Dec. 23, 1930. E. N. FALES 1,786,057

TURBINE

Filed July 14, 1924 2 Sheets-Sheet 1

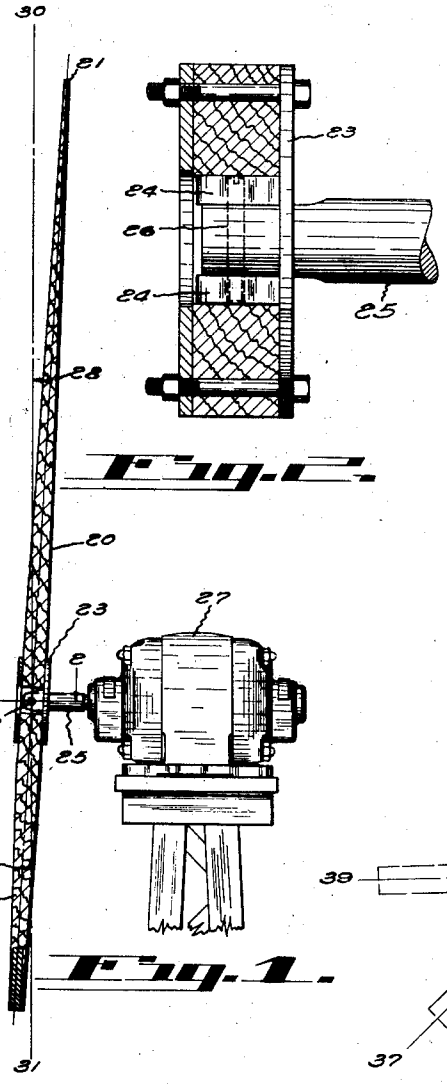

Fig. 1.

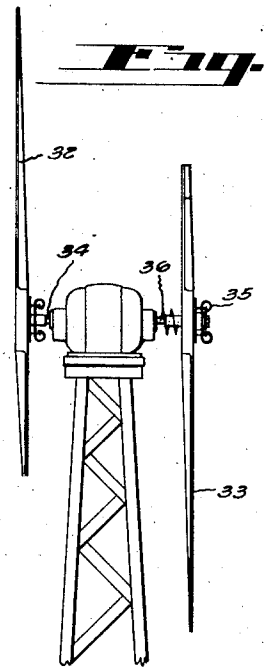

Fig. 2.

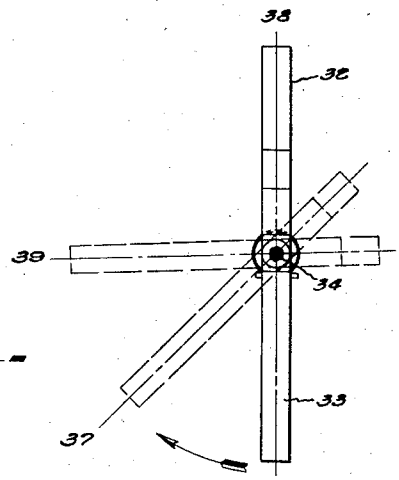

Fig. 4.

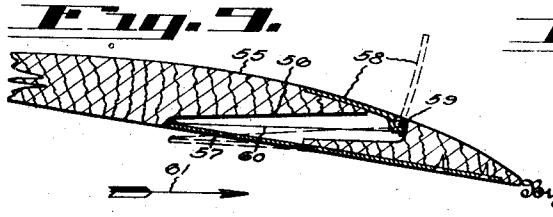

Fig. 3.

Inventor

Elisha N. Fales

By Marshall & Fehr

Attorneys

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TURBINE

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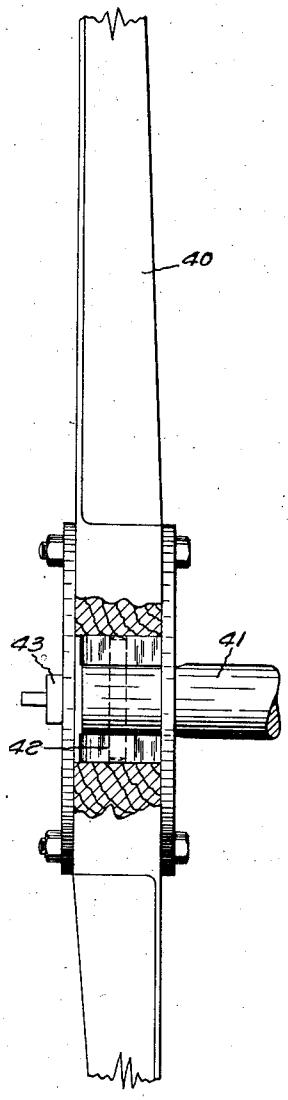

Fig. 5.

