United States Patent [19]

Kling

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[54] **PRECESSOR FLYING CRAFT**

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[22] Filed: **Sept. 29, 1971**

[21] Appl. No.: **184,891**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 845,381, July 28, 1969, Pat. No. 3,633,849.

[30] **Foreign Application Priority Data**

Feb. 25, 1969 Germany............................ 1909447

[52] **U.S. Cl.**................ **244/23 C,** 416/189, 416/193

[51] **Int. Cl.**.. **B64c 29/00**

[58] **Field of Search**............. 244/12 C, 23 C, 17.23, 244/17.21, 17.19, 17.11, 17.13; 416/189, 128, 129, 193, 210; 46/72, 75, 82–85

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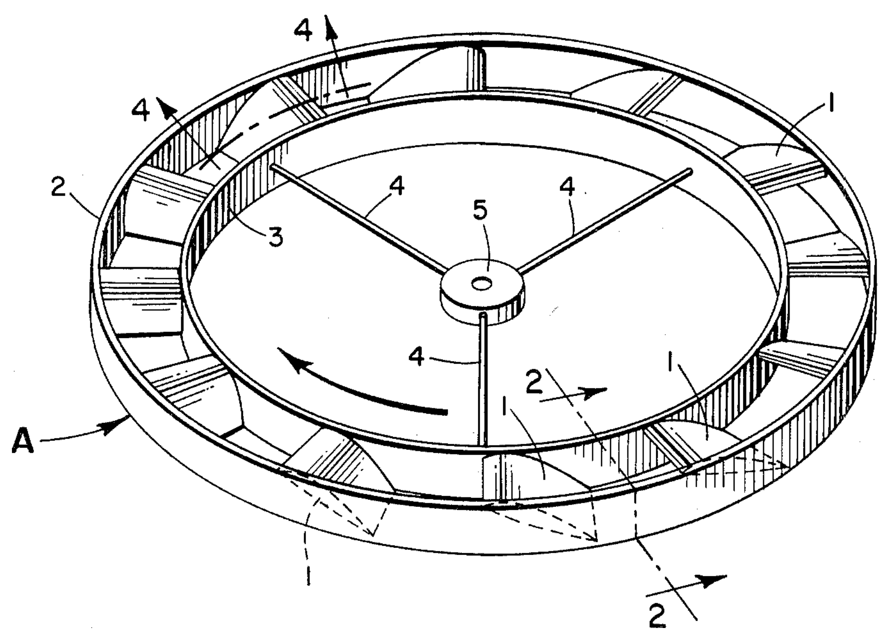
Primary Examiner—Milton Buchler
Assistant Examiner—Paul E. Sauberer
Attorney, Agent, or Firm—Stevens, David, Miller & Mosher

[57] **ABSTRACT**

The invention relates to an improved type propellor means and driving arrangement therefor, especially as applied to a flying craft which is directionally controllable according to the principles of gyroscopic precession as disclosed in the parent application. The propellor comprises a rotating annular loop between whose inner and outer radial walls are mounted blades. A pair of concentric loops are oppositely rotated by an engine in a manner whereby the counter-torque resulting from driving one of the loops is totally dissipated in driving the other loop whereby no torque is imparted to any static portion of the craft.

