of the rotor 4 with respect to the body 2. A rudder 9 is provided to steer the craft. A lateral plane 10 inhibits leeway when the wind driving the craft is not directly astern.

Figure III illustrates a top plan view of the craft shown in Figure I. It will be noted that a suitably notched sector 11 retains the handle 8 in any selected position.

Stays 12 attached to a coupling member 13 hold the mast 3 against lateral displacement and resist the thrust of the rotor 4. The mast 3, resting upon a pin bearing 14 shown enlarged in Figure VII, is freely rotatable within the coupling member 13. Thus the stays 12 are effective at any angle of the plane of rotation of the rotor 3 with respect to the body 2, but do not limit the angle to which such plane may be selected within the effective limits of the rotor for forward propulsion of the craft.

It will be noted that the rotor is tilted with respect to the vertical. There are several important advantages flowing from this arrangement which contribute toward making the use of an auto-rotating rotor practical on a wind propelled craft. There is provided, by this construction, an unobstructed space immediately below the rotor axis 7, unoccupied by the rotor at any position of rotation irrespective of the angle of its plane of rotation with respect to the body 2 of the craft. This space free of the rotor would be generally conical if the mast 3 were rotatable through a complete circle. I prefer to limit the movement of the mast 3 by means of stops 15 adjacent the ends of the sector 11 whereby the mast is rotatable only through an angle of about 140 to 160 degrees with the center of the disk swept by the rotor always forward of the mast 3. I thus provide adequate space for the operator in a craft where the axis of the rotor is preferably relatively low, such as in a small boat, for the disk swept by the rotor does not intersect any space below the axis of the rotor, behind the mast, and inside the stays 12. This, in a small wind propelled boat, provides means of propulsion more efficient than a conventional sail and at the same time frees the cockpit of all hazards of swinging booms, sprits and the like encountered with conventional sail rigs. The arrangement also permits of efficient staying of the mast without limiting the movement of the mast through the most efficiently usable angular motion. To my knowledge, this is the first time there has been made available, a mast stayed against lateral motion in all directions in conjunction with an auto-rotating rotor for wind propelled crafts. A further and important advantage attending the tilting of the plane of the rotor with respect to the vertical, is the fact that, as the craft heels to unsymmetrical sailing lines, the disk swept by the rotor becomes nearer to vertical plane so that the effectiveness of the rotor is increased, since, under all conditions of sailing excepting when the axis of the rotor is directed forward, the rotor disk is thereby turned more normal to the wind. A further advantage is that the spindle being inclined upwardly from the horizontal, the rotor tends to lift the craft and to that extent tends to neutralize the moment otherwise tending to nose the craft downwardly.

By taking advantage of the limit placed by the stops 15 upon the angle through which the mast may be turned, the rearward stays may be placed well outwardly and rearwardly with adequate clearances from the back of the rotor. Thus, notwithstanding the inherent hazard attending the use of a rapidly rotating rotor on small size craft, I provide a rotor propelled craft which is safer than a conventional sailing rig in that it is free of all dangers of jibing and of swinging spars crossing the cockpit in coming about, and in which the operator or passengers inside the stays are safe from all danger from the rotor.

Figures IV and V illustrate diagrammatically a blade of my preferred type. The region A adjacent the tip is set at a slight positive angle of incidence with respect to the plane of "no-lift", the region C near the root of the blade, is set at a negative angle of incidence with respect to the plane of no-lift of the blade, and the intermediate region B is set substantially at an intermediate angle with respect to such plane. Figure VI illustrates diagrammatically the advantage flowing therefrom when auto-rotation exists. In Figure VI the tangential speed of the region A is represented by $2\pi R_a N$, which, with the normal component of the wind velocity V, makes a resultant wind velocity as shown V_a. The lift L_a, drag D_a and resultant force R_a produce rotative component C_a as shown. For the region C, however, the tangential speed $2\pi R_c N$ is necessarily smaller, but V is the same, so that the resultant wind velocity V_c is different in angle and amount from V_a. By changing the angle of the blade in the region C with respect to the plane of no-lift the angle of attack may be held more nearly constant for the whole blade, for it is clear that the angle of the wind (V_a and V_c) with respect to the plane of no-lift is equal to an angle whose tangent is the wind velocity V divided by the tangential velocity $2\pi RN$. By maintaining sufficient negative angle of incidence at region C, I provide a rotor which is self starting, the negative portion acting as a wind-mill to rotate the rotor at low speeds. When sufficient rotational velocity has been reached the auto-rotating phenomenon takes place.

In Figure VII, I have shown a craft similar to that shown in Figures I, II and III, but provided with a three bladed rotor. I have found that the variations in effort required to turn the mast 3, due to changes in the gyroscopic effect of a two bladed rotor may be objectionable in a large sized rotor. With a two bladed rotor the gyroscopic resistance to turning the mast is a maximum when the blades are on a line 90 degrees displaced from the mast and is at a minimum when the blades are on a line making the least angle with the mast. By using at least three blades the difference in gyroscopic resistant to turning the mast is reduced to an unobjectionable amount, and for large manually directed rotors, I recommend the use of poly-bladed rotors.