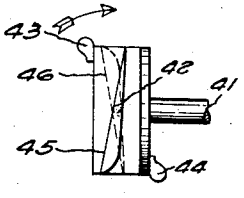

Fig. 8.

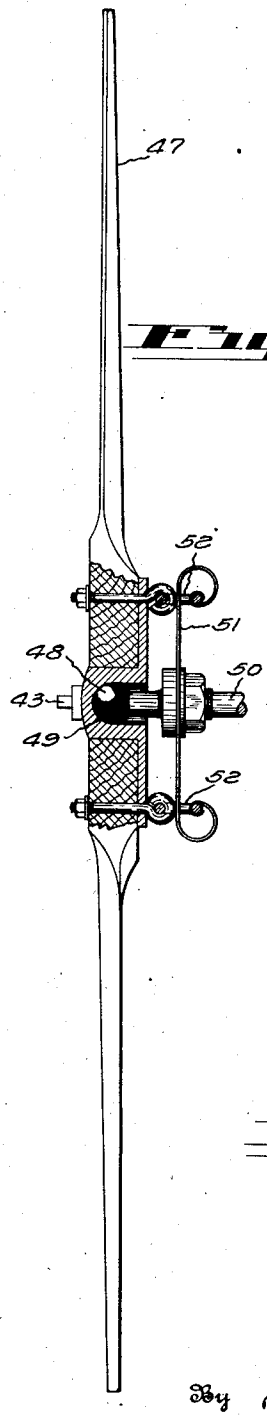

Fig. 6.

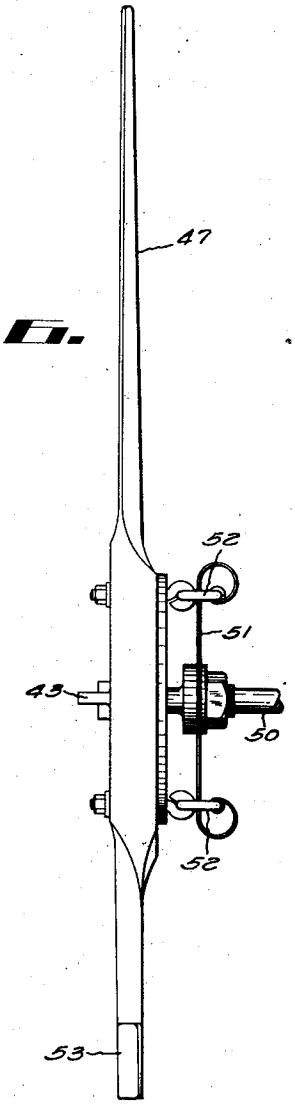

Fig. 7.

Inventor

Elisha N. Fales

By Marshall & Dehr

Attorneys

Patented Dec. 23, 1930 1,786,057

UNITED STATES PATENT OFFICE

ELISHA N. FALES, OF DAYTON, OHIO

TURBINE

Application filed July 14, 1924. Serial No. 725,894.

The present invention relates to wind or water turbines for utilizing the energy of wind or water to produce power which may be available for useful work.

One of the principal objects of the invention is to provide a high speed turbine, that is, a turbine in which a low wind velocity may be caused to produce a relatively high revolution speed of the shaft driven thereby.

Another object of the invention is to provide a turbine having a propeller provided with means for automatically reducing the efficiency or tip speed ratio of the propeller when excessive wind velocities are impressed upon the propeller in order to prevent undue increase in speed of the propeller shaft.

Still another object of the invention is to provide in a turbine having a propeller whose driving surface is or may be unsymmetrically positioned about the axis of turbine revolution, a construction and arrangement such as to inherently or automatically prevent lateral bending strains upon the propeller shaft under all conditions of operation.

Other objects of the invention will be apparent from the following description taken in connection with the accompanying drawings in which:

Fig. 1 is an elevation of a turbine having a single propeller pivoted to the propeller shaft on an axis substantially at right angles to the axis of the propeller blade.

Fig. 2 is a section on the line 2—2 of Fig. 1, parts being shown in elevation.

Figs. 3 and 4 are side and end elevations respectively of a turbine having two propellers.

Fig. 5 is a side elevation, with parts broken away, of a propeller pivoted about an axis substantially parallel with the axis of the propeller blade.