17 Claims, 15 Drawing Figures



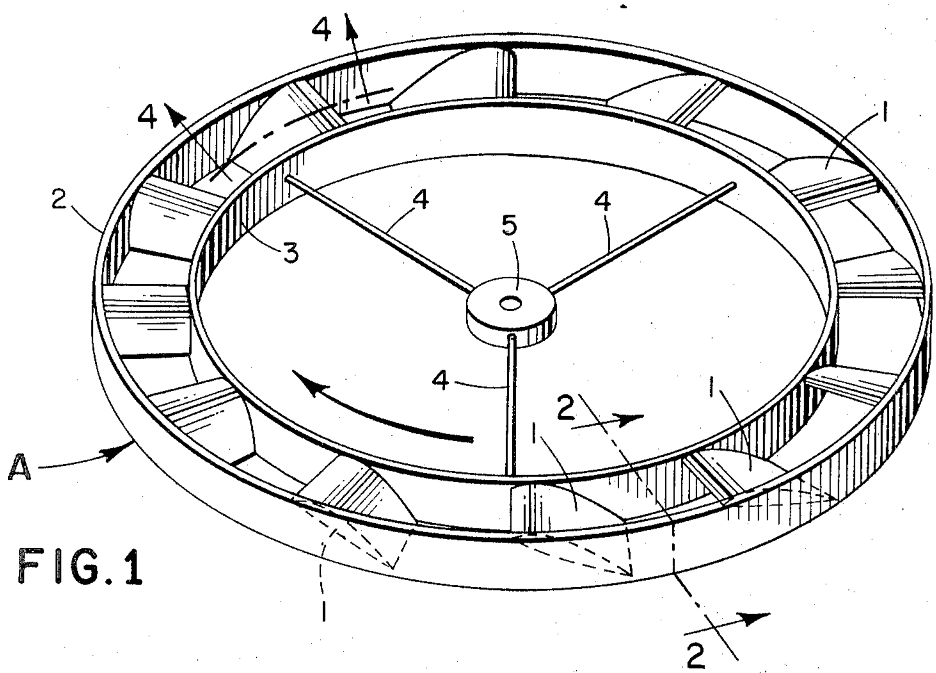


FIG. 1

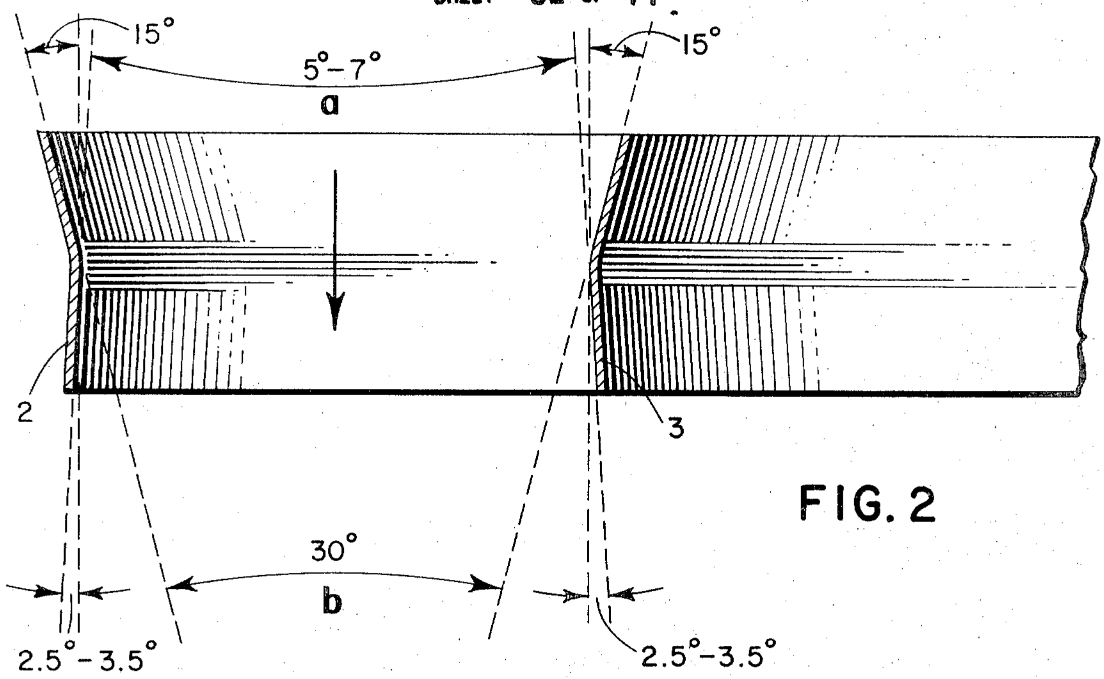

15°
5°-7°
a
15°
2
3
30°
b
2.5°-3.5°
2.5°-3.5°

FIG. 2

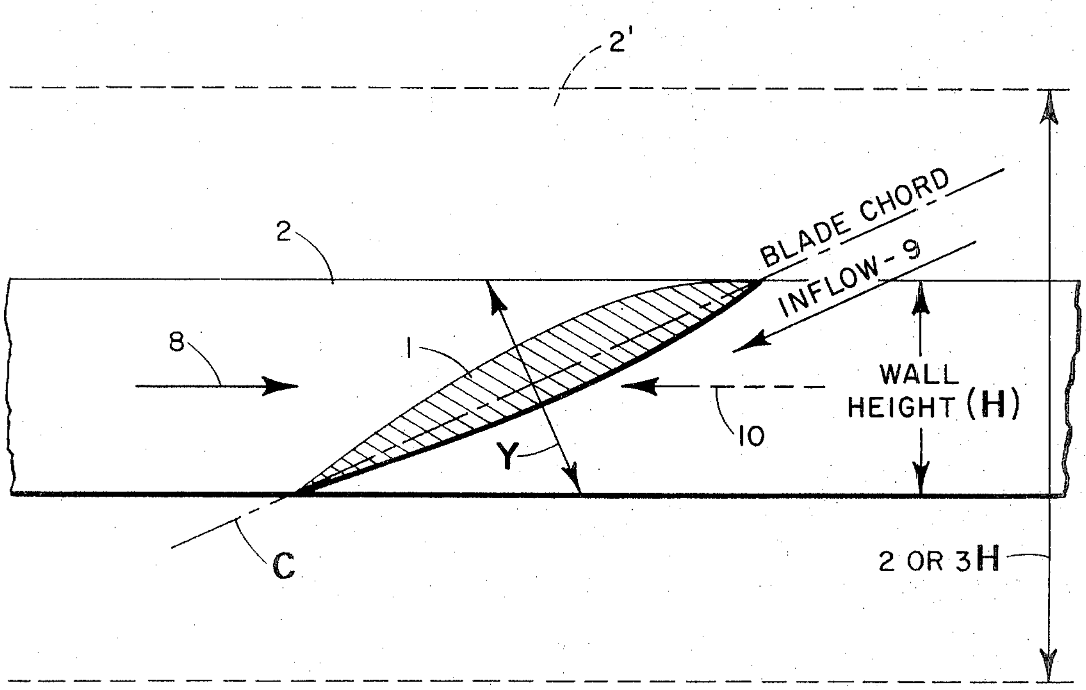

2'
2
BLADE CHORD
INFLOW-9
8
1
WALL
HEIGHT (H)
10
Y
C
2 OR 3H

FIG. 4

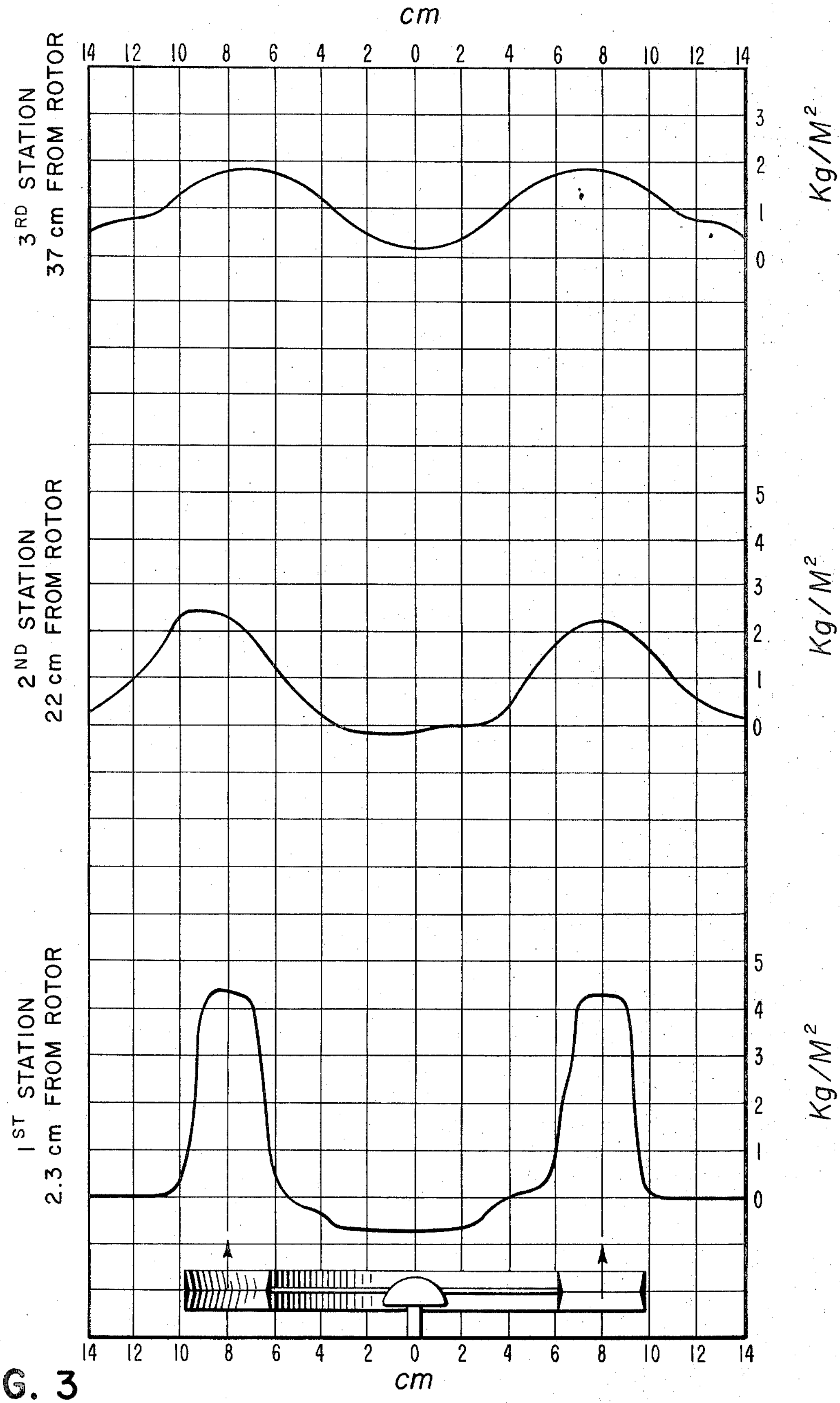

cm
3RD STATION
37 cm FROM ROTOR
2ND STATION
22 cm FROM ROTOR
1ST STATION
2.3 cm FROM ROTOR
Kg/M²
Kg/M²
Kg/M²
cm

FIG. 3

FIG. 5

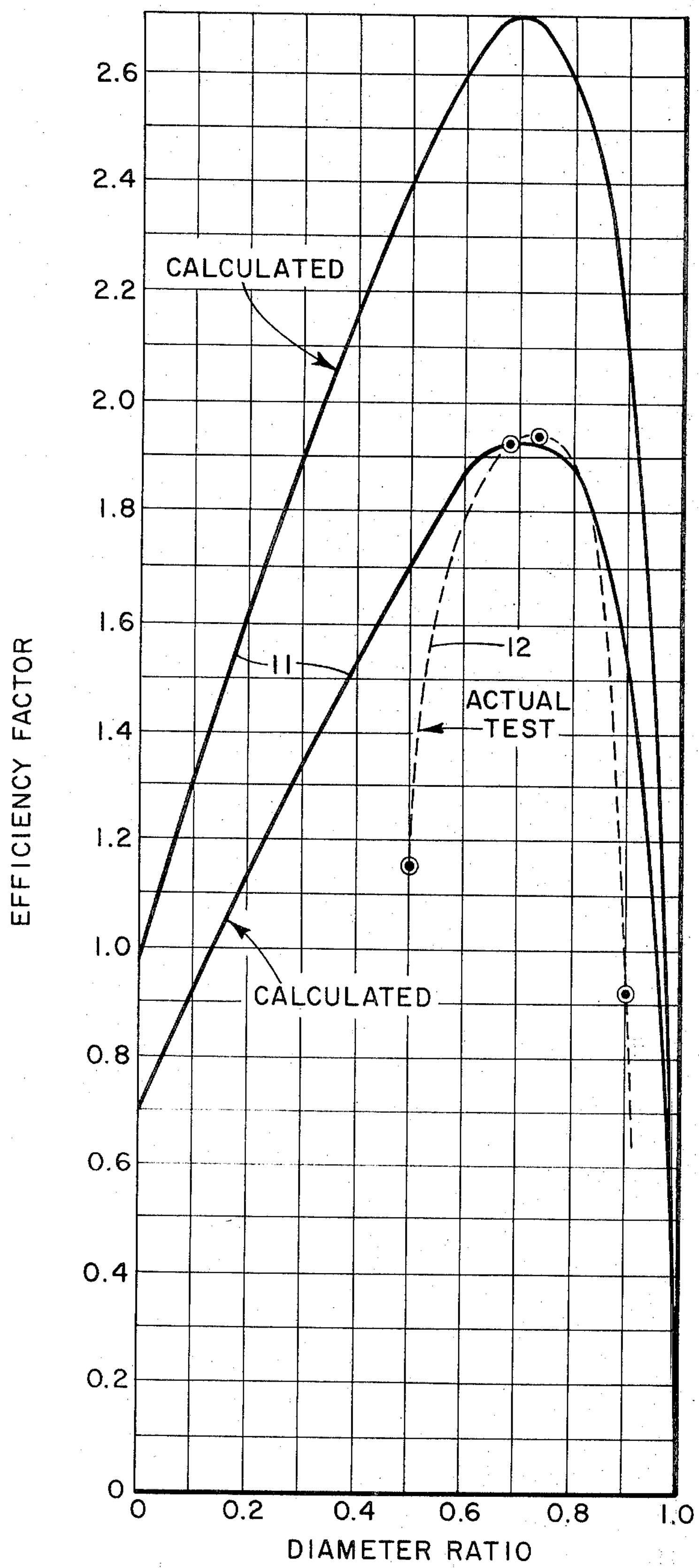
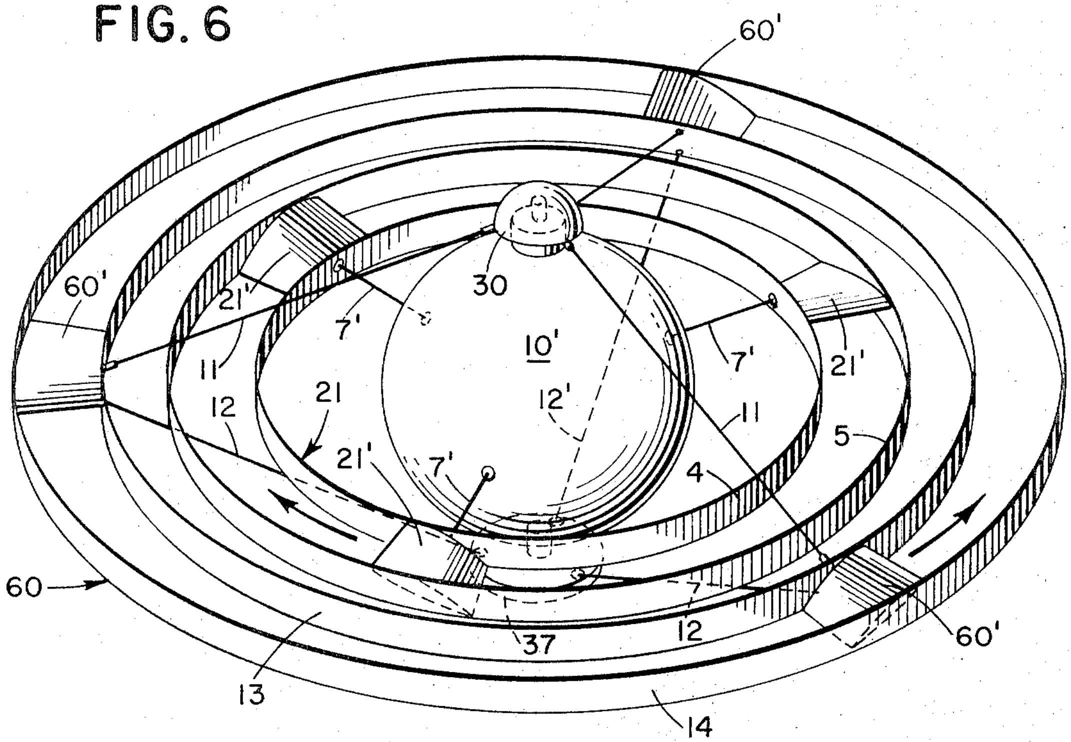

