

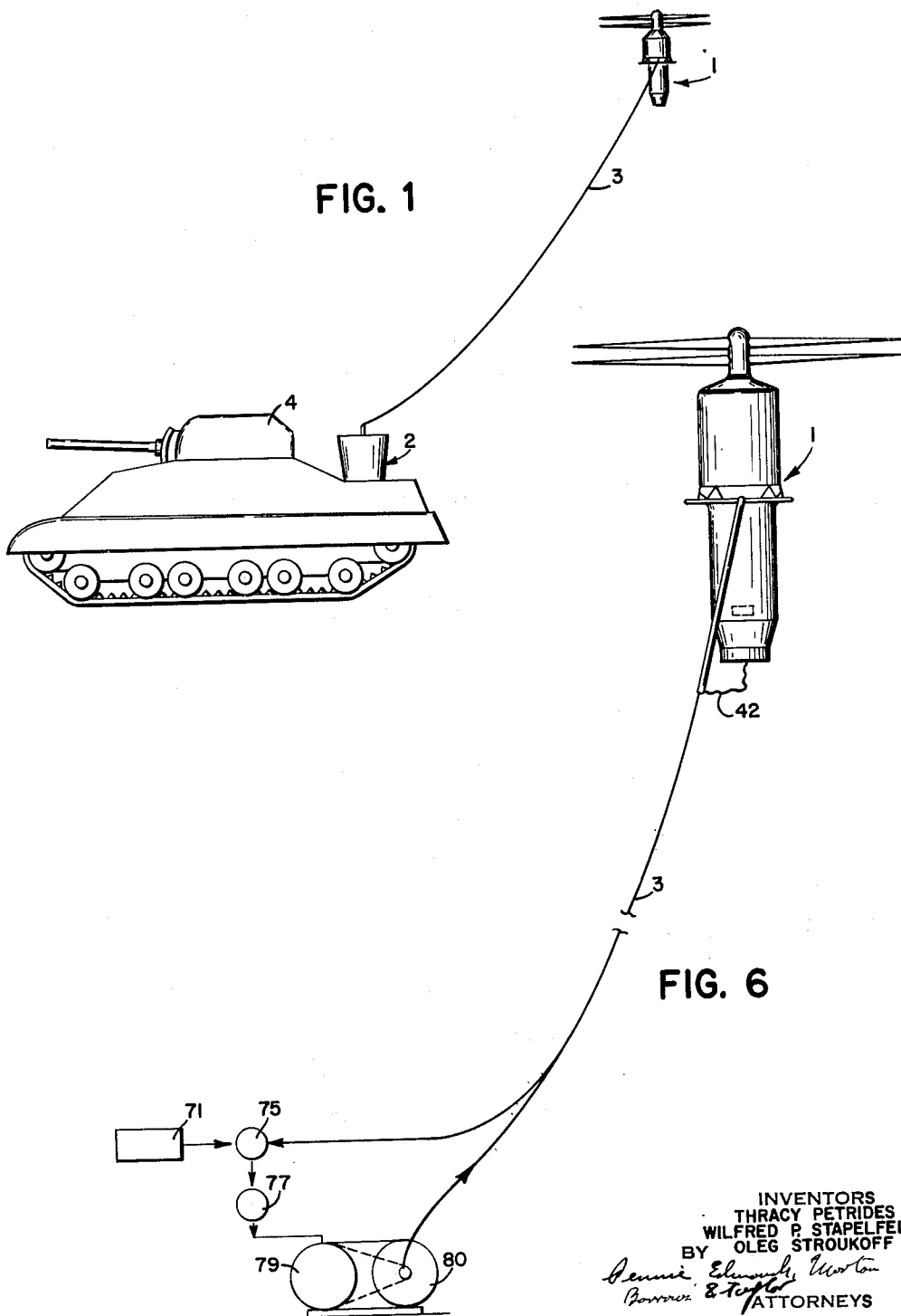
Sept. 22, 1964

T. PETRIDES ETAL
TETHERED HOVERING PLATFORM

