Nov. 28, 1939.

C. B. CHUPP

2,181,477

AERIAL DEVICE

Filed Aug. 1, 1936

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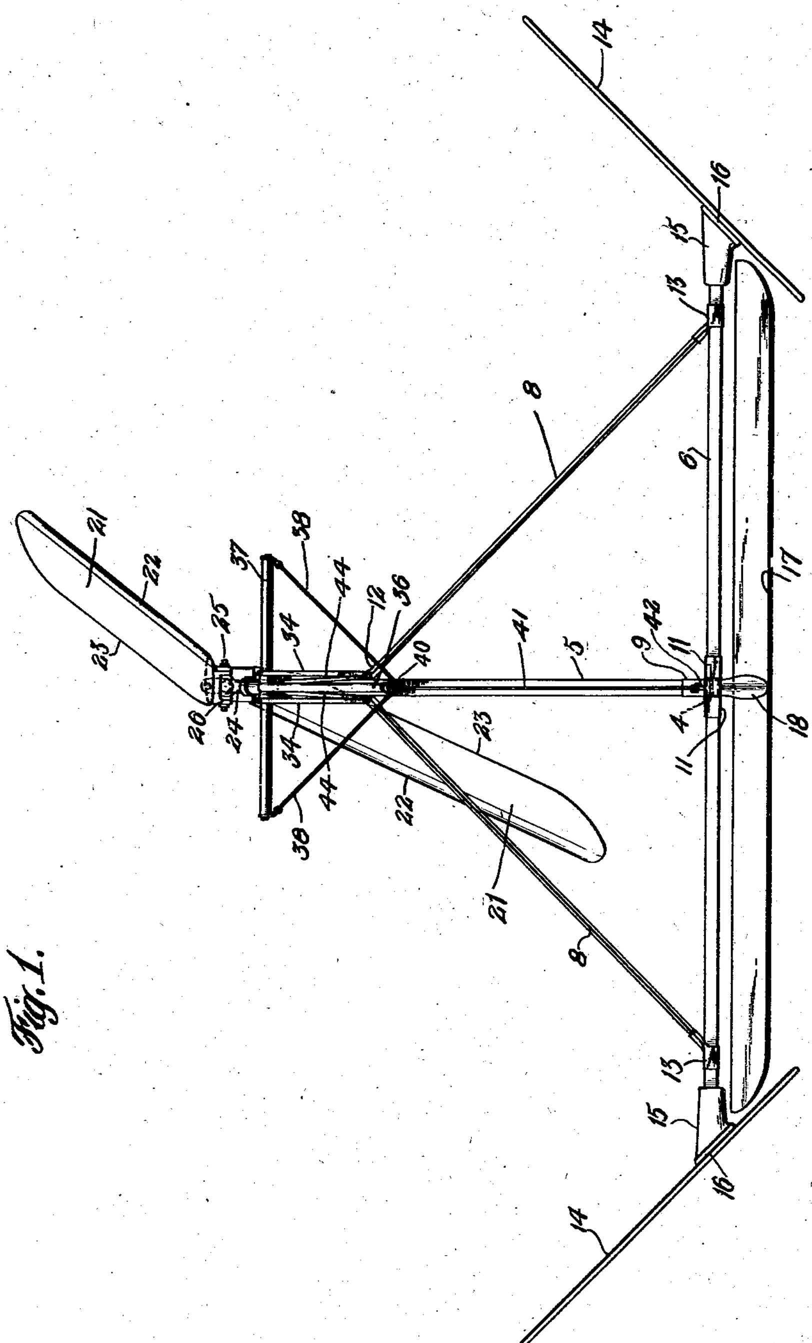

Fig. 1.

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Nov. 28, 1939. C. B. CHUPP 2,181,477