2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
CALCULATED
11
12
ACTUAL
TEST
CALCULATED
EFFICIENCY FACTOR
0
0.2
0.4
0.6
0.8
1.0
DIAMETER RATIO

FIG. 6



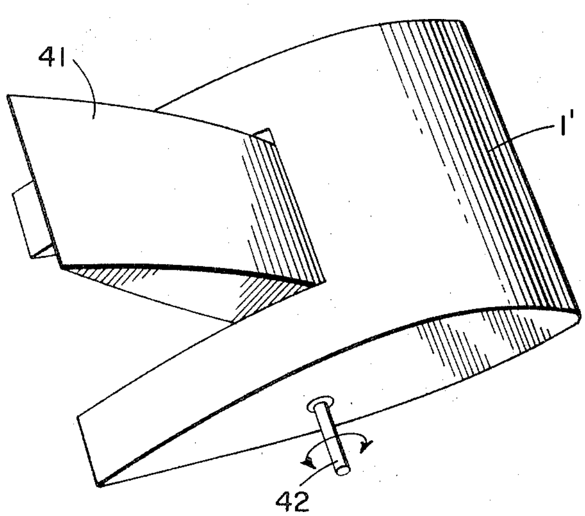
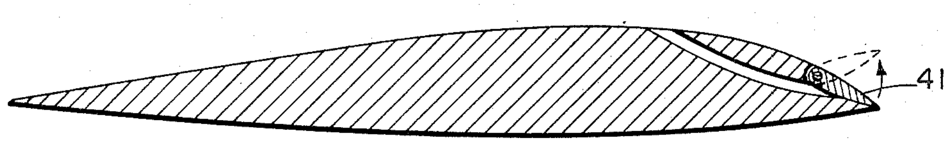


FIG. 8

FIG. 9



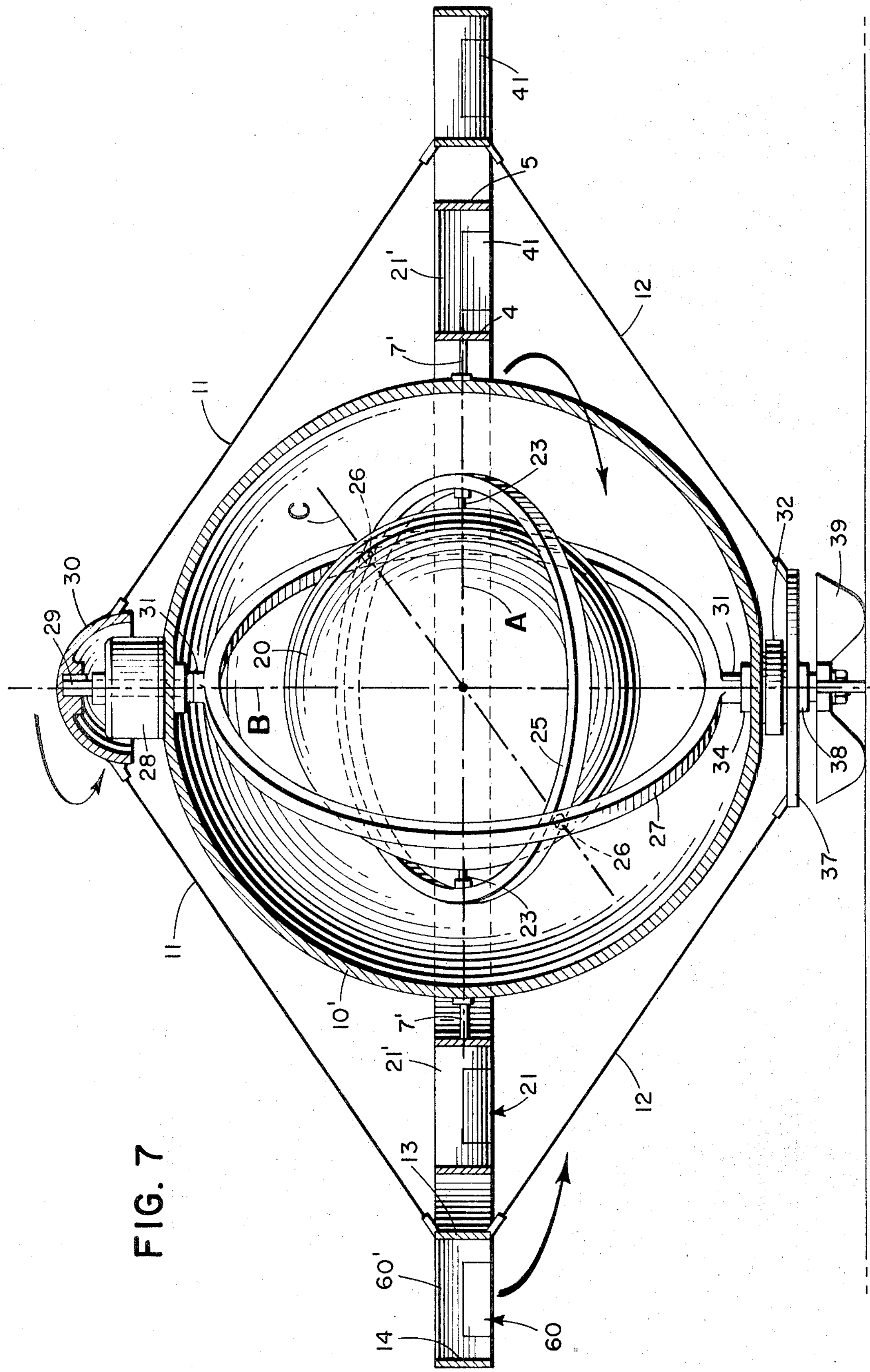
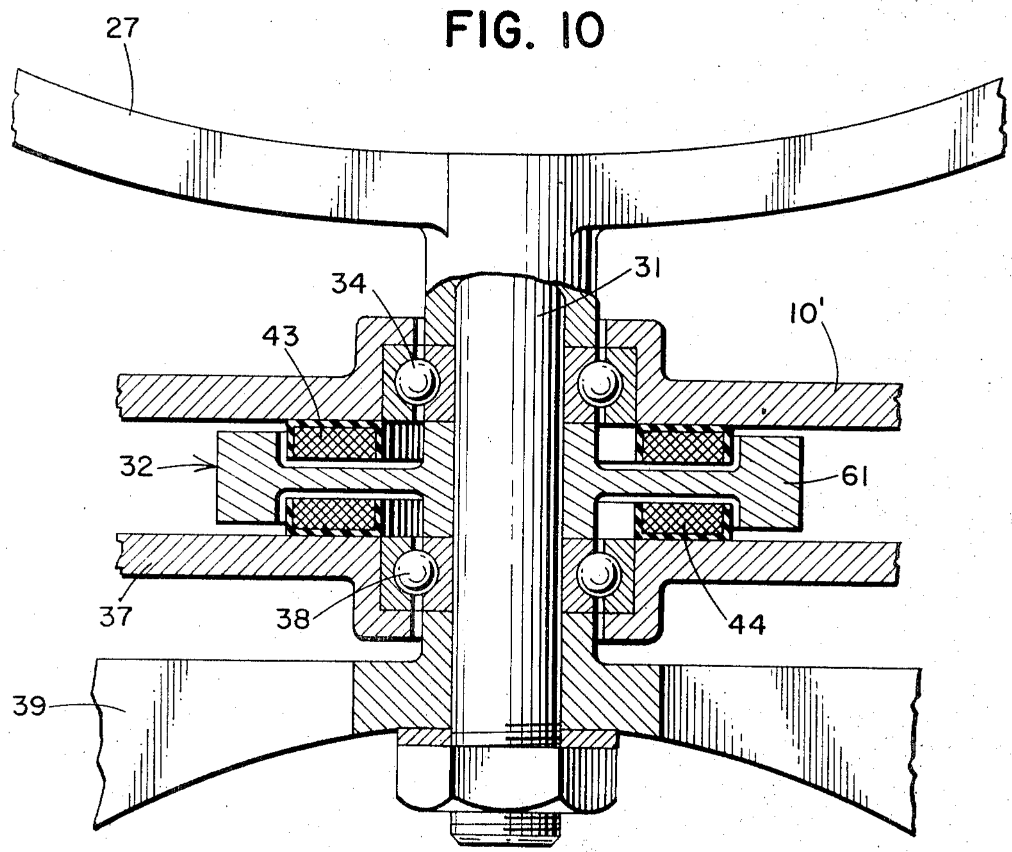