Fig. 6 is a part sectional and part elevational view of a two-bladed propeller having a universal connection with the propeller shaft.

Fig. 7 is an elevation of a propeller similar to Fig. 6 having but a single main working blade.

Fig. 8 is an end view of Fig. 5 and

Fig. 9 is a sectional view of a propeller blade having modified means for reducing the efficiency thereof.

Referring to Figs. 1 and 2, 20 denotes a propeller having a single blade 21 and a counter-weight 22, the counter-weight being herein shown as having the general outlines of a portion of a propeller blade, although it will be understood that the counter-weight may take any desired form. The propeller is secured at its hub to a supporting plate 23 having lugs 24 receiving therebetween the squared end of a sleeve or shaft 25, a pivot pin 26 connecting the shaft with the propeller as shown.

The blade of the propeller is designed with a very small blade pitch whereby a relatively small wind velocity will cause a rapid or high speed revolution of the propeller and the shaft 25. The best results thus far obtained have resulted from a propeller having a pitch of 3 degrees at the tip increasing to 10 degrees at the hub, while good results are obtainable from propellers having a pitch at the blade tip which may vary from 0 to 10 degrees, the corresponding pitch at the hub varying from 10 to 30 degrees. It will be understood that these dimensions may be varied as desired to meet different conditions. It has been found, also, as regards the shape of the blade that it is desirable that the blade should extend from the tip to the hub of the propeller, and further it has been found that the best results are obtainable in a blade in which the radius or length of the blade bears the ratio to the blade width of approximately six to one, although here again it is obvious that this ratio is susceptible of some variation in the hands of a person skilled in the art. The shaft 25 may be supported in suitable bearings and operatively connected with any apparatus to be driven thereby. In the present application the propeller is illustrated as mounted on the shaft of generator 27. It will be apparent that the high speed wind turbine herein disclosed, wherein a shaft speed of say 500 or 1000 R. P. M. may be produced with a wind velocity of about 15 miles per hour, is particularly suit-

able for driving such apparatus as electric generators, which may be designed to operate effectively at the shaft speeds mentioned.

It has been stated that an object of the invention is to provide a single blade propeller which does not transmit lateral bending strains to the propeller shaft under any operating condition. This object may be accomplished by pivotally mounting the propeller upon the propeller shaft so as to permit rotational or backward and forward movement of the propeller about the axis of the pin 26 which lies in the plane of the propeller passing through the center of gravity thereof and which pin is disposed substantially at right angles both to the longitudinal axis of the propeller blade and the axis of the shaft 25. Of course, the propeller is so constructed and mounted that its center of gravity lies in the axis of the shaft 25. The centers of gravity of the blade 21 and the counter-weight 22 may be assumed to be at the points 28 and 29 respectively at some distance from the axis of the propeller shaft 25. Upon revolution of the propeller the blade 21 and the counter-weight 22 tend to rotate about the pin 26 in such a direction that their centers of gravity 28 and 29 respectively will lie in a plane at right angles to the axis of the shaft 25, as indicated by the arrows passing through 28 and 29. The plane just referred to is indicated by the lines 30, 31 passing through the axis of the pin 26. However, the force of the wind on the propeller blade 21, which may be termed the aerodynamic force, tends to thrust the blade backwardly out of the plane 30, 31 until there is a balance between the aerodynamic force of the wind and the centrifugal force of the rotating propeller tending to move the propeller into the plane 30, 31.

The position of the propeller when driving a load under the influence of a 15 mile wind may be assumed to be the position illustrated in the drawing. Now should the load increase, causing the propeller to slow down, the centrifugal forces will decrease, and it is obvious that the propeller blade will move backwardly under the influence of the aerodynamic thrust taking position slightly back of the position illustrated. It will be observed from the above description that the propeller assumes various balanced positions in accordance with variations in the driving wind or the load; and it does so without transmitting to the shaft 25 any bending strains such as would tend to cause vibration. The pressure of the wind on the propeller thus offset against the centrifugal forces of the material, therefore results in a simple thrust pressure along the shaft 25.