3,149,803

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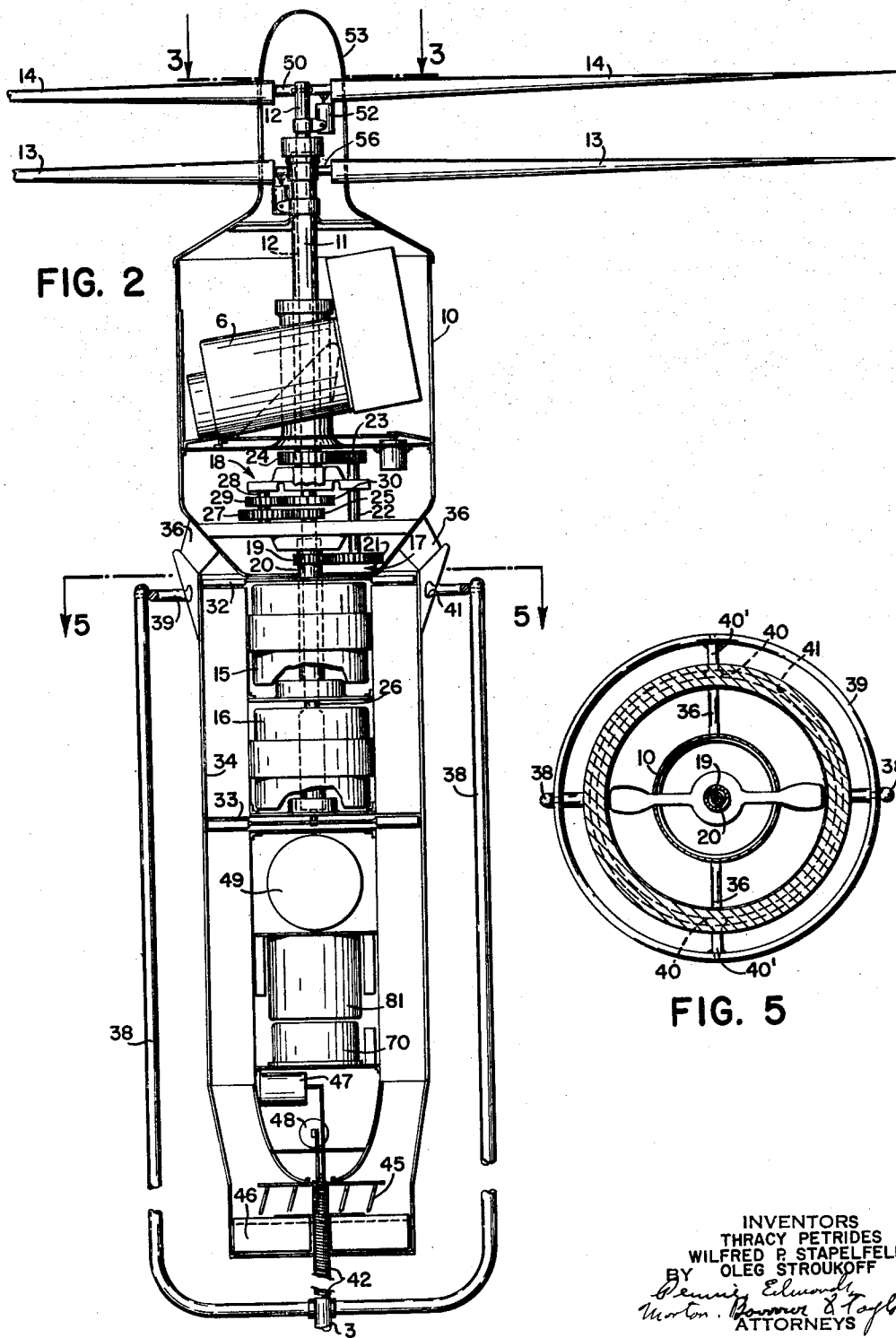