Figures VIII and IX show the mast, rotor spindle and brake assembly. As shown, the mast 3 is preferably hollow to obtain the greatest moment of inertia for the weight. A short tube 16 welded to the mast 3, supports, with removable fastenings 17, a tube 18 welded to a plate 19 bolted to a brake carrier plate 20 and to flange of spindle 21. The carrier plate 20 carries brake shoes 22. A main spar 23 and fairing 24 is supported by a bearing housing 25 to which is attached a brake drum 26 and which is rotatable on bearings held by spindle 21. A lever 27 supported by the carrier plate 20 and operating the brake shoes 22 is actuated by a cable 28 which is passed inside the tube 18 and thence downwardly through the mast 3 to a point 29 adjacent the base of the mast where it is passed outwardly through a hole, through a clamping device 30, to an operating lever 31. Thus, the setting or holding of the brake is independent of the position of the mast 3 with respect to the body of the craft.

The coupling member 13, to which the stays 12 are attached, is supported by a thrust bearing 32 fixed longitudinally of the mast 3.

A limiting device 33 prevents the handle 8 from being lifted from the sector 11 an amount sufficient to pass over the stops 15.

As shown in Figures I, II and IV, the tip portions T are preferably separate from the main blade, and I prefer that they be removable. The effect of removing the tip portions T is to materially reduce the available thrust from a given wind velocity and plane of rotation with respect thereto. The effect is also to materially reduce the gyroscopic resistance of the rotor by removing portions of which are most remote from the axis of rotation. By making the tip portions removable, I provide a ready means of "reefing" and insuring safe and manageable operating forces with high wind velocities.

It will be understood that the "twist" in the blades need not be carried to the point where the tip portions are disposed at a positive angle of incidence to the plane of rotation of the rotor, but that the advantages of self starting characteristics and more uniform angle of attack along the blade may be achieved by starting with a negative angle at the root portion and "twisting" the blade to a more positive angle without making the tip portions actually positive as described.

It will be understood that the removal of the tip portions T for the purpose of reducing the size of the rotor is not necessary if means are provided for minimizing or voiding the thrust available from the tips, as by turning the same with respect to the blade to such angle that the tip portions "stall". Other means, such for example as adjustable flaps may be employed for decreasing the effectiveness of the rotor.

If desired, the path of the tips of the rotor may be disposed remote from the mast by means other than tilting the axis about which the rotor rotates, one method of accomplishing this being to so dispose the blades of the rotor that they lie along the surface of a cone, the apex of which lies in the axis of rotation of the rotor. This construction provides, as the construction hereinbefore illustrated and described provides, that the rotor blades follow a path disposed at an acute angle to the vertical, providing adequate clearance for stays for the mast and supporting structure, and clearance for operators and passengers about the mast in the region of the hull.

The stabilizing effect available from the rotating rotor is useful in keeping the craft steady, but such stabilizing forces as are required in large craft are of considerable magnitude. The construction described is, therefore, desirable inasmuch as the stabilizing forces are distributed to the hull through the stays, to spaced points on the hull. Accordingly, opportunity is afforded for the employment of rotating masses adequate to stabilize large craft, coupled with opportunity for distributing such forces conveniently in old or new construction and without the necessity of resorting to special internal construction in the hull. For purposes of stabilization, it is immaterial whether the rotor be wind driven or power driven, although for commercial use, a rotor capable of auto-rotation offers the advantage of greater economy both from the standpoint of power supplied to rotate the stabilizing mass and from the standpoint of power contributed to the propulsion of the craft at times when the wind is favorable.

The advantages of rotating the mast are very material in the application of auto-rotating rotors to sailing craft. The windage offered by the mast is less than that offered by cage supports and since the strength of the mast must be sufficient to resist all torque incidental to the maneuvering of the craft, the weight aloft is least when the mast itself is effective for presenting the plane of rotation of the rotor at various angles with respect to the craft without the added weight of extraneous means. In large craft where adequate ballast is available, other means may be practicable, but in small craft the use of a rotatable mast offers advantages which are extremely important from the standpoint of strength, simplicity, economy and stability.

When the size of the rotor is such that direct manual turning of the mast becomes undesirable, a device such as shown in Figure X may be employed, in which a sector 34 of a worm gear is fastened to the mast 3 and is engaged by a worm 35 arranged to be turned by a crank 36 having a handle 37. This provides a slow and steady, but powerful, means for changing the angle between the rotor and the craft. As will be understood, the worm 35 is fastened to the craft by means not shown.

Figure XI illustrates an alternate means for turning the mast 3 in which a grooved wheel 38 is secured to the mast 3 and is driven by a chain or cable 39 passing around an appropriately shaped wheel or drum 40 to which the cable or chain is secured. The drum or sprocket 40 mounted on the craft may be turned by a crank 41 having a handle 42. The cable or chain 39 is secured to the wheel 38 at a point 43.