41
5
41
21'
4
7'
12
11
23
26
C
32
39
30
29
31
A
31
20
B
25
34
38
28
27
26
37
11
23
10'
7'
21'
21
12
13
60'
14
60

FIG. 7

FIG. 10



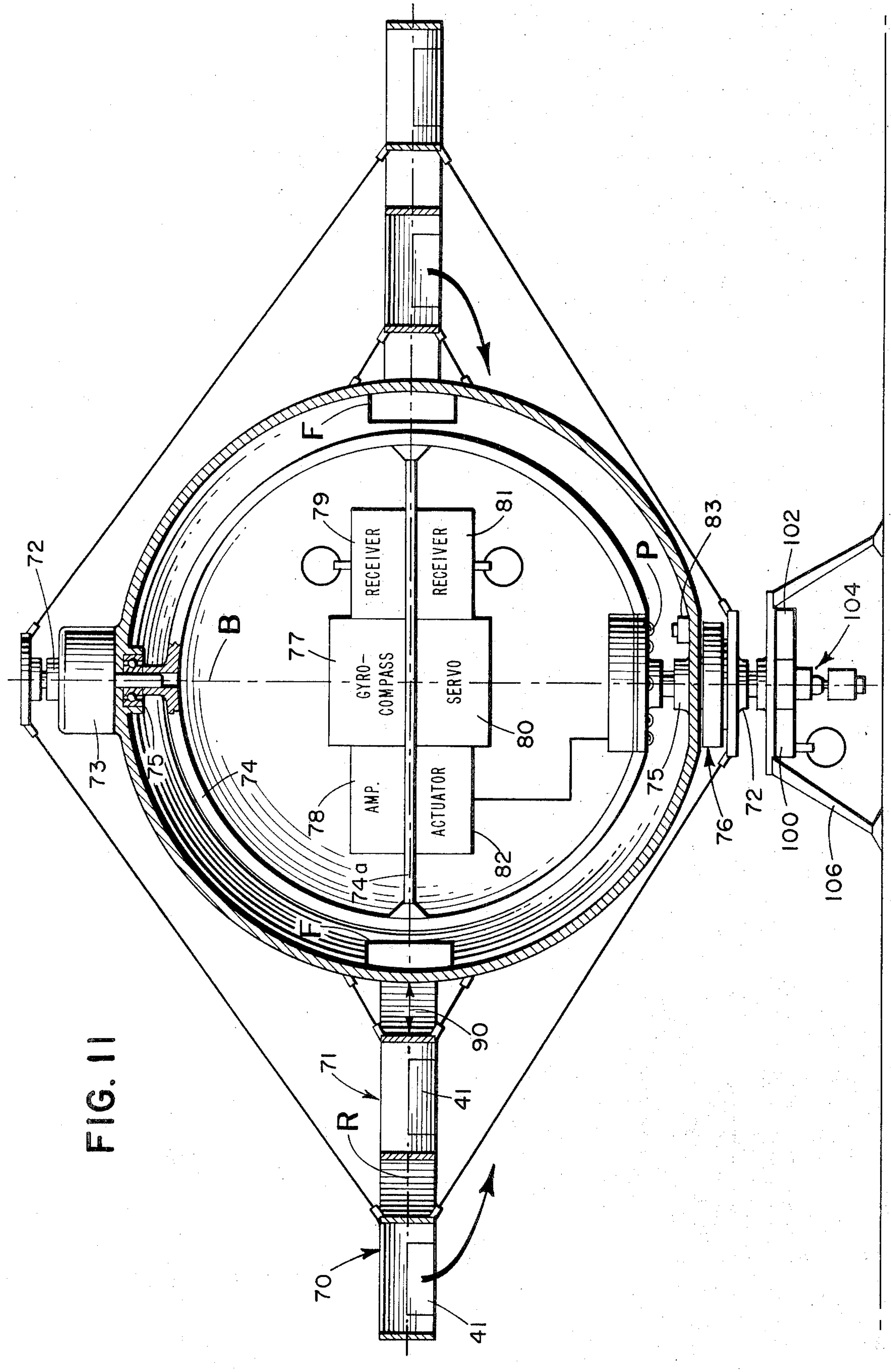

RECEIVER
RECEIVER
GYRO-COMPASS
SERVO
AMP.
ACTUATOR
70
71
72
73
74
74a
75
76
77
78
79
80
81
82
83
90
100
102
104
106
41
B
F
P
R