FIG. 5

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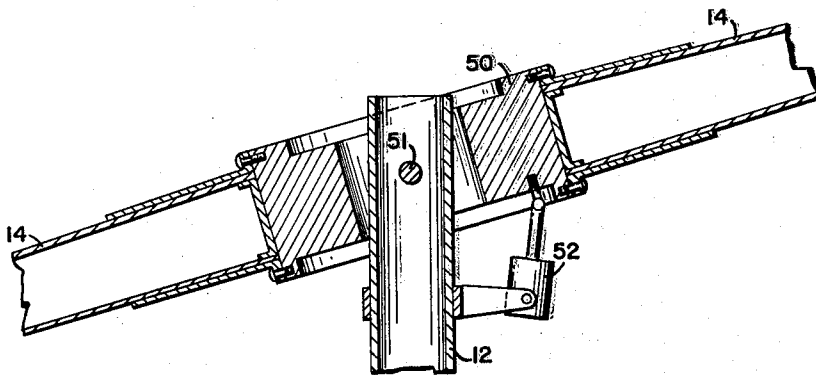
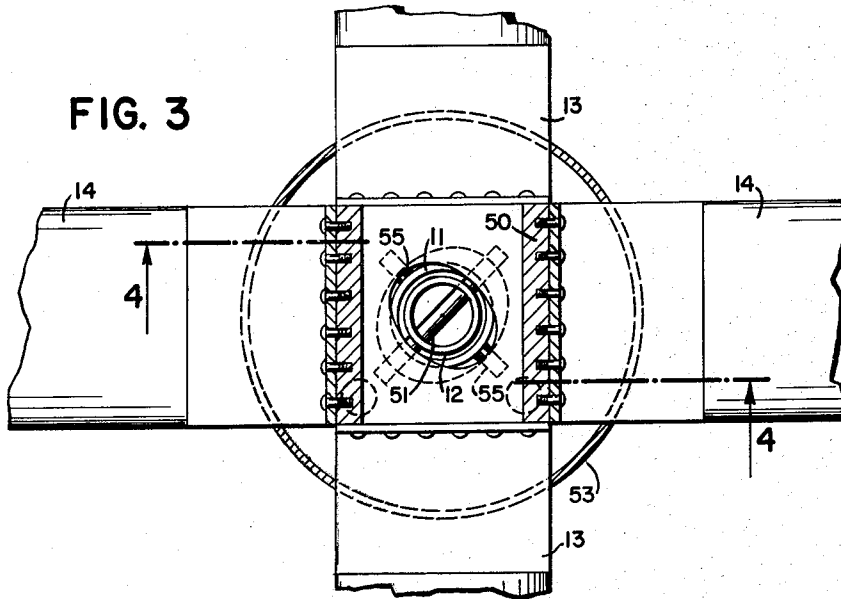


FIG. 4

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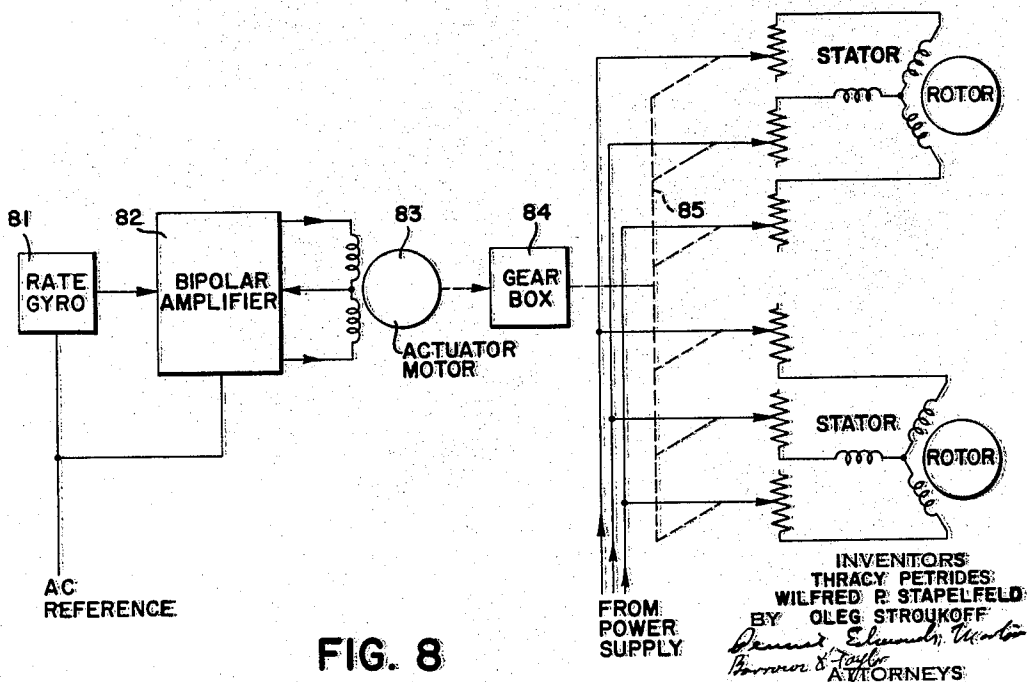
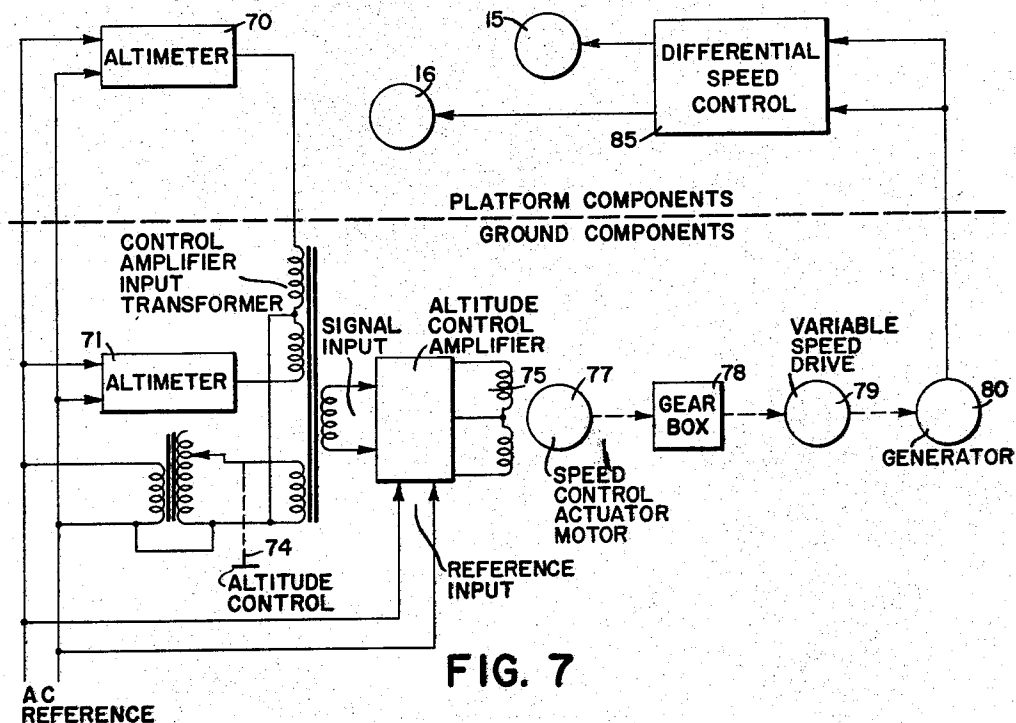
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3,149,803