AERIAL DEVICE

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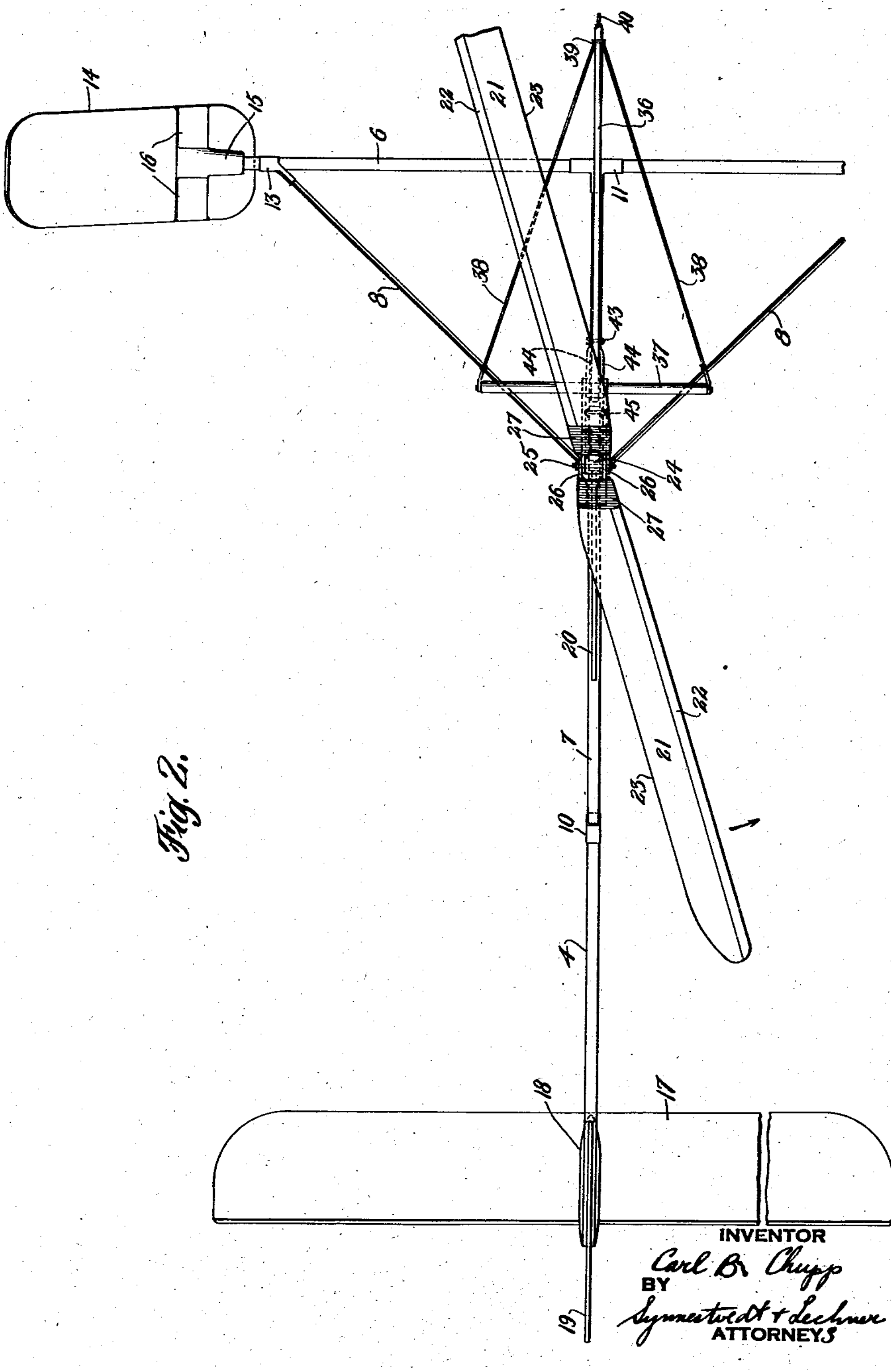

Fig. 2.

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Filed Aug. 1, 1936　　4 Sheets-Sheet 3

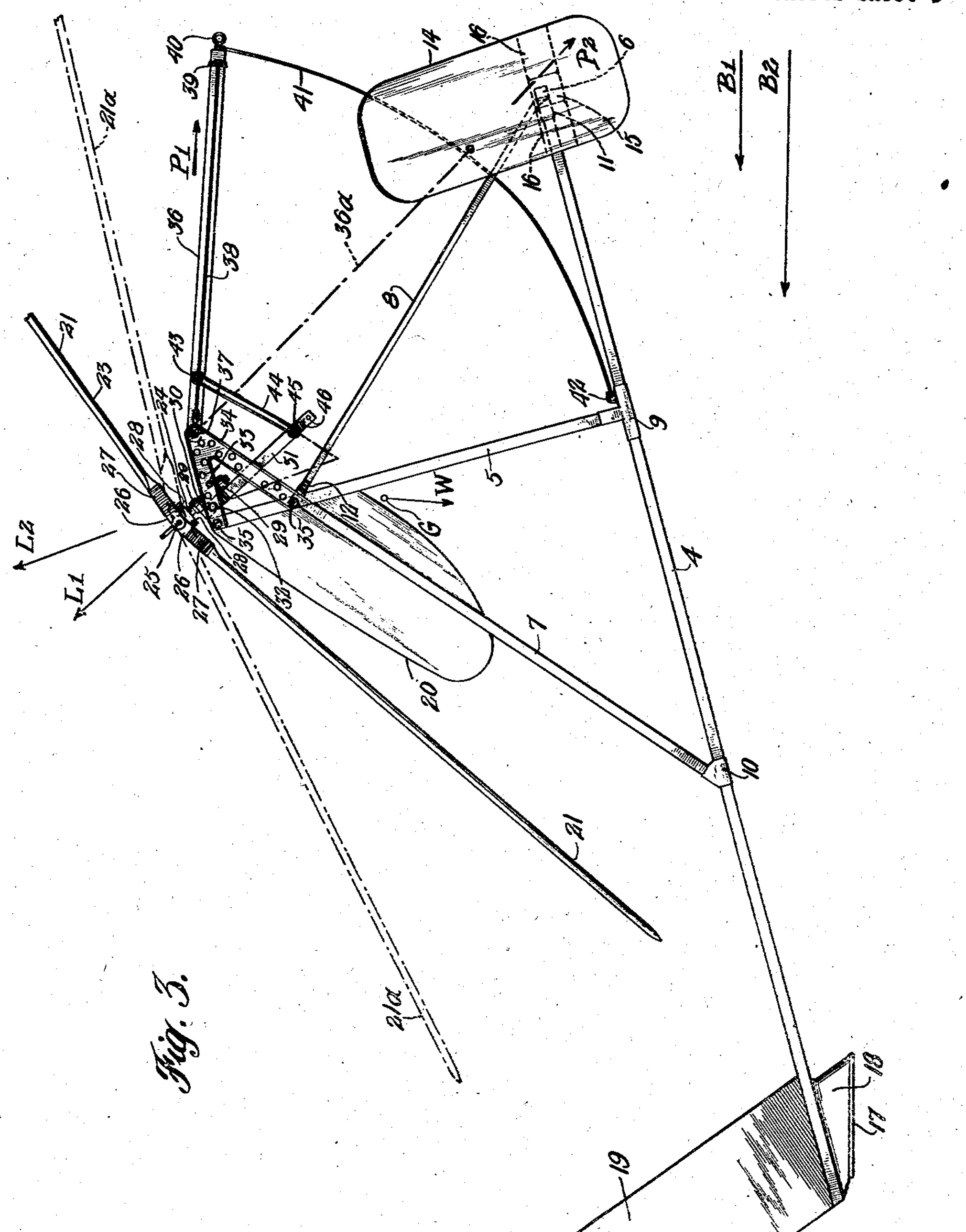

Fig. 3.