The brake is preferably so proportioned that the rotor is under control at all times and capable of being arrested if required to preserve the safety of the craft.

I thus provide a coordinated structure whereby the use of a rotor capable of auto-rotation is practicably applicable to craft of all sizes. Various supporting bodies may be employed and the rotor is permissibly dimensioned for the maximum results without sacrificing the stability, safety or maneuverability of the craft.

I further provide a stabilized craft in which passenger, cargo, or deck space is not sacrificed for making space available for a rotating stabilizing mass, and in which additional internal reenforcing and bracing is not required for distribution of the stabilizing stresses.

This application is a continuation in part of my copending application Serial No. 738,219, filed August 3, 1934.

While I have illustrated and described certain preferred embodiments of my invention, it will be understood that the invention may be otherwise embodied and practiced within the scope of the following claims.

I claim:

1. In a watercraft, a hull, a mast, stays fixed adjacent the head of the mast and to said hull holding the mast in a position vertical to said hull, and a rotor mounted on the top of the mast, the rotor being of such weight and proportions as to produce a gyroscopic effect sufficient to stabilize the craft.

2. In a watercraft for propulsion by a rotor capable of auto-rotation, a hull, a rotor, a mast supporting said rotor above said hull, means extending from the upper region of the mast to points on said hull spaced from the base of the mast, and a spindle affixed to said mast at an angle to tilt the plane of rotation of said rotor outwardly from the base of the mast an amount sufficient that the rotor path is outside the securing means, whereby said securing means not only function as rigging but also as guards, the mast being rotatable with respect to said securing means and hull.

3. In a watercraft for propulsion by a rotor capable of auto-rotation, a hull, a rotor, a mast supporting said rotor on said hull, rigging secured to the mast and hull, a spindle affixed to said mast at an angle to tilt the plane of rotation of said rotor outwardly from the base of the mast an amount sufficient that the rotor path is outside the rigging, the mast being rotatable with respect to said rigging and hull, a brake effective for arresting rotation of the rotor, and control means for the brake disposed within the mast and within the means for attaching the rigging to the mast, whereby the mast is freely rotatable without interference between the rotor, the rigging and the brake control means.

4. In a wind propelled craft for propulsion by a rotor capable of auto-rotation, a rotor having a plurality of blades mounted for rotation, each of said blades having a root portion presenting a negative angle of incidence with respect to the plane of rotation, and a tip portion having a more positive angle of incidence with respect to the plane of rotation, and an airfoil section joining the root and tip portions.

5. In a wind propelled craft for propulsion by a rotor capable of auto-rotation, a rotor with blades each having a portion disposed at a negative angle of incidence and a portion disposed at a positive angle of incidence, there being sufficient portion disposed at a negative angle of incidence that the rotor is self-starting and at least a part of the portion disposed at a positive angle of incidence being readily removable for decreasing the size of the rotor.

6. In a wind propelled craft for propulsion by a rotor capable of auto-rotation, a rotor having removable portions equivalent in weight and ef-

fectiveness in the region of the tips of each of said blades, which portions are readily removable to decrease the size of the rotor while preserving its symmetry, whereby the rotor is balanced with the removable portions removed or attached.

7. A craft according to claim 6 in which the rotor includes means for attaching the removable tips to present a positive angle of incidence with respect to the plane of rotation.

8. In a wind propelled craft for propulsion by a rotor capable of auto-rotation, a rotor with blades each having a portion disposed at a negative angle of incidence with respect to the plane of rotation thereof and a portion disposed at a more positive angle of incidence, there being sufficient portion disposed at a negative angle of incidence that the rotor is self-starting.

9. A craft according to claim 2 including a vertical fin extending longitudinally thereof and effective for inhibiting side-slip and a rotor having at least three blades.

10. A craft according to claim 2 including means for adjustably securing the rotatable mast in desired positions whereby the rotor operates in one of a plurality of predetermined planes with respect to the hull.

11. In a wind propelled craft for propulsion by a rotor capable of auto-rotation, a rotor having removable portions equivalent in weight and effectiveness, which portions are removable to decrease the size of the rotor while preserving its symmetry, whereby the rotor is balanced with the removable portions removed or attached.

12. In a wind propelled craft, a rotor capable of auto-rotation, means supporting said rotor for rotation, controlling means for rotating the rotor support, limiting means for said controlling means, limiting the normal rotation of the rotor support to not more than about the angle included forwardly of a plane which is normal to the longitudinal axis of the craft and which includes the axis of the rotating support for the rotor, a hull supporting the structure aforesaid, the disposition and the proportioning of the parts being such that in the region of the hull the path of the rotor nearest the hull at any position of the rotor support is remote from a vertical line through the rotor support, whereby all possible paths of the rotor are clear of a substantial space in the region of the hull adjacent the rotor support.

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