TETHERED HOVERING PLATFORM

Thrace Petrides, New York, and Wilfred P. Stapelfeld, Jamaica, N.Y., and Oleg Stroukoff, Bogota, N.J., assignors to U.S. Industries, Inc., a corporation of Delaware

Filed July 19, 1961, Ser. No. 125,200

9 Claims. (Cl. 244—17.13)

This invention relates to a tethered hovering platform and more particularly to a hovering rotary wing platform receiving energy for rotating the wings from a ground power plant to which the platform is connected by a tethering cable.

Hovering platforms have been proposed to provide a means whereby the range of microwave equipment, such as television reconnaissance cameras, can be extended beyond that to which it is normally restricted by the curvature of the earth. By increasing the altitude at which microwave equipment may be positioned, the range of such equipment may be increased while at the same time any interfering objects, such as hills or buildings, overcome. Such equipment has particular application to military use wherein microwave equipment can take the form of a television or infrared receivers which may be used to spot targets beyond the range of comparable land based or fixed equipment.

Some platforms proposed have utilized rotating lifting blades which are rotated by means of wing-tipped mounted rocket or ramjet motors. A difficulty of such platforms is that of providing a sufficient fuel capacity in order to give the platform a reasonable hovering time while, at the same time, maintaining an adequate pay load for the platform. In addition, such platforms require elaborate ground support facilities and are easily detectable because of the high noise and heat levels at which they operate. Other platforms proposed, such as anchored balloons, do not provide a stable platform except under calm, no cross-wind conditions.

We propose to provide for a hovering platform which may be easily transported on the ground by means of a tank or other vehicle, which is compact in size, which will have an indefinite hovering duration, and which, at the same time, will have a sufficient pay-load capacity whereby the platform may carry sufficient microwave equipment either to receive or send information. The platform will further be stable and not subjected to adverse cross-wind effects.

Broadly, our platform comprises a body member having thereon coaxially rotatable driven shafts on which lifting blades are mounted at one end. The blades themselves are joined to the shafts in the manner described in an application filed in the United States Patent Office entitled Supersonic Rotary Wing Platform, filed June 26, 1961, inventors Thrace Petrides and Wilfred P. Stapelfeld, to provide yaw and pitch stability. The body member carries two electric motors which are connected to a ground power station by means of a tethering cable for counter-rotating the driven shafts. Control blades are mounted to the electric motor shafts so that they extend into a duct formed by a shroud which surrounds the lower part of the body. Movable control vanes are mounted in the duct in the downwash area below the control blades and are actuated by yaw and pitch sensitive actuators to provide additional yaw and pitch stability to the platform.