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AERIAL DEVICE

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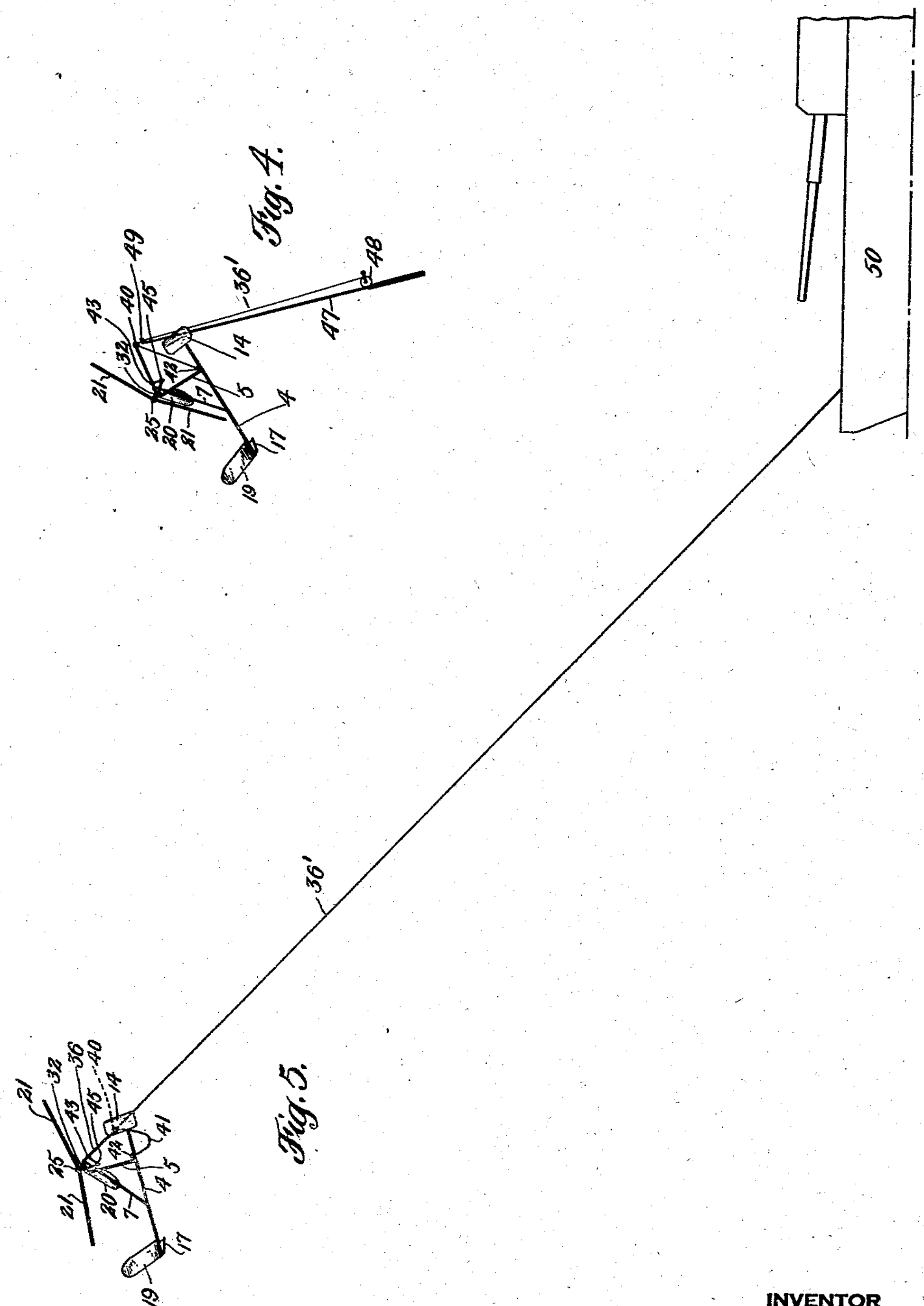

Fig. 4.

Fig. 5.

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Patented Nov. 28, 1939

2,181,477

UNITED STATES PATENT OFFICE

2,181,477

AERIAL DEVICE

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Application August 1, 1936, Serial No. 93,833

31 Claims. (Cl. 244—154)

This invention relates to aerial devices, primarily captive flight devices (although in certain aspects it is capable of use also in machines adapted for free flight), and to methods of flying such devices; and it is concerned especially with devices which may be generaly classed as kites, the invention being particularly directed to kites or similar aerial devices having rotative sustaining blades.

One of the primary objects of the invention is to provide an aerial device, particularly of the captive type, which is capable of sustension by virtue of breezes of extremely low velocity.

Another important object of the invention is to substantially improve the stability of such devices.

Still another object is to render it possible for the operator to exert a measure of control over the kite, particularly through the intermediation of the kite string.

Still further, the invention contemplates: the provision of a kite in which all or a part of the sustension is obtained by means of one or more freely revolving rotors; the movable mounting of the blades thereof, particularly for flapping and also desirably for some pitch variation; the movable mounting of the axis of the kite rotor, preferably by pivotation thereof; the obtaining of proper longitudinal balance, stability and control by means of said rotor and/or its movable mounting; and the interconnection or other coordination of the pivoted rotor axis with the kite string or its connecting means.