FIG. 11

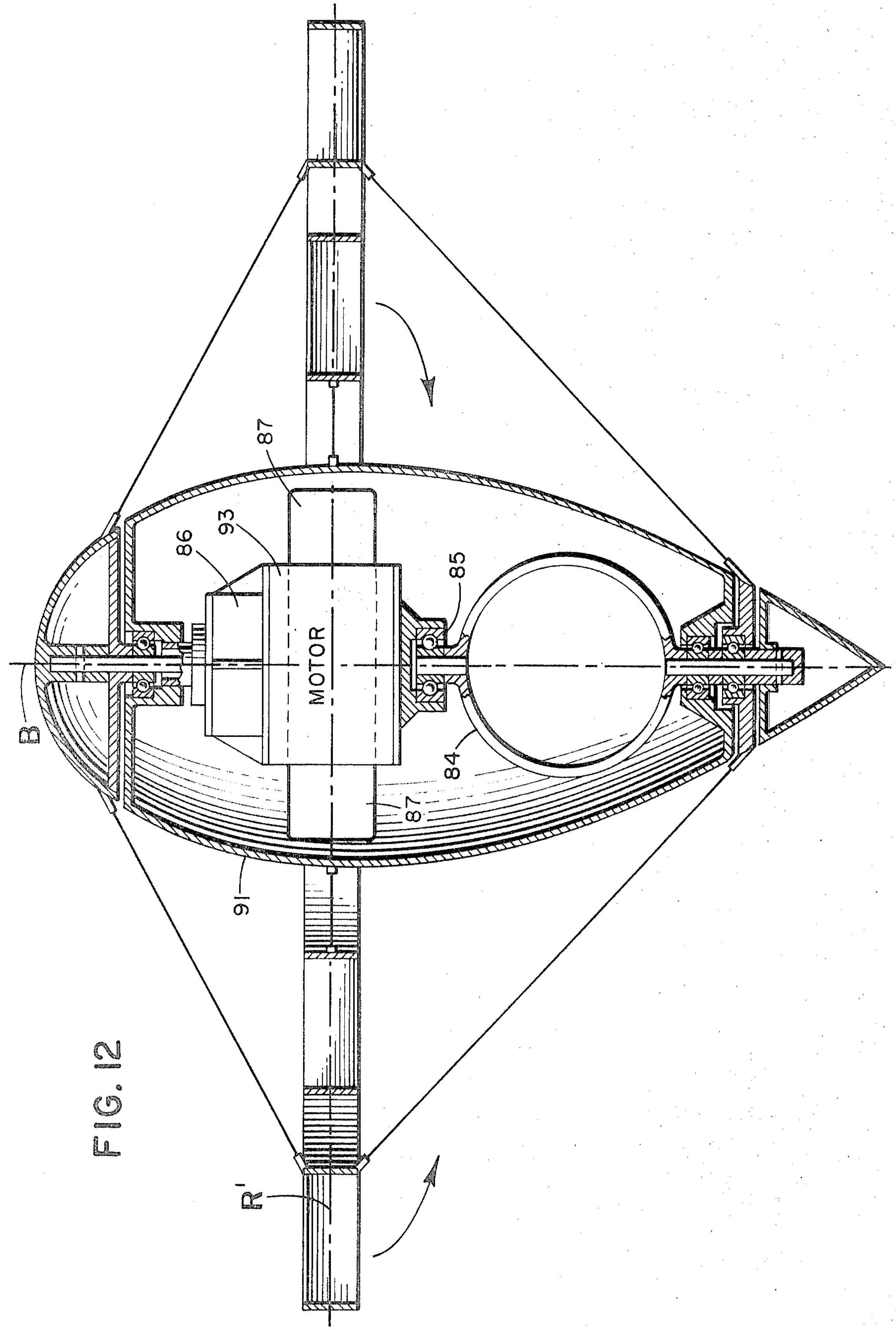


FIG. 12

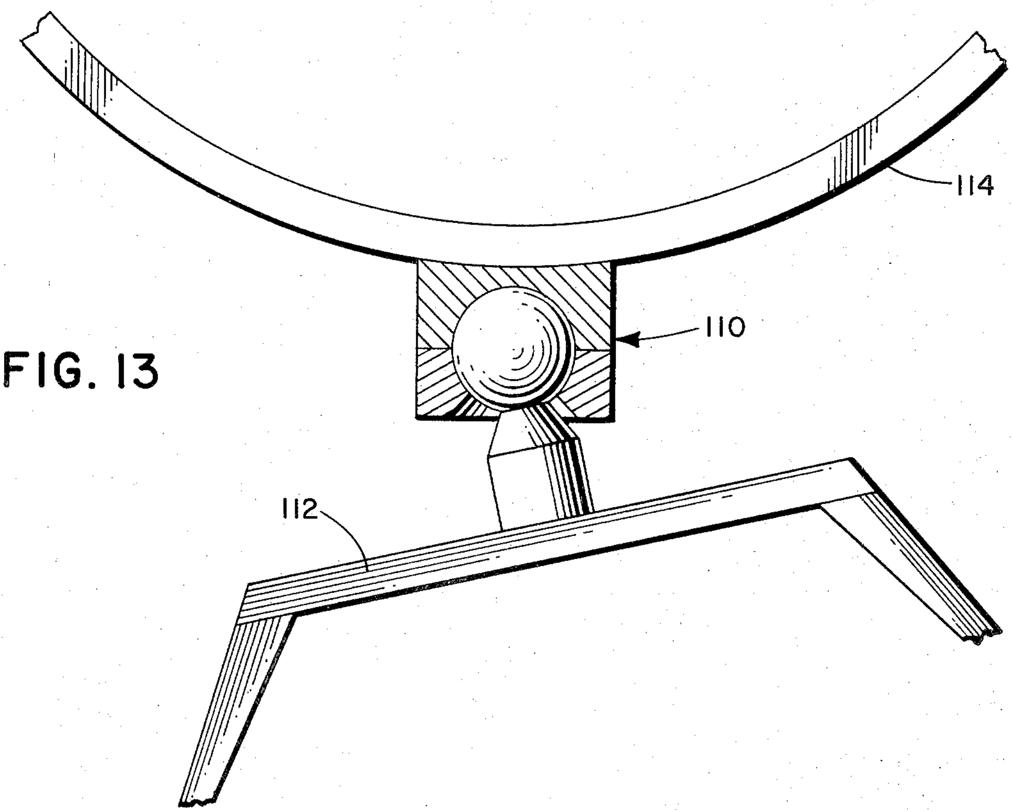


FIG. 13

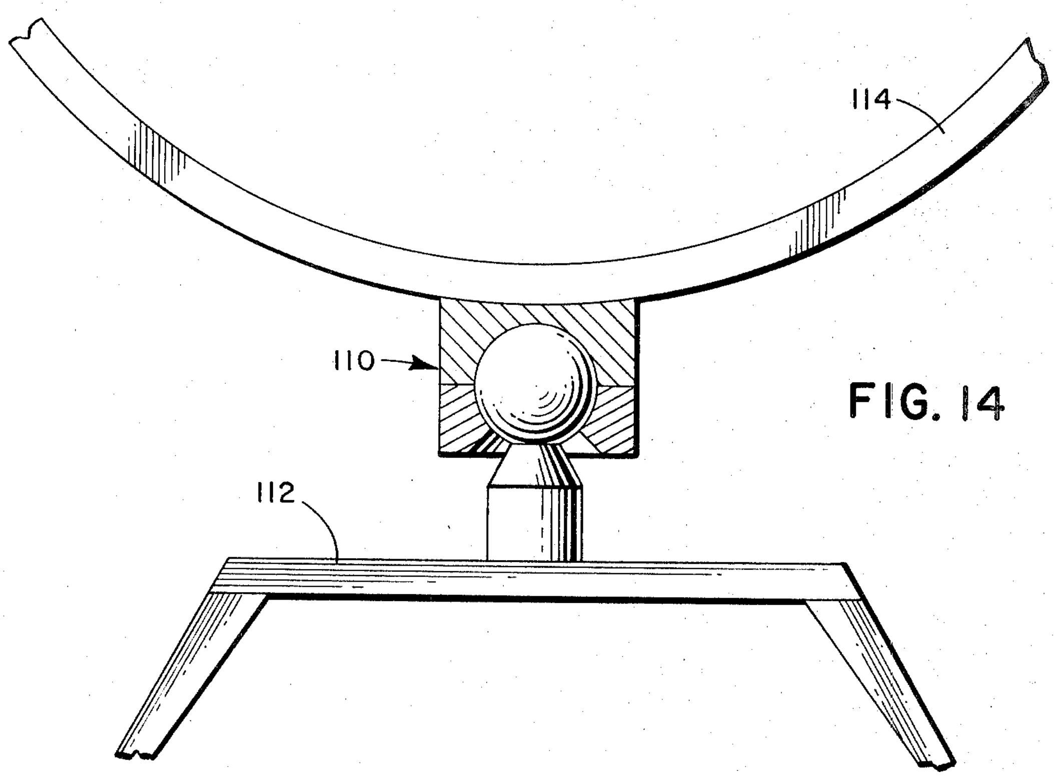


FIG. 14

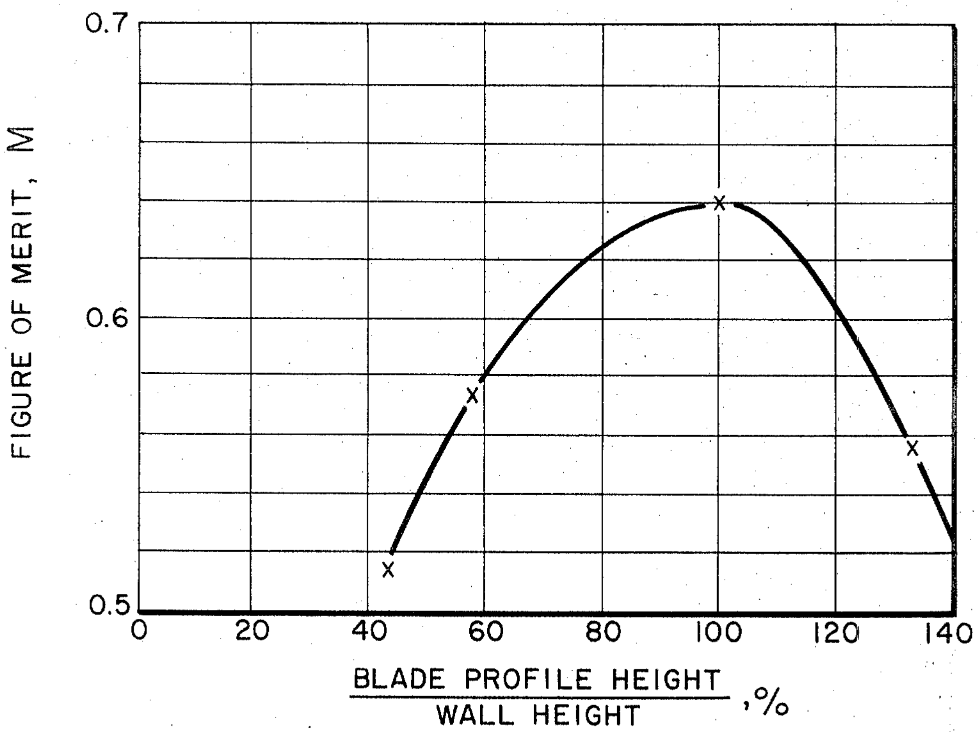

0.7
0.6
0.5
FIGURE OF MERIT, M
0
20
40
60
80
100
120
140
BLADE PROFILE HEIGHT / WALL HEIGHT, %

FIG. 15

PRECESSOR FLYING CRAFT

This application is a continuation-in-part of application Ser. No. 845,381 filed on July 28, 1969 now U.S. Pat. No. 3,633,849, the entire disclosure of which is hereby incorporated by reference hereinto.