The tethering cable is gimbaled onto the body member by means of a yoke at a point which extends substantially through the center of gravity of the complete hovering platform so that any force on the cable will act through the center of gravity of the platform without effecting its stability. The tethering cable also contains wiring by

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which signals from the television receiver, infrared receiver, or other pay load may be transmitted to the ground and by which the speed of the electric motors may be controlled.

Preferably, the height of the platform above the ground is determined by the difference between readings of barometers contained on the platform and on the ground, whereby the difference in readings is used to control the speed of the motors and thus lift the rotating wings. In addition, means are provided for varying the relative speed of rotation of the two motors to provide roll stability to the platform.

Referring to the drawings in which a preferred embodiment of our invention is illustrated,

FIG. 1 is a view illustrating a hovering platform constructed according to our invention tethered to a mobile ground power unit;

FIG. 2 is an enlarged cross-sectional side view of the hovering platform of FIG. 1;

FIG. 3 is an enlarged cross-sectional plane view of FIG. 2 taken along lines 3—3 illustrating the hub construction of the rotor assembly;

FIG. 4 is a cross-sectional view of FIG. 3 taken along lines 4—4;

FIG. 5 is a cross-sectional view of FIG. 2 taken along lines 5—5;

FIG. 6 is a schematic figure illustrating a power plant supplying variable power to the platform;

FIG. 7 is a schematic of the altitude control system; and,

FIG. 8 is a schematic of the roll control system.

Referring in greater detail to the drawings and in particular to FIG. 1, 1 illustrates generally a hovering platform connected to a mobile ground power plant denoted generally by 2 by means of a tethering cable 3. In the form of the invention shown in FIG. 1, the mobile ground power plant is mounted on a tank 4 and the hovering platform is used to support a television reconnaissance camera 6 as shown in FIG. 2.

The platform 1 comprises a body portion 10 having therein coaxially rotatable driven shafts 11 and 12 which are concentric with the platform and on which are mounted lifting blades 13 and 14, respectively. The driven shafts 11 and 12 are rotated by means of electric motors 15 and 16 through means of speed reducing gear trains denoted generally by 17 and 18.

The gear train 17 comprises a spur gear 19 mounted on a hollow drive shaft 20 connected to the rotor of the electric motor 15. Gear 19 in turn meshes with a gear 21 mounted on a shaft 22 on which is also mounted a gear 23. Gear 23 in turn meshes with a gear 24 mounted on the hollow driven shaft 11 on which the lifting blades 13 are mounted. Gear train 18 comprises a spur gear 25 mounted on a drive shaft 26 which connects with the rotor of motor 16. Gear 25 in turn meshes with a gear 27 mounted on a shaft 28 and on which a gear 29 is also mounted. Gear 29 meshes with a gear 30 which in turn is mounted on driven shaft 12 on the end of which lifting blades 14 are mounted.

Also mounted on drive shafts 20 and 26 are control blades 32 and 33 which induce a downward flow of air between a shroud 34 surrounding the lower portion of the body member 10. The shroud 34 is connected to the body member 10 by means of struts 36 as shown in FIGS. 2 and 5.

The tethering cable 3 connects with the platform 1 through a yoke 38 which is gimbaled to the platform by pivotally connecting it to a ring member 39 so that it is free to pivot with respect therewith. Ring 39 in turn is pivotally connected to rollers 40 by shafts 40' where the rollers are free to roll in a track 41 contained in the body member with the result that yoke 38 is free

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to move in three dimensions with respect to the body member. The cable 3 is pigtailed at 42 so that the yoke can easily move with respect to the body portion and not be impeded by tension in the cable. The shafts 40' are so mounted with respect to the body member that they lie in a plane passing through the center of gravity of the platform and perpendicular to the vertical axis of the platform. Any force exerted by the cable will then pass through the center of gravity of the platform and not contribute to any upsetting or destabilizing moment. In the machine illustrated in FIG. 1, the center of pressure caused by cross flow of air passing around the sides of the platform coincides with the center of gravity of the complete platform since, as shown, the area or side silhouette of the platform subjected to cross flow above and below the center of gravity is substantially the same. It is apparent from the drawings that if the area subjected to cross flow on either side of the center of gravity was substantially different, the center of pressure would be raised or lowered with respect to the center of gravity with the center of pressure moving towards that portion of the platform having the greater area subjected to the cross flow. In order that upsetting moments would not be imparted to a platform having the center of pressure vertically positioned with respect to the center of gravity when it is subjected to cross flow such as when it is toward over the ground, the towing force should be applied through the center of pressure.