Still further, the invention contemplates the coordination, in a captive aerial device, of an autorotative sustaining and stabilizing rotor and nonrotative stabilizing and/or sustaining surfaces, in a novel and effective manner; the provision of means for adjustably locating the fulcrum of the rotor axis on the kite relative to the center of gravity thereof as well as relative to the nonrotative surfaces; the provision of means for adjusting the interconnection between the kite string and the tilting rotor axis; and the provision of means for adjusting the kite to fly at various desired altitudes in breezes of varying strength, preferably by means of one or more of the adjustment devices just mentioned, and/or by means providing for substitution of rotor blade elements of different contour and/or size.

Among other features contemplated by the invention are: improvements in the autorotative sustaining blades themselves and in the frame or rigid structure of the device; and in general the provision of a kite of sturdy construction, attractive appearance, and considerable efficiency, at relatively low cost.

Still further, the invention involves an improved method of flying such kites.

How the foregoing objects and advantages are obtained, together with such others as may be incident to the invention or may occur to those skilled in the art, will be evident from the following description taken together with the accompanying drawings, in which drawings:

Figure 1 is a front elevational view of the captive aerial device of the present invention in its present preferred embodiment;

Figure 2 is a top plan view thereof, with portions broken away;

Figure 3 is a side elevational view of the device, in a typical flight attitude with respect to the horizontal;

Figure 4 illustrates the device in association with a preferred form of launching and handling mechanism; and

Figure 5 is an illustration of a man-carrying kite constructed in accordance with the present invention, showing its use in association with a naval vessel.

Referring first to Figs. 1 to 3, the frame of the device comprises a central longitudinal member 4, a central upright member 5 spaced from the front end of the longitudinal member about one-third (or slightly less) of the length thereof, a main transverse member 6 located at the extreme forward end of the longitudinal member, one rearward diagonal member 7 bracing the member 5 to the member 4, and two forwardly and laterally diverging members 8, 8, bracing the upright member 5 to the transverse member 6. While the frame members may be made of aluminum alloy or other suitable tubing, and joined in any desired manner, I have shown them as being made from wooden sticks, joined by small aluminum fittings 9, 10, 11, 12, 13, etc.

The device is provided at its forward end with lateral stabilizing means, comprising a pair of fixed surfaces 14, one at each side of the craft, set at a substantially positive dihedral angle (a suitable angle having been found to be 45° with respect to the horizontal). These surfaces may be made of thin flat sheets of balsa wood, or the like, and they are secured respectively to the ends of the main cross members 6, as by means of a rounded wooden block 15, bored to receive the end of the stick 6 and flared outwardly at 16, 16 to form a pad or brace which is glued to the surface 14. The location of these surfaces sufficiently far forward to place their centers of pressure in front of the thrust line of the rotor throughout the range of angles of the latter (viewed in side elevation) appears to be of some importance in preventing nosing-over of the craft.

For stabilization in pitch, there is provided adjacent the rear end of the longitudinal member 4 a transverse tail surface 17, also of balsa wood, which is secured beneath the stick 4 as by means of a faired or smoothed wooden block 18; the tail plane 17 being desirably about equal to the area of the two lateral planes 14 combined, and being set at a substantially negative angle of incidence (for example 15°) considered with relation to the angle of incidence of the planes 14 when viewed in the direction of the longitudinal axis of the stick 4. Furthermore, the negative tail setting is negative with relation to a plane perpendicular to the axis of the rotor (hereinafter to be described) throughout the range of adjustment of the latter. Considered in another way, when the tail plane is flying approximately horizontally the surfaces 14 and the angle of attack of the rotor are both positive.

For directional, and also to some extent for lateral, stability, I provide a vertical stabilizing fin 19, of high aspect ratio, which is also of balsa wood and may be let into a slit at the rear end of the stick 4; and for a similar purpose I may supplement the vertical tail fin 19 with a fin 20 extending rearwardly and downwardly from the upright post or pylon 5, and secured in the member 7 by being let through a vertical slit therein. It seems, by test, to be suitable to make the combined areas of the two vertical fins approximately equal to the area of the tail plane or to the combined areas of the lateral stabilizing surfaces. The surface 19 is given a rearward rake and surface 20 a downward inclination, primarily in order to provide ample clearance for the rotor blades now to be described.

The rotor may be made up of two elongated blades or wings 21, having an overall span about equal to the overall length of the craft, the aspect ratio of each blade being about 12 or 13. I have found it satisfactory to make these of balsa wood strips, with an approximately flat under surface and a slightly cambered upper surface, the leading edge portion of the blade, however, as indicated at 22 being preferably formed of a narrow strip of more robust wood, such as spruce, which strengthens the blade and brings the sectional center of gravity a little further forward. The blades may be initially set at a slight positive angle of incidence, when at rest, as indicated by the position of the trailing edge 23 (Figure 3). They are secured to the hub 24 by means of a pivot 25, which passes through a transverse aperture in the hub and through a pair of ears 26 for each blade, these ears or forks being desirably made as metal fittings between which the root end of the blade is placed, suitable means being employed to secure the root end into the forked fitting, such as small dowels and/or gluing, the assembled root end being preferably bound round with thread or wire, as shown at 27. As clearly seen in Figure 2 the axis of the flapping hinge 25 makes an acute angle (preferably just a little less than a right angle) with the leading edge of the blade, the direction of rotation being indicated by an arrow, so that as the blades flap upwardly they decrease their incidence slightly. The root end of each blade has secured on its under face a small rubber bumper or the like 28, so that when the blades drop slightly below the true radial position they are supported against the hub 24.