In the above description it has been assumed that the aerodynamic forces upon the counter-weight 22 are negligible. However, when the counter-weight 22 takes the form of a short blade, as herein illustrated, the effect of aerodynamic forces upon it may be appreciable, and the propeller may then be considered as having two blades of unequal surface, and the aerodynamic forces as being unsymmetrically distributed on the propeller. The means herein disclosed for relieving the shaft of bending strains is adequate for counter-balancing any unsymmetrical distribution of the aerodynamic forces on the propeller whether the latter is of the type known as the single bladed type or whether it is of the multibladed type. While the counter-balancing action is herein described as taking place as a result of the movement of the blade about a pivotal axis, it is obvious that any means which permits movement of the center of gravity of a blade to effect the counter-balancing action herein described comes within the spirit of the present invention, and further it is apparent that the blade or propeller need not necessarily be pivoted to the shaft but may have inherent flexibility or be otherwise constructed to effect the desired result.

Fig. 5 shows a form of the invention in which the propeller 40 is pivotally connected with the propeller shaft 41 by a pin 42 which is disposed longitudinally of the axis of the propeller blade. As shown in Fig. 8 the propeller is provided with counter-weights 43 and 44 which lie on opposite sides of the central plane of the propeller, and which have the tendency, upon revolution of the propeller, to turn the propeller about the axis of the pin 42. At normal wind pressures this form of the propeller may be assumed to take approximately the position shown in Figs. 5 and 8. However, with excessive wind velocities resulting in increasing speed of the propeller shaft, the counter-weights 43 and 44 come into action by reason of their centrifugal force to rotate the blade in a clock-wise direction as indicated by the arrow in Fig. 8. The pitch of the upper blade 45 is thus increased thereby tending to reduce the speed of the propeller. The pitch of the lower blade 46 is decreased and the blade is moved out of its position of maximum efficiency. The effect of rotation of the propeller about the axis 42 is thus seen to decrease the efficiency of the propeller as a whole thereby reducing to some extent the effect of high wind velocities which might cause damage to the wind turbine itself or to the apparatus driven by the propeller shaft 41. It will be seen that this apparatus provides means for automatically reducing the tip speed ratio of the propeller, that is, the ratio of the tip speed to the wind speed.

Figs. 6 and 7 illustrate a form of the invention embodying both of the rotational movements disclosed in Figs. 1 and 5, that is, the propeller 47 may rotate about an axis at right

angles to the longitudinal axis of the propeller blade and also about an axis coincident with the longitudinal axis of the propeller blade. This freedom of motion is obtained by providing the propeller with a hub having a spherical socket or bearing surface 48 which is adapted to receive therein the cooperating spherical ball 49 carried by the shaft 50. Motion is transmited from the propeller 47 to the shaft 50 by means of a suitable spring 51 which is non-rotatably secured to the shaft 50 and which is connected at its ends by means of links 52 to the hub portion of the propeller the connection being such as to hold the propeller in normal position with respect to the longitudinal axis of the propeller blades, but to permit rotation about this axis when centrifugal force overcomes the spring restraint, or to permit rotation about an axis at right angles to the axis of the propeller blades. Fig. 7 shows a single bladed propeller similar to the two bladed propeller disclosed in Fig. 6, one of the propeller blades being shortened or otherwise of special form and provided with a weight 53 to form a counter-weight for the other blade.

Fig. 9 shows an alternative means for reducing the efficiency or tip speed ratio of a propeller blade upon an undesirable increase in the speed of revolution in the propeller as a result of increased wind velocity impressed upon the propeller. The blade 55 is provided with a passage or opening 56 extending through the blade from the front to the rear surface thereof. The end of the passage is closed at normal speed by a plate of spring material 57 fastened at one end and lying flush with the front surface of the blade, and the rear opening of the passage is normally closed by a light fin 58 pivoted at 59 and lying in the rear surface of the blade. A flexible connection or cable 60 is connected between the plate 57 and the pin 58 as illustrated. Upon excessive speed of the blade in the direction indicated by the arrow 61, the free end of the spring member 57 moves out of the front surface of the blade and holds the fin 58 in an angular position which may vary according to the speed of revolution of the propeller, thereby introducing excessive resistance to the motion of the blade and reducing its efficiency. Means is thus provided for automatically reducing the efficiency of the propeller to prevent any undue increase in the revolution speed or R. P. M. of the wind turbine or of the apparatus driven by the turbine and possibly causing damage thereto.