It is known that conventional rotary wing platforms are not inherently stable and that they require the application of continual control forces in order to insure pitch, yaw, and roll stability. The major destabilizing moments on rotary wing devices consist of pitch and yaw moments arising from relatively lateral motion between the rotor and surrounding air mass. This relative motion or cross flow arises from cross winds, platform oscillations, or platform manoeuvres as is the case of a tethered platform when the ground station is moved.

To provide stability to such a platform, moments must be available for counterbalancing the destabilizing moments. The yaw destabilizing moment arising from the fact that more lift is generated on an advancing blade rather than on a retreating blade under cross-flow conditions is eliminated when counterrotating rotors are used. Therefore, by having blades 13 and 14 counterrotating, moments about the vertical axis which occur when a single rotating rotor is used are eliminated and it is not necessary to use a tail rotor as used in conventional helicopters to compensate for unbalanced forces. For this reason, electric motors 15 and 16 are made counter-rotating. A further advantage of having the blades counterrotating is that swirl created by one blade is neutralized by the swirl created by the other blade.

The remaining pitching moment arising which even with counterrotating rotors under cross-flow conditions, can be counteracted either by cyclic blade control as is used in conventional helicopters or by supplying counter-acting moments to the tail or portion of the platform below the center of gravity. Cyclic blade control is undesirable where a simple, reliable, long-service life platform is required. Further the use of large aerodynamic tail surfaces are not desirable where the platform must be kept steady and in a vertical position. For this reason, we mount a plurality of movable yaw and pitch control vanes 45 and 46 in the downwash area of the control blades 32 and 33 so that yaw and stability control may be imparted to the platform. The control vanes 45 and 46 are moved by means of a yaw control actuator 47 and a pitch control actuator 48 which are connected by conventional linkage with the control vanes. The actuators 47 and 48 are in turn controlled by a vertical gyro 49 which establishes a pitch and yaw reference, the deviation from which moves the actuators. By utilizing the downwash caused by the control blades, a strong constant control force is assured by the control

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vanes with a minimum of control variance due to changes in downwash caused by the main lifting blades or by ground effect. The shroud, as shown, has a converging section at its lower end which creates a nozzle effect for the air passing therethrough so increasing its velocity over the vanes and thus increasing the effectiveness of the vanes.

Adverse destabilizing moments are also minimized by mounting the lifting blades to the driven shafts in the manner taught and fully explained in the prior-referred to application. Referring to FIGS. 3 and 4 which illustrate such mounting, it is seen that the upper lifting blades 14 are rigidly mounted to a hub member 50. A skew pin 51 is positioned on the shaft 12 so that it is perpendicular to the concentric axis of the shaft and skew with respect to the longitudinal axis of the blades 14. Hub 50 is journaled on the pin so that the blades 14 are free to rotate about the skew pin 51 upon the application of lifting force to the blades when they are rotated and are subjected to any cross wind. A damper 52 connects the hub member 50 to the shaft 12 to control the rate of movement of the hub and lifting blades about the pin 51. The complete hub assembly is protected by means of a nose cone 53.

While we have described mounting of only the upper lifting blades 14 to their driven shaft, it is to be understood that the lower lifting blades 13 are similarly mounted on the driven shaft 11 with the exception that a skew pin 53 about which the lower hub member 56 rotates does not extend completely through the shaft 11 but comprises two pins welded onto the shaft so that the lower hub may rotate thereon.

A further means of minimizing the control force necessary to stabilize the platform is to eliminate gyroscopic effects by having a net angular momentum of all rotating parts equal to zero or near to zero. This is accomplished by making the platform as symmetrical as can conveniently be done and by having equal weight counter-rotating parts. By minimizing gyroscopic effects, rapid control response is assured.

Altitude control of the hovering platform is maintained by varying the speed of rotation of the electric motors. Referring to FIG. 7 which illustrates an altitude control means, there is shown schematically a barometric element 70 carried by the platform and a corresponding element 71 carried on the ground which are also shown in FIGS. 2 and 6. A reference voltage is fed into both elements with the altitude reading of both elements being in turn fed into a control amplifier input transformer 72 as a voltage. An altitude control voltage in turn is manually set in the altitude control unit 74. The altitude control amplifier 75 is so constructed that the altitude control voltage determined by 74 is normally equal and opposite to the differences between the voltages of the two elements 70 and 71. The signal output due to the differences between the altitude control unit 74 and the control amplifier input transformer 72 is fed into an altitude control amplifier 75, and any change in the platform altitude or control voltage setting causes an error signal to be sent to the input of the altitude control amplifier. The altitude control amplifier in turn regulates a speed control actuator motor 77 which is connected by a gear box 78 to a variable speed drive unit 79 which in turn will vary the speed of a generator 80. Change of the frequency of the generator 80 will in turn vary the speed of electric motors 15 and 16 which are of the induction type.