The rotor hub 24 is mounted, as by small ball bearings (the casings of which are shown at 29, 29) in a non-rotative tubular sleeve 30. The non-rotative sleeve 30 is strapped or otherwise secured to an extension or stick 31 which is pivoted by a fulcrum 32 (offset rearwardly from the rotor hub axis) and mounted in one of the holes 33 which are formed in the V-shaped aluminum bracket 34 which is secured at 35, 35 to the upright stick 5. The bracket 34 in the embodiment shown, is actually composed of two separate plates, one positioned on either side of the upright member 5, the hub 30 also fitting between said plates, with its pivot 32 extending as a through-bolt through both plates as well as the hub extension stick 31. Said stick 31 also lies between the two plates of the bracket 34 and extends downwardly therebelow. The location of the rotor axis may be variously adjusted by shifting the fulcrum 32 to various of the holes 33, as will be referred to later on.

At the forward corner of the V-shaped bracket there is a stick 36, the end of which fits between the two plates of the bracket and is pivoted therein by means of a cross stick or dowel 37, from the outer end of which guide wires or bracing cords 38 extend downwardly and forwardly to a point of connection with the lower end of the stick 36, where said bracing cords may be secured thereto as by a cord or wire winding 39. At the extreme lower or forward end of the stick 36 there is screwed into the stick or otherwise secured thereto a ring member 40, or any other suitable means for attaching the kite string. Also secured at this point is a flexible stay cord 41, which at its other end is secured, as by a screw-eye 42 to the frame of the device, preferably to the longitudinal base member 4.

The kite string connection or stick 36 may swing in a longitudinal vertical plane, between a lower position indicated by the dot and dash line 36a and an upper position limited only by the length of the stay cord 41 (which in Figure 3 is shown as still somewhat slack).

Intermediate its ends but relatively close to its upper end, the stick or rigid tow-member 36 has a pivotal connection 43 to one end of a link member 44, the other end of which is pivoted at 45 to the lower portion of the rotor hub extension 31, adjustment holes 46 being provided, in order to regulate the relative angles between the rotor axis and the stick 36, and to alter the geometry of the linkage. For convenience the link 44 is made of two aluminum strips, as shown in Figures 1 and 2, one lying on each side of the members 36 and 31, the pins 43 and 45 serving as through-bolts.

From the foregoing description it will be seen that changes in the angular position of the stick 36 on its fulcrum 37, due to variations in the pull on the kite string. either by the action of the operator or by virtue of change in wind velocity will always be accompanied (assuming for the moment a fixed attitude of the frame of the device) by a tilting of the axis of the rotor hub 24 about its fulcrum 32. Furthermore, because of the differences in the distances between the several fulcrums 32, 37, 43, and 45, in the embodiment shown, the range of rotor tilt is reduced somewhat from the range of the tilt of the kite string connecting arm 36. In other words, the linkage between the pivoted lever 36 and the pivoted rotor hub is designed to produce a somewhat smaller range of angular variation of the rotor axis for a given angular movement of the stick 36, which seems to produce somewhat smoother flying of the kite.

In operation, looking at the device in Figure 3, and assuming that there is a very light breeze blowing in the direction of the arrow B1, the kite string will extend in the direction of the stick 36, at a very slight inclination to the horizontal, the stick being substantially in the full line position shown. Under these conditions the rotor axis will be tilted upwardly and rearwardly, the axis extension 31 being in the position shown in full line so that the rotor as a whole has a very high angle of attack with respect to the relative air flow B1. The pull of the kite string will, of course, be substantially in the direction of the axis of the stick 36 indicated by the arrow P1, (i. e., along a line extending to the rear of the rotor center, which is the point of intersection of the rotor axis with the blade axes) and the lift of the rotor will lie close to the axis of the hub, in the direction of the arrow L1.

The weight of the machine will be acting through the center of gravity G (which lies substantially below and slightly behind the rotor fulcrum) such weight acting in the direction of the arrow W. For a given wind velocity, the rotor axis will take such a position about its fulcrum that the lift thrust L1 will lie at a position of equilibrium between the thrusts P1 and W.

With a substantial increase in the breeze, as represented for example by the arrow B2, the thrust of the rotor will increase and raise the machine to a higher altitude, until the thrust line L2 assumes a new position of equilibrium between the direction of pull P2 of the kite string (which is now forwardly of the rotor center) and the weight of the machine acting in the direction W; the rotor hub tilting about its fulcrum 32 to the necessary position of equilibrium. The angle of attack of the rotor indicated by the dot and dash line position of the blades at 21a will at the same time be reduced by virtue of the linkage connecting the rotor axis with the kite string stick 36. The stiffer the breeze, the greater will be the thrust of the rotor, and the angle of the kite string will steepen as the breeze increases; the kite under some conditions, attaining a position directly over the head of the operator.

It may be here noted that the blades 21 in their full line position and also in their dot and dash line positons 21a are shown at their drooped angle which is the angle of rest, but it will be understood that in actual flight, when the rotor is turning, the individual blades will assume angles inclined upwardly from a true radial position on the hub as they are at all times free to flap on the pivot axis 25 to positions of equilibrium between the lift and centrifugal forces acting on the blades, the average upward coning angle being about 6° with respect to a plane perpendicular to the axis of rotation.

Let us assume now that the kite is again flying in a breeze of the velocity B1. If a sudden wind gust or acceleration occurs, the rotor will speed up and its thrust acting in the direction L1 is increased in magnitude. This creates a substantial moment arm acting about the kite stick fulcrum 37, turning the body of the kite (viewed in Figure 3) in a clockwise direction, thus raising the tail. An increase in negative lift at the tail plane then occurs, and restores the machine to a position of equilibrium. If the increase in wind velocity should continue the kite will, of course, rise to a higher altitude, remaining in a position of equilibrium. Similarly, by jerking upon the kite string and by paying it out and drawing it in, the operator can cause the device to perform various antics, and fly momentarily at various altitudes.