Figs. 3 and 4 illustrate a form of wind turbine having two propellers 32 and 33 mounted upon the propeller shaft 34, the propellers being arranged to revolve in offset or parallel planes, and in such relation with one another that there is a minmum of mutual interference between the two propellers; that is, so that each blade, in its helical motion through the air encounters to a minimum extent the wake of the other blade. The blade 32 may be mounted directly upon the shaft 34 or upon a sleeve secured to the shaft, in the manner illustrated in Figs. 6 and 7. The propeller 33 is mounted upon a sleeve 35 which is free to rotate or slide on shaft 34, connected thereto only by means of a coiled spring 36, the sleeve 35 being free to rotate upon the shaft except as it is limited by the spring 36. The blades 32 and 33 are herein shown as disposed at an angle of 180 degrees from one another which may be assumed to be their relative position when the apparatus is at rest. During normal operation in a wind of say 15 miles per hour the pressure of the wind upon the blade 33 causes it to advance or rotate with respect to the shaft 34 and to assume a position with its axis on the line 34, 37. The blade 33 is now behind the blade 32, as viewed in Fig. 4, to the extent indicated by the angle 38, 34, 37. If this relative position of the blades 32 and 33 is assumed to be the one developing maximum power for given load and wind values then it is obvious that any movement of the blade 33 from the line 34, 37 will result in such interference as to decrease the output of the two blades or in other words to decrease the efficiency or tip speed ratio of the two blades. Advantage is taken of this to reduce the effect of a high wind velocity or pressure such as would result in excessive speed of the unit. The operation under high wind pressures is illustrated in Fig. 4 wherein the blade 33 is assumed to have advanced to the position indicated by the line 34, 39 in which position the blades 32 and 33 develop less power than when they are disposed at the angle 38, 34, 37. Suitable yielding means may be provided to hold the turbine blades normally in relation 38, 34, 37.

While the forms of apparatus herein described constitute preferred embodiments of the invention, it is to be understood that the invention is not limited to these precise forms of apparatus, and that changes may be made in either without departing from the scope of the invention which is defined in the appended claims.

What is claimed is:

1. In a wind driven apparatus of the character described, a shaft, a two bladed propeller mounted thereon for revolution about the axis of said shaft, said propeller being mounted for movement at right angles relative to the axis of said shaft and the longitudinal axis of the blades and having such unsymmetrical distribution of its mass and form with relation to the axis of said shaft as to automatically counter-balance variously changing aerodynamic forces upon the propeller, which are unsymmetrically distributed relative to the axis of said shaft.

2. An air driven propeller of the class de-

scribed having a plurality of aerofoil blades differing in size and having their centers of gravity respectively at different distances from the axis of revolution, the propeller having such unsymmetrical distribution of its mass and form as to automatically counterbalance unsymmetrically distributed aerodynamic thrust forces on the propeller to produce a resultant propeller force in line with the axis of rotation.

3. An air driven propeller of the class described having an aerofoil blade on one side of the propeller axis and a weight member on the other side thereof, said blade and weight member differing in size and having their centers of gravity respectively at different distances from the axis of revolution, means pivotally supporting said blade and weight member for movement about an axis angularly related to both the propeller axis and the blade axis, the propeller having such unsymmetrical distribution of its mass and form as to automatically counterbalance unsymmetrically distributed aerodynamic thrust forces on the propeller to produce a resultant propeller force in line with the axis of rotation.

4. In an air driven propeller of the class described having a plurality of rigidly connected aerofoil blades, a shaft, means for pivotally connecting the propeller with the shaft to rotate about an axis substantially coincident with the longitudinal axis of a blade and about another axis angularly related to the shaft axis, the distribution of the masses of the blades and the blade form being such that unsymmetrical aerodynamic thrust forces on the propeller blades when set at different angles will produce a resultant propeller force substantially in line with the axis of rotation.

5. In an air driven propeller of the class described having a plurality of rigidly connected aerofoil blades, a shaft, means for pivotally connecting the propeller with the shaft to rotate about an axis substantially coincident with the longitudinal axis of a blade and about another axis angularly related to the shaft axis, the distribution of the masses of the blades and the blade form being such that unsymmetrical aerodynamic thrust forces on the propeller blades when set at different angles will produce a resultant propeller force substantially in line with the axis of rotation, and means exerting a positioning force on said blades.

6. In an apparatus of the character described, a shaft, a fluid driven propeller on the shaft having a blade, and means for pivotally mounting the propeller on the shaft for rotation about an axis angularly related to the shaft axis and transverse to the longitudinal axis of the blade.

7. In an apparatus of the character described, a shaft, an air driven propeller on the shaft having a blade, means for pivotally mounting the propeller for rotation about an axis substantially transverse to both the shaft and the longitudinal axis of the blade, said propeller having such unsymmetrical distribution of both mass and form with relation to the axis of rotation as to automatically counterbalance unsymmetrically distributed air thrust forces on the propeller at different positions on said first axis for the production of a resultant propeller force in line with the axis of rotation.