It is further necessary to provide means for maintaining roll stability in the event the platform rotates about its vertical axis due either to outside forces being applied or because of slight differences in speeds of the two electric motors. For this reason, a roll gyro 81 is carried by the platform to establish a reference point, the deviation from which may change the speeds of rotation of the electric motors to provide a compensating moment to turn the platform about its vertical axis back to the reference point.

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Referring to FIG. 8 which illustrates schematically a roll control device for controlling relative speed of the electric motors, the rate control gyro 81 is shown connected to a reference voltage so that the gyro will send a voltage signal to a bipolar amplifier 82 upon any deviation from a fixed reference point. The voltage signal caused by deviation from the preset reference point is fed into the amplifier 82 which in turn controls an actuator motor 83. Difference in polarity and amplitude between the reference voltage and the voltage signal from the rate gyro activates the motor 83 which through a gear box 84 moves a differential motor speed control unit 85 to control current passing to the stators of electric motors 15 and 16 and thus control relative speed of the motors.

The various circuit arrangements described above and the components making up the roll and altitude control systems are conventional in design and are described only as a means of one way of controlling roll by varying the relative speed of the two motors and altitude by varying over-all speed of the two motors together.

The position of the platform with respect to the ground station can be controlled by reeling in or letting out the tethering cable. If the platform is to be moved relative to the ground, the ground station is moved whereby the tethering cable will pull the platform through the air. Since the tethering platform is connected to the hovering platform through its center of gravity, there are no destabilizing moments applied to the platform as it is moved. Any destabilizing moments caused by cross flow are counteracted by the control vanes 45 and 46 and by the mounting of the lifting blades on the skew pins of the driven shafts.

The electric motors 15 and 16 can be of the induction type. Such motors presently available are rated at approximately $2\frac{1}{2}$ horsepower each at a voltage of 400 volts. The r.p.m. of such motors is approximately 11,000 and their rotational speed controlled by varying the voltage or frequency. By using such motors, we have calculated that they will support a platform including payload of approximately 37 lbs. and 150' of cable weighing 13 lbs. giving a total weight of 50 lbs. The rotor or lifting blade diameter of such a platform would be approximately 36" while the over-all length of the platform would be 40". The tethering cable itself would contain a multiplicity of circuits and include the circuits for transmitting power to the electric motors from the ground generator, circuits to the television or other microwave equipment, and circuits to the necessary speed control and altitude control means. A reason that we can obtain such high power output relative to the weight of the motors is that the air caused to flow between the body portion and shroud by the control blades also serves to cool the motors.

The operation of the tethered platform is as follows: The operator on the ground first selects the desired observation altitude by making the appropriate setting on the control unit 74 which prescribes a given difference in readings of the ground based and platform-borne barometric elements. The launch sequence consists of getting the rotor up to speed, energizing the gyros 81 and 49 and releasing mechanical fittings which hold the platform to the launching platform mounted on the tank or other vehicle.

At full rotor r.p.m., the platform will climb to the desired observation altitude in 10-15 seconds, the trailing cable being paid out by a winch cable drum, not shown. During climb, the platform maintains its vertically and is stabilized in roll—e.g. remains oriented in a desired azimuth direction. If the launching vehicle is stationary and if there is a cross wind, the tethered platform will drift downwind always in a vertical stabilized position until restrained by the action of the tethering cable with wind drag forces on the platform being balanced by the horizontal component of cable tension. If the launching vehicle is in motion, the tethering cable will

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tow the platform and the platform will remain continuously automatically stabilized since the cable force acts through the center of gravity of the platform.

Upon completion of the observation mission, the tethered platform is winched back to the launch platform under positive lift, e.g. at full rotor r.p.m., to assure continued tail control effectiveness and to make the landing flight path as steep as possible in face of cross wind.

While we have described particular features of our platform in detail, it is obvious that structural changes could be made in such details as the precise means for maintaining altitude and roll control and still come within the scope of our invention.