With further reference to operation of the device, it will be noted that a very stiff wind, causing the kite to fly higher, tends to level off the rotor, i. e., reduces its general angle of attack. Similarly, if the wind is such as to cone the blades upwardly excessively on their flight pivots, the individual blades have their pitch reduced by virtue of the angularity of the pivot axis 25. The device is further adjustable with respect to the light wind and high wind conditions, by shifting the rotor fulcrum point 32 forwardly and rearwardly to different holes 33, for high wind conditions the fulcrum being moved forwardly and for low wind conditions, rearwardly. The fulcrum may also be adjusted to different heights, to alter the relation of the rotor to the center of the gravity and with respect to other parts of the craft.

As before mentioned, the fins 19 and 20 are inclined, one rearwardly and the other downwardly. This not only gives ample room for rotation and flapping of the rotor blades but also for tilting of the rotor axis, without having said blades foul on said surfaces. In addition, it will be noted that this arrangement is such that blades of larger diameter may be substituted, if desired; for example, if extremely light winds are encountered; this being accomplished by pulling the root end of the wing out of the forked fitting, and substituting a new one.

I have found, in very light machines, that the range of wind velocities in which the device will fly, and the range of angles which the rotor may assume is substantially enlarged by some automatic variation of incidence of the blades (as is obtained by the angularity of their flapping pivot). Without this feature, the individual blades may cone up excessively and under some circumstances autorotation would cease. The obliquity of the flapping pivots, in conjunction with the tilting ability of the rotor axis, also improves the operation of the kite during launching and landing.

In considering longitudinal stability and balance, it should be noted that the arrangement provides that the upward thrust of the rotor normally lies between the downward component of the kite string thrust (which is forwardly located) and the downward thrust of weight and/or negative tail lift (which are rearwardly located). In considering the equilibrium of the rotor about its fulcrum, it should be noted that the thrust of the rotor constantly tends to tilt the rotor counterclockwise about its fulcrum 32, (viewed in Figure 3), and that the linkage mechanism is so arranged that this tendency is counterbalanced by the downward thrust component of the kite string. In considering directional stability, it will be observed that the pull of the kite string is located forwardly of the center of gravity and the stabilizing effect of the surfaces 19 and 20 is located rearwardly thereof. In considering the matter of lateral stability it should be noted that the dihedral surfaces 14 and the laterally rigid stick connection 36 cooperate to attain this end.

In general, as to the location of the various fulcrum points as seen in Figure 3, it seems desirable that the rotor blade fulcrum 25 intersect the axis of the rotor hub and be located above the level of the hub-tilting fulcrum 32, that the tilting fulcrum be located rearwardly of the hub axis and the stick fulcrum 37 be located substantially forwardly thereof and below the rotor center; and that the link 44 be fulcrumed at 43 below the fulcrum 37 and fulcrumed at 45 still farther below the fulcrum 32.

By reference now to Figure 4, it will be seen that I provide a launching and securing device comprising a pole 47 (such as a fishing rod) on which is mounted a reel 48, with the string 36' extending through an eye 49 at the end of said pole and coupled to the ring 40 of the stick 36. With the device suspended on the string at the tip end of the pole, it may be carried to the field of operations, the device hanging approximately in the position shown. As the wind catches the rotor blades, they will cone up steeply until they are individually at negative incidence, with the wind blowing directly through the rotor from its under side. As they commence to rotate and pick up speed, the blades pivot more nearly to a radial position on the hub and come gradually into a more normal range of incidence and the rotor axis to a more normal inclination, whereupon the string is paid out (at less speed than the breeze) and the kite commences to rise. When the kite is pulled in by winding up the string on the reel, it comes back to the tip of the pole thus avoiding damage to the kite and the possibility of the operator being struck by the revolving blades.

Referring now to Figure 5, it will be evident that by making this device of larger size, it can be used as a man-carrying observation kite, which can be launched from a vessel 50, such as a cruiser or battleship, the altitude of the observer being regulated, if desired, by varying the speed of travel of the vessel. While I have shown the towing or tethering means, i. e., rigid element 36 and the flexible element or cord 36', in direct alignment, it will be understood that the tow-line normally flexes somewhat under the pressure of the breeze.

Various modifications may, of course, be made, within the spirit and scope of the following claims, and the invention is therefore not limited in its broad aspects to the exact arrangement shown, nor to the exact proportions and relationship of the parts as described, nor to the constructional materials referred to. The preferred embodiment has been described in considerable detail purely by way of example and not by way of limitation, in order to render it easy for anyone following this description to carry the invention into practice.

I claim:

1. A captive flight device comprising a body, a sustaining rotor having autorotatable pivotally mounted blades and a generally upright hub, a tilting fulcrum for the rotor located rearwardly of the hub axis and providing for longitudinal tilt of the rotor, direction and attitude stabilizing surfaces located on the body behind the rotor axis and lateral stabilizing surfaces located on the body forward of the rotor axis, the center of gravity of the entire device being rearwardly of the rotor tilting fulcrum, a towing member flexibly connected to the body forwardly of the rotor axis, and means for restraining the tilting of the rotor.

2. A captive flight device comprising a body, a sustaining rotor having autorotatable pivotally mounted blades and a generally upright hub, a tilting fulcrum for the rotor located rearwardly of the hub axis and providing for longitudinal tilt of the rotor, direction and attitude stabilizing surfaces located on the body behind the rotor axis and lateral stabilizing surfaces located on the body forward of the rotor axis, the center of gravity of the entire device being rearwardly of the rotor tilting fulcrum, a towing member flexibly connected to the body forwardly of the rotor axis, and means connecting the towing member and the rotor axis to coordinate their movements.