For purposes of brevity, the operation of the craft will not be described in full detail since such detail is set forth in said parent application. It is understood, therefore, that only those portions of the craft which differ from the disclosure in the parent application will be fully described herein.

The basic invention to which the parent and this application relate is a flying craft which is directionally controlled in accordance with the principles of gyroscopic precession, the craft as a whole constituting a Foucault (free) gyroscope.

The present application is specifically directed to various improvements to the craft of the parent application, as follows.

First, the provision of an improved type of air propellor means for the craft, namely: a new type double-walled, ducted type propellor.

Second, the provision of a different driving system for the propellor within the same limitations set forth in the parent application, namely: that the drive means impart no rotative torque to the stationary inner structure of the craft.

Third, the adaptation of the basic principles of the parent application to a craft, such as an unmanned drone, which does not require a pilot cabin and various structure appurtenant thereto.

Other improvements of a more detailed nature are also disclosed.

The purpose of the new type propellor is mainly to realize increased efficiency or thrust per horsepower.

The purpose of a different driving system is that of being able to mount the driving engine stationarily within the craft rather than on the rotating propellor itself.

The adaptation of the basic invention to a drone type craft is of paramount importance in that it reveals the basic simplicity and variable applicability of the concepts upon which the basic invention is based.

The improved propellor of this invention has applicability to all environments in which air-moving propellors are employed and perhaps also to water-moving propellors. In any event, the propellor of this invention clearly is applicable to all air moving or air pressurizing fans, blowers, and the like although it has been especially developed as a propulsive means for aircraft and especially aircraft of the type disclosed in parent application Ser. No. 845,381 filed July 28, 1969.

Ducted propellors per se are well known, their advantage being the elimination of propellor tip losses, such as eddy currents at the tips which are common to open type propellors. The circumscribing wall of a ducted propellor, on the other hand, serves to guide the air so that it flows axially even at the propellor tips.

In known ducted propellors, the circumscribing duct is usually stationary and the propellor comprises solid elongate blades extending radially from a central hub up to the inner periphery of the duct, a working clearance being provided between the propellor tips and the said inner periphery.

The efficiency of known propellors of both types, open and ducted, is not of the highest order and it is an object of this invention, therefore, to realize a propellor having a notably higher efficiency as compared to any known propellors. It is known, for example, that the blade cross-section in known propellors varies from tip to hub as also does the twist and angle of incidence of the blade. This is necessary in known propellors because the circumferential velocity of the propellor blades obviously is different at successive radial points therealong. In fact, the rotational speed of the propellor is limited by its tip diameter and corresponding tip speed, which of course may not surpass the speed of sound.

What this means is that the efficiency and usefullness in known types of radially extending propellor blades varies at successive radial points therealong and that only a small part of the radial extent of each blade (measured from the tip towards the axis of rotation) is efficient in producing thrust. Propellor hubs are as large as they usually are and the blades are often circular in cross-section for an extent adjacent to said hub simply because the efficient portion of each blade only commences at some point distally removed from the rotational axis.

It is an object, therefore, of this invention to realize a new type propellor which maximizes the utilization of the most efficient radial extent of known propellor blades.

It is a further object to realize a new type propellor wherein the circumferential velocity, the cross-sectional configuration, and the efficiency of the blades varies to a minimum amount from the radially inner to the radially outer limits of the blade.

According to the present invention, the blades are not elongate members extending solidly from hub to tip but are vanes radially separated from the hub. Further, these vanes are mounted onto a circumscribing duct wall which itself must rotate with the vanes and is, therefore, a part of the propellor itself. Still further, the circumscribing wall is complemented by a radially inner wall to which the radially inner ends of the vanes are attached.

In effect, therefore, the propellor comprises a rotary hollow annular loop in which are mounted a plurality of vanes (blades) which interact with the atmosphere pursuant to rotation of said loop, said loop being connected to a central hub by radial stays which occupy a minimum of space and which are very light in weight.

As to the propellor driving system, the parent application discloses in FIGS. **2** and **8** thereof a rotary drive means which comprises reaction means located on the rotating shell itself and which rotates with the shell. Such an arrangement is employed in order to protect the internal structure against any tendency to be rotated by said drive means. The fact that the engines **9** and **10** of FIGS. **2** and **8** in the parent application themselves rotate with the rotating shell presents, however, a disadvantage in that said engines are subjected to centrifugal forces which complicate the running characteristics and lubrication problems of such engines.

It is therefore an object of this application to overcome the aforementioned disadvantages and to realize a rotary drive means for a craft of the type of the parent application, which itself may be non-rotating but especially not mounted on the propellor itself.

A corollary object of this application is the realization of a drive means for the aforementioned craft which requires standard engines, readily available on the market, instead of engines which must be especially developed to withstand centrifugal forces.

Specifically, it is an object of this application to realize a drive arrangement, for the aforementioned craft, whereby the drive engine may be supported on the stationary internal support structure of the craft and may constitute a conventional internal combustion engine and not necessarily a reaction engine means.

The problem to be resolved in order to realize the foregoing, however, is that of eliminating the imposition of rotative torque upon the stationary support structure and this problem is resolved herein by having the drive engine drive two separate thrust producing rotors in a manner whereby their respective torques counter-balance and cancel each other. The concept of one engine driving counter-rotating propellors in per se known as, for example, in helicopters wherein one engine drives two counter-rotating propellors, one axially above the other. The known helicopter concept, however, is disadvantageous because the airstream of the upper propellor detrimentally affects the counter-rotating lower propellor, requiring more energy therefor without increasing the thrust to a corresponding extent.

Further, a practical drive arrangement for two axially superposed propellors would be extremely difficult to realize in a craft of the type of the parent application wherein it is necessary that the rotating propellors be properly balanced so as to avoid the exertion of precessive torques upon the craft. According to the present application, however, the two counter-rotating propellors are of the aforementioned improved type and they are radially one within the bounds of the other so that their respective airstreams do not interfere with each other and, further, the means for driving them is very simple.

The foregoing and the drone type craft will be better understood with reference to specific embodiments of realization of the present invention, a detailed description of which follows which is referenced to the accompanying drawings wherein:

FIG. 1 is a pictorial view of a new propellor according to this invention;

FIG. 2 is an enlarged sectional view taken along line 3—3 of FIG. 1;

FIG. 3 is a graph of actual test results taken on a propellor of this invention having a venturi cross-section as shown in FIG. 3;

FIG. 4 is an enlarged sectional view taken along line 5—5 in FIG. 1;

FIG. 5 is a graph showing actual test data relating to the new propellor of this invention;

FIG. 6 is a pictorial view of the exterior of a precessor craft of the parent application having the new type propellor means of this application applied thereto;

FIG. 7 is a vertical view of the craft of FIG. 7;

FIG. 8 is an enlarged pictorial view of the wings, blades, or vanes useable with the new type propellor of this invention;

FIG. 9 illustrates a modified version of the wing of FIG. 9;

FIG. 10 is detailed sectional view of the lower pole of the craft of FIG. 8;

FIGS. 11 and 12 are elevation views of two respective drone type craft according to this invention;

FIGS. 13 and 14 are schematic illustrations of a new type landing gear for any of the craft of the parent and this application; and,

FIG. 15 is a graph of actual test results of a propellor according to this invention.

With reference to FIG. 1, the propellor comprises an annular airscrew, A, defined by outer and inner concentric boundary walls 2 and 3, between which are mounted a plurality of blades or vanes 1. Stays 4 which can be rigid or flexible connect the inner wall 3 to hub 5 which, in turn, is connectable to a rotary drive means. The entire assembly of elements 1, 2, 3, 4, and 5, is therefore integrally rotatable as a unit.

The blades 1 may be aerodynamically configured as shown or they may simply comprise flat plates whose angles of incidence will result in the production of aerodynamic thrust during rotation thereof. Not illustrated conventional means may be employed to render blades 1 adjustable as to angle of incidence such adjustment being accompanied by a corresponding adjustment in the height of walls 2 and 3.

It should be noted that the stays 4 may be of relatively light construction because the stresses generated by the centrifugal force of the rotating blades and walls 2, 3 are entirely absorbed by the circular walls themselves in the form of a loop tension. The stays 4 actually are subjected to no or very little tension as the result of rotation of the assembly and they, therefore, can be very small in cross-section thereby giving rise to very little drag. The walls 2, 3 likewise give rise to very little drag because of their cylindrical shape. In this regard, it should also be noted that the lack of obstruction inwardly of wall 3 (hub 5 and stays 4 occupying relatively little space) makes it possible for a separate axial airstream to be developed within the cylindrical space circumscribed by wall 3. Such separate airstream can be generated, for example, by another analogous propellor positioned radially within the boundary of wall 3.

The hub 5 imparts rotational drive to the wall 3 via the stays 4 and the vanes 1 and wall 2 of course follow along since they are all integrally constructed.