We claim:

1. A tethered hovering platform comprising a symmetrical body member, two coaxially rotatable driven shafts extending vertically through said body member, lifting blades mounted on the upper end of each said driven shaft, electric motor means for rotating said shafts in opposite directions, a shroud surrounding the lower part of said body member, rotatable control blades extending into a duct formed between said body member and said shroud and being rotated by said electric motor means, movable control vanes mounted in said duct and in the downwash area of said control blades for imparting yaw and pitch stability to said platform, a tethering yoke gimbaled onto said body member through substantially the center of gravity of said hovering platform, and cable means extending from said body member through said yoke to an electric power supply unit whereby electric power is supplied to said electric motors to rotate said lifting blades and control blades.

2. A tethered hovering platform according to claim 1 having in addition altitude responsive means for varying the speed of rotation of said electric motors whereby said hovering platform will maintain a predetermined altitude above ground.

3. A tethered hovering platform according to claim 2 wherein said altitude responsive means comprises a first barometric unit in said platform, a second barometric unit on the ground, and an altitude regulating means for varying the power supplied to said electric motor means in response to the difference in barometric pressure between said first and second units.

4. A tethered hovering platform according to claim 1 having in addition speed reducing gears connecting said driven shafts with said electric motor means whereby the speed of rotation of said lifting blades is less than the speed of rotation of said electric motor means.

5. A tethered hovering platform according to claim 1 wherein said tethering yoke comprises a U-shaped member surrounding the lower part of said body member, a ring surrounding said body member substantially along a plane passing through the center of gravity of said hovering platform and connected to the open arms of said U-shaped member, track means on the outer periphery of said body member in a plane passing through the center of gravity of said hovering platform, and pin means connecting said ring to said track member whereby said ring and U-shaped member may rotate relative to said body member.

6. A rotary wing vertical takeoff and hovering aircraft adapted to provide a relatively stable platform at a predetermined distance over the ground comprising a body portion symmetrical about a vertical axis, two rotatable drive shafts coaxial with each other and with said vertical axis, a plurality of lifting blades connected to the upper end of each said shaft to provide lifting rotors for said aircraft, electric motor means symmetrical about said vertical axis and connected to said rotatable driven shafts to rotate them in opposite directions, two drive shafts coaxial with said vertical axis and connected to said electric motor means, a plurality of control blades mounted on the lower end of each said drive shafts, a shroud surrounding the lower part of said body portion

such that said control blades extend into a space between said shroud and said body portion, control vanes in said space for providing yaw and pitch stability positioned below and in the downwash area of said control blades, a gimbaled tethering yoke connected to said hovering platform wherein its point of connection passes through the center of pressure of said hovering platform, cable means extending from said electric motor means and passing through said yoke, and electric generator means connected to said electric motor means by said cable to provide electric power to said electric motor means whereby said lifting rotors may be rotated to lift said hovering platform and whereby said hovering platform may be moved horizontally over the ground by exerting a pulling force on the cable.

7. A hovering aircraft according to claim 6 having gyroscopic control yaw and pitch units for moving said control vanes to provide yaw and pitch stability to said aircraft.

8. A hovering aircraft according to claim 7 wherein the blades comprising each said rotor are rigidly connected to a hub and wherein each said hub of each said lifting rotor is journaled to a skew pin carried on the upper end of each said shaft and extending normal to the longitudinal axis of each said shaft and skew to the longitudinal axis of said blades.

9. A ground anchored rotary wing aircraft comprising a body member symmetrical about a vertical axis, two coaxial rotatable driven shafts concentric with said axis, a hub for each said driven shaft, a plurality of lifting blades rigidly mounted on each said hub, a skew pin

carried on the upper end of each said shaft extending normal to said vertical axis and about which a hub is journaled with the skew pin associated with a hub being skew to the longitudinal axis of the blades mounted on that hub, drive means for counterrotating said driven shafts, a tethering yoke gimbaled onto said body member so that its point of connection to said body member extends through the center of pressure of said aircraft, a tethering cable connecting said yoke to the ground, a spaced shroud surrounding the lower portion of said body member, counterrotating control blades extending into the space between said shroud and body member and being rotated by said drive means, movable control vanes connected to said body member extending in the downwash area of said control blades and being surrounded by said shroud, and gyroscopically controlled actuators for moving said control vanes to impart yaw and pitch control to said aircraft.

References Cited in the file of this patent

UNITED STATES PATENTS

1,491,997	Messick	Apr. 29, 1924
2,479,549	Ayres	Aug. 23, 1949
2,995,740	Shreckengost	Aug. 8, 1961
2,996,269	Parry	Aug. 15, 1961
3,071,335	Carter	Jan. 1, 1963

FOREIGN PATENTS

612,551	Canada	Jan. 17, 1961
864,986	France	Jan. 3, 1940