8. In an apparatus of the character described, a shaft, an air driven propeller on the shaft having a blade, means for pivotally mounting the propeller for rotation about an axis substantially transverse to both the shaft and the longitudinal axis of the blade, and also for rotation about the longitudinal axis of the blade, said propeller having such unsymmetrical distribution of both mass and form with relation to the axis of rotation as to automatically counterbalance unsymmetrically distributed air thrust forces on the propeller at different attitudes on the shaft for the production of a resultant propeller force in line with the axis of rotation.

9. In an apparatus of the character described, a shaft, a plurality of fluid driven propellers mounted on the shaft to revolve in separate areas which are axially displaced along the shaft, the propellers being commensurate in size so as to have a large overlap in the fluid areas operating thereon, and means for automatically varying the distance between the blade of one propeller and the blade of another propeller in accordance with the aerodynamic forces on the blades.

10. A wind driven propeller comprising a plurality of blades adapted to rotate about an axis transverse to the axis of rotation of the propeller, and centrifugal force means for tending to increase the angle of attack of one blade and decrease the angle of attack of the other.

11. In an apparatus of the character described, a shaft, a fluid driven propeller on the shaft having a blade adapted to revolve in a plane at right angles to the axis of the shaft, and means for pivotally mounting the propeller on the shaft for movement about an axis substantially at right angles to the axis of the shaft and angularly related to the blade axis, said second mentioned axis lying in the plane of the propeller which passes through the center of gravity thereof, and said propeller having such unsymmetrical distribution of its mass or form as to automatically counterbalance unsymmetrically distributed aerodynamic forces upon the propeller.

12. In an apparatus of the character described, a multi-bladed fluid driven propeller having its blades rigidly connected together, a shaft, means for pivotally connecting the propeller with said shaft to rotate about an

axis extending substantially lengthwise of a propeller blade, and means for exerting various forces on said blades tending to turn them about said axis to increase the angularity of one blade and decrease the angularity of the other.

13. In an apparatus of the character described, a multi-bladed fluid driven propeller having its blades rigidly connected together, a shaft, means for pivotally connecting the propeller with said shaft to rotate about the longitudinal axis of one of the blades, and about another axis angularly related to the shaft axis, and additional means exerting a positioning force on said blades.

14. In an apparatus of the character described, a multi-bladed fluid driven propeller having its blades rigidly connected together, a shaft, means for pivotally connecting the propeller with said shaft to rotate about an axis transverse to the axis of said shaft, and means for exerting various forces on said blades for governing the position of the propeller on said shaft.

15. In an apparatus of the character described, a multi-bladed wind driven propeller having its blades rigidly connected together, an axial support for the propeller, means for dissimilarly varying the pitch of the several blades, and spring means for exerting various forces tending to maintain the blades at the same pitch.

16. In an apparatus of the character described, a multi-bladed propeller having its blades rigidly connected together, an axial support for the propeller, means connecting said propeller to said support for movement about a plurality of axes thereon and spring means acting on said propeller to control its movement about the said axes and govern the position of said propeller on said axial support.

17. In an apparatus of the character described, a multi-bladed air driven propeller having its blades rigidly connected together, an axial support for the propeller, and weight means carried by the propeller for automatically changing the pitch of the blades according to the velocity of revolution of the propeller to increase the angularity of one blade while decreasing the angularity of another.

18. In an apparatus of the character described, a bladed wind driven propeller, a shaft therefor, and means for supporting the propeller on the shaft for universal movement thereon.

19. In an apparatus of the character described, a bladed wind driven propeller, a shaft therefor, and means for movably connecting the propeller with the shaft for movement thereon about a plurality of axes to automatically counterbalance unsymmetrically distributed forces, said connecting means having cooperating spherical bearing surfaces forming a universal joint carried by the shaft and the propeller respectively.

20. In an apparatus of the character described, a bladed propeller, a shaft therefor, means for supporting the propeller on the shaft for universal movement thereon, and yielding means for restraining movement of the propeller relatively to the shaft.

21. In an apparatus of the character described, a shaft, a plurality of fluid driven propellers mounted on the shaft to revolve in separate planes at right angles to the axis of the shaft, and means for automatically varying the angular distance between the blade of one propeller and the blade of another propeller in accordance with the areodynamic forces on the blades.

In testimony whereof I hereto affix my signature.

ELISHA N. FALES.