3. A captive flight device including a frame, a bladed sustaining rotor constituting the primary means of sustension for the device, a non-rotative stabilizing surface located to the rear of the rotor axis and positioned at an angle of incidence which is in flight substantially negative with respect to a plane perpendicular to the axis of the rotor, and towing means coupled to said frame forwardly of the rotor axis.

4. A captive flight device including a frame, a bladed sustaining rotor constituting the primary means of sustension for the device, the rotor being mounted for movement to different angles of incidence in a fore and aft plane, and a non-rotative stabilizing surface located to the rear of the rotor axis and normally positioned in flight at an angle of incidence which is substantially negative with respect to a plane perpendicular to the axis of the rotor throughout the entire range of incidence adjustment of the rotor.

5. A captive flight device including a frame, a bladed sustaining rotor constituting the primary means of sustension for the device, a non-rotative stabilizing surface located to the rear of the rotor axis and positioned at an angle of incidence which is substantially negative with respect to a plane perpendicular to the axis of the rotor, and means responsive to fluctuations in velocity of air flow to increase the angle of incidence of the rotor as a whole upon decrease in velocity of air flow, and vice versa.

6. A captive flight device including a frame, a bladed sustaining rotor constituting the primary means of sustension for the device, a non-rotative stabilizing surface located substantially rearwardly of the rotor axis and positioned at an angle of incidence which is in flight negative with respect to a plane perpendicular to the axis of the rotor, a pair of sharply dihedraled stabilizing surfaces laterally spaced toward opposite sides of the axis of the rotor, and a flexible towing apparatus coupled to the device forwardly of the rotor axis.

7. A captive flight device including a frame, a bladed sustaining rotor mounted on the frame with freedom for movement in a fore and aft plane to different angles of incidence, and mechanism for controlling the angle of incidence of the rotor including a member adapted to cooperate with the captivating means for the device.

8. A captive flight device including a body, a bladed sustaining rotor mounted on the body with freedom for tilting movement in a generally fore and aft plane, a member pivotally mounted on the frame having means adapted to cooperate with the captivating means, and mechanism interconnecting the said member and the rotor to provide for tilting of the rotor upon pivotal movement of said member.

9. A captive flight device incorporating a tow-member, a bladed sustaining rotor and stabilizing surfacing, the device being adapted to flight in air flow of different velocities, and the rotor and the said surfacing being relatively positioned and arranged to set up stabilizing moments in the

longitudinal vertical plane in opposite senses with respect to the pull of the tow-member, whereby to provide an attitude of substantial equilibrium for any given velocity of air flow.

10. A frame for a rotor-kite, comprising a single main longitudinal member adapted to mount tail surfaces at its rear end, a single main upright member secured to the longitudinal member intermediate its ends and adapted to mount the rotor at the top, and a single main transverse member positioned forwardly of the upright member and secured intermediate its ends to the longitudinal member and adapted to carry lateral stabilizing surfaces at its outer ends.

11. In a captive aerial device or the like, a frame or body, a freely revolving rotor mounted on a generally upright axis at the top of said frame, positively dihedraled stabilizing surfaces located at each side of the frame well forwardly of the rotor axis, and a towing member flexibly coupled to the frame rearwardly of said surfaces.

12. In a captive aerial device or the like, a frame or body, a freely revolving rotor mounted on a generally upright axis at the top of said frame, positively dihedraled stabilizing surfaces located at each side of the frame well forwardly of the rotor axis, directional and pitch stabilizing surfaces located on the frame rearwardly of said rotor axis, and a towing member flexibly coupled to the frame rearwardly of said dihedraled surfaces.

13. In a captive aerial device or the like, a frame or body, a freely revolving rotor mounted on a generally upright axis at the top of said frame, said axis being forwardly of the center of gravity, positively dihedraled stabilizing surfaces located at each side of the frame well forwardly of the rotor axis and center of gravity, a tow-member coupled to the frame forwardly of the center of gravity, and a fulcrum about which the rotor axis is tiltable in a fore and aft direction, the range of rotor tilt and the forward location of the lateral stabilizing surfaces being so related that throughout the range of rotor tilt the lift-line of the rotor lies behind the center of pressure of said lateral stabilizing surfaces.

14. In a captive aerial device or the like, a frame or body, a freely revolving rotor mounted on a generally upright axis at the top of said frame, positively dihedraled stabilizing surfaces located at each side of the frame forwardly of the rotor axis, directional and pitch stabilizing surfaces located on the frame well rearwardly of said rotor axis, and a fulcrum about which the rotor axis is tiltable in a fore and aft direction, and said directional stabilizing surface extending upwardly in a region behind the path swept by the rotor to provide ample clearance throughout the range of rotor tilt.

15. In a captive aerial device or the like, a frame or body, a freely revolving rotor mounted on a generally upright axis at the top of said frame, positively dihedraled stabilizing surfaces located at each side of the frame well forwardly of the rotor axis, and directional and pitch stabilizing surfaces located on the frame rearwardly of said rotor axis, said pitch stabilizing surface being set at negative pitch with relation to the setting of the lateral stabilizing surfaces.

16. In a captive flight device, an autorotatable sustaining rotor including a rotative spindle mounted in a non-rotative sleeve or casing, a mounting structure for the rotor, a fulcrum for tiltably securing said sleeve in said mounting structure, means for towing or tethering the device, and means for adjusting the rotor fulcrum point to different heights on said mounting structure.

17. In an aerial device, a frame or body, a rotatable sustaining rotor thereabove having a downwardly extending hub or axis located forwardly of the center of gravity of the device, a transverse pivot axis mounting said hub on the frame for longitudinal tilt of the rotor, and a towing member secured to said frame forwardly of the rotor axis.