An important advantage of the use of flexible stays 4 is the fact that they transmit no bending movement from airscrew A to hub 5. Thrust forces which develop in the airscrew are transmitted to hub 5 in the form of tensile stresses via the stays 4 rather than in the form of bending stresses.

With reference to FIG. 2, it is seen that the outer and inner walls 2, 3 define therebetween a venturi, the purpose of which is to widen the inflow and outflow wind area and to assure a parallel outflow (slipstream) pattern as compared to a converging slipstream pattern. The vertical arrow in FIG. 2 denotes the air flow direction and it is seen that, for best results, the diffusion angle is between 5 and 7°. It should not exceed 7° in order to regain kinetic energy in the form of potential energy. Further, the entrance angle b is preferably 30°. The venturi walls can be streamlined.

FIG. 3 shows the experimental points determined with a pitot to find the velocity distribution on the exhaust side of a double walled rotor according to this invention.

The dimensions of the tested rotor were:

Outer diameter		18.6 cm
Inner diameter		12.2 cm
Hub diameter		3.6 cm
12 blades:	Cord	3.7 cm
	Length	3.2 cm
	Angle of incidence =	24°
2 boundary walls:	Height	1.75 cm
RPM of rotor =	2000	

A study across the diameter of the rotor was made at three different distances, whereby the pressure was determined with an inclined water gauge 1/200.

FIG. **3**, definitely confirms the fact, that with this type of rotor the down wash velocity does not become twice the inflow velocity since it does not converge into half the area of the rotor as is common to known airscrews, showing that it has a higher figure of merit than the maximum theoretically possible with a helicopter rotor.

Experiments conducted with a rotor with six blades gave the same pattern.

In the case of conventional propellors, it is known that the slipstream is contracted to substantially half the area of the propellor disc, such degree of contraction occurring within an axial distance donwstream of the rotor equal to said tip diameter. This means that the final velocity of the air is twice the induced velocity. In a propellor according to this invention, on the other hand, no contraction of the slipstream occurs because the respective boundary walls **2** and **3** act as a diffuser and the final velocity is, therefor, equal to the induced air velocity.

In view of the foregoing, and employing known formulas for determining thrust, one arrives at the conclusion that under equivalent conditions and with the same power, the propellor of this invention provides 26 percent more thrust than conventional propellors.

A particular feature of the annular airscrew A of this invention resides in the fact that the height of walls **2, 3** is much less than believed possible according to heretofore known theoretical considerations according to which a ducted propellor would require a duct wall height of at least 2 to 3 times the axial height of the propellor profile in order to achieve a cylindrical down flow air pattern. The aforementioned heights are measured parallel to the rotational axis of the propellor or, stated in another manner, perpendicular to the plane of rotation of the propellor. In FIG. **4**, the theoretical wall height is shown by the dash lines which represent a wall **2'** which is 2 to 3 times the height of wall **2**, while the plane of rotation is represented by the arrow **8**.

Because of the aforementioned theoretical considerations as to wall height, it has not been practical to use ducted propellors in aircraft because the frictional drag attendant to such a great wall height would be prohibited since the drag losses are proportional to the wall height. It has been found, however, that since the walls **2** and **3** of the propellor of the present invention rotate with the blades, the actual wall height H need not exceed the height of the blade profile because the wind inflow direction **9** is substantially along the direction of the blade chord so that the effective wall height (the wall dimension perpendicular to inflow direction) actually corresponds to dimension Y instead of dimension H.

On the other hand, in standard wind tunnel tests, the inflow wind direction, as indicated by arrow **10**, is not along the blade chord but is, instead, parallel to the plane of rotation.

The boundary wall **2**, in fact, is analogous to the end plates which are often attached to the tips of wings in conventional aircraft. It is well known that such end plates increase the cross-section of the effective cylindrical stream of air which is deflected by the wing, thereby increasing its lift coefficient. It is also known that the effects of the end plates are not altered whether they are in the same plane as that of the wing or whether they are positioned above or below that plane. Finally, it is also known that the induced drag decreases linearly as a function of the end plate height ratio while the skin friction drag increases proportionally to the area of the end plates.

The foregoing known relationships, however, have been found to not be applicable to the boundary wall **2** of this application and FIG. **15** documents this with actual test data of the figure of merit for respective ratios of blade profile height to actual wall heights (H in FIG. **4**). The highest figure of merit, in a test rotor according to this application, was obtained when the wall height (H) equaled the blade profile height, as shown in FIG. **4**.

The boundary wall **2**, therefore, serves the primary function of acting as a duct which prevents the air stream from converging and thereby induces an axial or cylindrical down flow air pattern and this results in 26 percent of efficiency. Another function of wall **2** is that of preventing the formation of air currents (tip vortices) from the underside of the blade tip to its upper side, which vortices reduce efficiency.

A major important feature of the ducted propellor of this invention resides in the discovery of the criticality of the diameters of the inner and outer walls **2, 3** relative to each other. Stated otherwise, the ratio of the diameter of inner wall **3** to the diameter of outer wall **2** should be in the range of 0.55 to 0.75, the optimum being 0.71, in order to realize maximum efficiency factor. Efficiency factor is a theoretical measure of the thrust delivered by a ducted propellor as compared to that delivered by a helicopter type propellor. That is, a ducted propellor being one whose rotating blades are confined within a circumscribing wall and a helicopter propellor being one which rotates freely in the atmosphere with no boundary wall.

Defined, the efficiency factor is a measure of what is the thrust per horsepower of a propellor according to this invention taking into account solidity ratio, velocity, and drag factors as compared to a helicopter type propellor having ideal twist and taper and an outside diameter equal to that of the outer wall of the ducted propellor.

The criticality of the aforementioned diameter ratio is illustrated in FIG. **5** wherein the curves **11** and **12** respectively, represent calculated and actual test efficiency factors for a ducted propellor according to the present invention.

It should be noted in summary that the propellor according to the present invention not only is a ducted propellor, but is a particular type of ducted propellor as follows:

a. The propellor blades do not extend radially from a central hub; instead, they constitute blade portions distancially positioned relative to their own rotational axis;

b. The blades are bounded on both radial sides thereof, inner and outer;
c. Both bounding walls rotate with the blades;
d. The walls define a venturi nozzle;
e. The diameter ratio of the walls is within a particular range; and,
f. The height of the walls is within a particular range.

The foregoing results in a propellor of remarkably increased efficiency relative to known types of either ducted or open, helicopter type propellors.

The ducted propellor of this invention is relatively noiseless for two reasons. First, the inner and outer boundary walls prevent the formation and shedding of vortices at the blade tips, which vortices are a major cause of propellor noise. Second, it is not critical that the tip speed be a maximum (sonic speed) because the average speed along the entire blade radius is higher than in conventional propellors, and therefore, sonic boom is avoided.

Referring to FIG. **7**, the craft comprises, as in the parent application, a stationary cabin **20** which is cardanically suspended from a rotating outer member **21** by a Foucault type suspension system comprising successive rings **25** and **27** and respectively perpendicular pivot means **23, 26, 31** whose axes are A, C, B, respectively. The craft operates and is controlled according to the same principles of operation as disclosed in said parent application. The improvement of the present application, however, resides in the fact that the thrust producing means of the craft comprises a first rotor **21** carrying blades **21'** and outwardly thereof a second rotor **60** carrying blades **60'**.

The first rotor **21** is pivotally mounted to ring **27** along rotational axis B by pivot means **31.** A drive engine **28** is fixedly mounted on first rotor **21** and its shaft **29** is drivingly engaged at **30,** with second rotor **60.** During operation of engine **28,** therefore, the two rotors **21** and **60** are simultaneously driven in opposite rotative senses since the driving torque exerted by the engine on rotor **60** is counteracted by an equal and opposite torque exerted on rotor **21.**

The coupling means between engine **28** and rotor **60** could include a reduction gear means whereby the two rotors would rotate at different speeds. The torque, however, would always be equal and opposite in both rotors because one is driven in counterreaction to the driving of the other.

The inner rotor **21** may comprise a substantially imperforate shell **10'**; which encloses the inner support structure from the atmosphere. Alternatively said rotor **21** could be constructed analogously to rotor **60** which comprises a rigid crown member **30** connected to shaft **29** of engine **28** at one pole of rotational axis B and a rigid base plate **37** at the opposite pole of said axis. Extending from said crown and plate are flexible stay wires **11** and **12** which support the blade assembly **60'**.

The outer rotor blade assembly must be supported by open means such as wires **11, 12** in order not to obstruct the air flow to the inner rotor blade assembly **21'**.

The inner rotor **21,** however, may support its blade assembly **21'** by means analogous to elements **30, 37, 11, 12** or it may comprise a substantially imperforate shell **10'**.

The following relationships should be noted.