18. In an aerial device, a frame, a rotatable sustaining rotor thereabove having a downwardly extending hub structure, a transverse pivot axis mounting said hub on the frame for longitudinal tilt of the rotor, a towing member secured to said frame forwardly of the rotor axis, said tilting axis being positioned rearwardly of the rotor axis, and an interconnection between the towing member and the rotor axis to control the tilt of the latter in accordance with the variations in position of the former.

19. In an aerial device, a frame, a rotatable sustaining rotor thereabove having a downwardly extending hub structure, a transverse pivot axis mounting said hub on the frame for longitudinal tilt of the rotor, a towing member secured to said frame forwardly of the rotor axis, said tilting axis being positioned rearwardly of the rotor axis, and an interconnection between the towing member and the rotor axis to control the tilt of the latter in accordance with the variations in position of the former, said interconnection comprising linkage coupled to the tow-member and to the rotor axis structure at points respectively below the point of connection of said member to the frame and the point of tilting of the rotor axis.

20. In an aerial device, a frame, a rotatable sustaining rotor thereabove having a downwardly extending hub structure, a transverse pivot axis mounting said hub on the frame for longitudinal tilt of the rotor, a towing member secured to said frame forwardly of the rotor axis, said tilting axis being positioned rearwardly of the rotor axis, an interconnection between the towing member and the rotor axis to control the tilt of the latter in accordance with the variations in position of the former, said interconnection comprising linkage coupled to the tow-member and to the rotor axis structure at points respectively below the point of connection of said member to the frame and the point of tilting of the rotor axis, and means for adjusting the geometry of said linkage.

21. In an aerial device, a frame, a sustaining rotor thereabove having a downwardly extending hub or axis structure, a transverse fulcrum positioned behind the rotor axis and mounting the same on said frame for longitudinal tilt, a rigid tow-member extending downwardly and forwardly, and a transverse pivot securing its upper end to said frame in a position in front of said rotor axis, and motion multiplying means coupling the rotor axis to the tow-member so that a given angular tilt of the rotor axis is accompanied by a greater angular movement of the tow-member.

22. In an aerial device, a frame, a sustaining rotor thereabove having a downwardly extending hub or axis structure, a transverse fulcrum positioned behind the rotor axis and mounting the same on said frame for longitudinal tilt, a rigid tow-member extending downwardly and forwardly, a transverse pivot securing its upper

end to said frame in a position in front of said rotor axis, motion multiplying means coupling the rotor axis to the tow-member so that a given angular tilt of the rotor axis is accompanied by a greater angular movement of the tow-member, and means at the forward lower end of the tow-member for securing the same to a kite string or the like.

23. In an aerial device, a frame, a sustaining rotor pivotally mounted thereon for longitudinal tilting of the rotor axis, a tow-member pivotally mounted on the frame for pivotation in the vertical longitudinal plane but restrained as against lateral pivotation, and means interconnecting the rotor axis and the tow-member.

24. In an aerial device, a frame, a sustaining rotor pivotally mounted thereon for longitudinal tilting of the rotor axis, a tow-member pivotally mounted on the frame for pivotation in the vertical longitudinal plane but restrained as against lateral pivotation, means interconnecting the rotor axis and the tow-member, and means limiting the range of pivotation of the tow-member.

25. In a captive flight device, a frame, a tow-line secured thereto, and an autorotatable sustaining rotor comprising a hub and blades arranged to flap individually with respect to said hub, said blades having means for effecting automatic reduction in pitch of the individual blades under the influence of upward flapping thereof, and said hub having means providing for automatically controlled variation of the angular position of the hub, within the vertical longitudinal plane, with respect to the frame, whereby to accommodate variations in wind velocity.

26. In a captive flight device, a frame, a tow-line secured thereto, an autorotatable sustaining rotor comprising blades and a hub, said blades having means for effecting automatic variation in pitch of the individual blades, said hub having means providing for automatic variation of the angular position of the hub, within the vertical longitudinal plane, with respect to the frame, whereby to accommodate variations in wind velocity, and means formed as a rigid part of the tow-line pivoted to the frame and having an interconnection with the hub whereby to coordinate the pivotal movement of the latter and of the tow-member.

27. In a captive flight device, an autorotative sustaining rotor, a towing element having flexible connection to the device at a point forwardly of the rotor axis and above the center of gravity of the device, and a negative tail surface rearwardly of the rotor axis and of the center of gravity.

28. In a captive flight device, an autorotative sustaining rotor comprising an axis member and a plurality of rotor blades pivoted thereon, a towing element having pivotal connection to the device about a transverse pivot located forwardly of the rotor axis and below the general point of intersection of the rotor blades and rotor axis, a tail surface located rearwardly of the rotor axis, a transverse fulcrum mounting the rotor axis for variation of the angle of said axis within the vertical longitudinal plane, and means coupling together the said towing element and rotor axis member so constructed that when the rotor is at high angles of attack the pull of said element is on a line passing rearwardly of said point of intersection and when the rotor is at low angles of attack the pull of said element is on a line passing forwardly of said point.

29. In a captive flight device, an autorotative sustaining rotor, a towing connection to the device forwardly of the rotor, a negative tail surface rearwardly of the rotor, and means for bodily shifting the position of the rotor axis.

30. A captive flight device comprising a body having stabilizing surfacing, a sustaining rotor having autorotatable pivotally mounted blades and a generally upright hub, means for shifting the lift-line of the rotor relative to the center of gravity of the device, and a towing member for the device coupled to the last named means to control the same.

31. In a captive flight device, a body, an autorotative sustaining rotor thereabove having an axis positioned forwardly of the center of gravity of the body, a towing connection to the device forwardly of the rotor axis, and means for bodily shifting the position of the rotor axis in the longitudinal vertical plane.

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