1. The torques of the two rotors must be equal and opposite in order to avoid the exertion of rotative torque upon the inner support structure and this equality of torque is automatically assured in the herein disclosed arrangement.
2. The blades for both rotors must be supported in such a manner that the resultant of the forces acting on the rotors passes through the center of gravity of the craft; otherwise, precessive forces will be exerted upon the craft. This, therefore, excludes the possibility of arranging both blade assemblies to one axial side of the center of gravity. They may be in the same plane in which lies the center of gravity, as illustrated in FIG. **7,** or they may be on opposite sides of that plane, but the resultant of the respective lift forces must pass through that center of gravity.
3. The most efficient utilization of power comes about when the power of each rotor is proportional to its rotational speed.
4. Since the two torques are equal ($T_1 = T_2$), the power of each rotor is proportional to its rotational speed ($P_1 = K_1 W_1$), so that the following variable parameters must be adjusted to satisfy the foregoing;
   a. solidity
   b. angle of attack
   c. rotor blade area.

It will be clear that the ideal tip speed for each rotor is the speed of sound in order to realize maximum horsepower per unit area of blades. The use of a double rotor is more efficient in this regard that a single rotor whose blades have the same radial length as the blades of both rotors combined. This is true because in the case of a single long blade, it is only the tip which may travel at the speed of sound while the remaining radial extent must necessarily travel at a progressively decreasing speed as the distance from the tip increases. In the case of the double rotor of this application, on the other hand, the tips of both rotors may travel at the speed of sound so that the difference in speed between tip and root of each blade is less in the case of the double rotor than it is in the case of a single rotor having longer blades.

The blade assemblies **21'** and **60'** may comprise blades of the type disclosed in the parent application; however, for maximum efficiency it is preferable to employ ducted type propellors such as illustrated in FIGS. **1** to **5.** With reference to FIGS. **6** and **7,** it is seen that the ducted propellor of the inner rotor **21** comprises inner and outer concentric circular walls **4, 5** between which are mounted the blades **21'**. The outer rotor **60** also comprises analogous inner and outer concentric circular walls between which are mounted analogous blades **60'**.

In FIGS. **6** and **7,** the shell **10'** is shown as being radially spaced from the inner rotor **21** with struts **7'** connecting said rotor **21** with said shell **10'** so that shell **10'** and rotor **21** are integrally rotatable with each other in the same rotative sense.

The respective strut members **7', 11** and **12** because of their minimum area give rise to very little drag forces. Further, they support very little in the way of forces since the centrifugal forces generated in the rotating rotors are absorbed almost entirely by the loop tension effect in the circular walls **4, 5, 13, 14.** The stays 7′, 11, 12 must carry only axial thrust forces and torque forces.

Instead of the rigid struts 7′ for the inner rotor, stays analogous to 11 and 12 could be employed for this rotor.

The craft is controlled, as disclosed in the parent application, through utilization of the principles of gyroscopic precession in order to alter the orientation of the rotational axis B. To achieve this, shiftable weights can be mounted in either of rings 25 or 27, as disclosed in the parent application. The precessive torque, however, can also be obtained by providing means for varying the lift at one location relative to another on the blade assemblies 21′, 60′. FIG. 8 illustrates a practical realization of this expedient.

Either all or only certain ones of the blades 21′, 60′ may include flap means 41 pivoted about axis 42 at the trailing edge. These flaps can be controllably pivoted through suitable control means extending from the cabin to pivot means 42. The flap 41 of course acts in a very well known manner as a "spoiler", as is well known in all aircraft. In order to steer the craft, the flaps on diametrically opposed blades may be oppositely positioned so that there is a greater lift in one side of the craft than on the other, this variance in lift imposing a precessive torque on the craft whose axis of rotation B will consequently alter position.

It is to be understood that the control means for the flaps will necessarily be such that as the respective blades pass a certain point in their rotational path, the corresponding flap will pivot in one direction and then when that same blade passes the diametrically opposite point the said flap will pivot in the opposite direction. This will continue until the control means is deactivated whereby the craft remains on a particular course.

The spoiler means could, alternatively, be located in the leading edge of the blade in the form of a passageway having a closure flap 41′ therein as illustrated in FIG. 9.

FIG. 10 illustrates the construction of the lower pole of the craft with specific regard to a means for controlling the orientation of the outer ring 27 and through it the cabin 20 of FIG. 7.

The shell 10′ and outer ring 27 are rotationally connected to each other by means of pivot shaft 31 and roller bearings 34. Likewise, the plate 37, which, as already described, is part of rotor 60, also is rotationally mounted about shaft 31 by means of bearings 38. The shell 10′ and the plate 37 can, therefore, freely rotate in opposite senses without interfering with each other while shaft 31 and ring 27 remain stationary.

Shaft 31 will, however, be subjected to some frictional forces tending to cause it to rotate in one sense or another. Further, it will be necessary to turn ring 27 to reorient the cabin 20 whenever a course change is effected. In the parent application, a trimming means is disclosed for this purpose. According to the present application, such trimming means comprises a magnetic clutch 32.

The clutch comprises a magnetizable metal part 61 rigidly mounted on shaft 31, and respective electric coils 43 and 44 mounted on shell 10′ and plate 37, respectively. If coil 43 is energized, shell 10′ (also of magnetic material at least in the vicinity of said clutch) becomes magnetically locked with the clutch member 61 whereby shaft 31 and ring 27 are caused to rotate with the shell 10′ in one rotative sense. On the other hand, if coil 44 is energized, shaft 31 becomes locked with plate 37 so that said shaft and ring 27 are caused to rotate in the opposite rotative sense together with rotor 60.

Landing gear 39 is rigidly connected to ring 27 through shaft 31.

FIG. 11 illustrate an embodiment of the precessor type craft which is contemplated to be highly usefly as an unmanned drone having a multitude of military and non-military applications. For example, in the military field the precessor type drone can be used inter alia, as a target, for reconnaissance, bomb carrier, radar carrier.

Referring to FIG. 11, the precessor drone is seen to comprise an outer rotor 70 and an inner rotor 71 rotatively mounted about a common rotational axis B by suitable pivot and bearing means 72, as described previously. An engine 73 is mounted on inner rotor 71 and its shaft is connected to the outer rotor whereby said engine while running, applies an equal and opposite torque to both rotors, also as heretofore described.

The drone, however, is different from the previous embodiment of precessor craft in that, since it is unmanned, it does not require a cabin nor the appurtenant trimming and stabilizing means therefor. Specifically, the drone is seen to only require a single internal ring 74 pivotally connected to inner rotor 71 by pivot means 75 about axis B.

Said ring 74 includes a rigid platform means 74a upon which are mounted a gyro-compass 77, amplifier 78, receiver 79 and servo 80. The compass serves to sense changes in direction of the inner ring 74 which changes are translated into signals sent to the amplifier 78 and from there to the servo 80. The receiver 79, on the other hand, receives signals from Earth and transmits them to said servo. The servo reacts to said signals to activate the magnetic clutch 76 which is the same as that described with reference to FIG. 11 and which, depending upon the signals received by the servo, will either clutch ring 74 to the inner (71) or outer (70) rotor.

The rotors 70 and 71 for the drone are in accordance with the construction set forth with reference to FIGS. 1 to 4. The directional control flaps 41 (FIG. 8) are controlled in the drone by another receiver 81, which receives signals from Earth and transmits them, for example, to an actuator 82 which will cause the lighting of one of a plurality of bulbs on plate P which is rigid with the ring 74. A light sensing device (photoelectric cell) 83, rigid with and rotative with inner rotor 71, faces said plate P so that the lighted bulb or bulbs on P activates said device which in turn (by means of a battery) may transmit a signal to a solenoid in a certain blade or blades of rotor 71 to actuate the corresponding spoiler flap or flaps thereof whereby the lift distribution of rotor 71 becomes unbalanced. This unbalance gives rise to a precessive torque which in turn changes the disposition of axis B and the course of the craft.

Another receiver 100, actuator 102, television camera and camera pointer 104 may be mounted on the landing gear 106. Theoretically, the first receiver 79 could be eliminated and the camera pointed solely by receiver 100, but the gyro compass 77 is still required for preventing the ring 74 from rotating with the inner rotor 71.

FIG. 12 illustrate another embodiment of the precessor drone, which illustrate the variability of possible designs which, however, all are based upon the common processor concept. The FIG. 12 embodiment differs from that of FIG. 11 in that the inner stationary suspension structure involving either one or more rings 84 is not symmetrically disposed relative to the rotational plane of the craft, as heretofore been the case. In FIG. 11, for example, as in all previous embodiments of this and the parent application, the suspension ring 74 is symmetrical to rotational plane R. In FIG. 12, however, the entire internal suspension structure is to one side of plane R'. Further, in FIG. 12, the craft includes a non-spherical rotating shell 91 in contrast to the heretofore illustrated spherical shells.

The FIG. 12 embodiment is different also in the disposition of the drive means for the respective rotors. The engine 93 is mounted on first suspension ring 84 (which is the counterpart of ring 74 in FIG. 11), by means of a pivot means 85 which is coaxial with rotational axis B. The engine in turn drives a gear means 86 which simultaneously is drivingly connected to the inner and outer rotors to rotate same in opposite senses with equal and opposite torque. It should be noted that engine 93 imparts no rotational torque to ring 84 and that the engine itself remains nearly stationary while both rotors turn in opposite senses.

It is important in all embodiments, whether that of FIG. 11 or FIG. 12 that the lift vector pass through the center of gravity of the craft. The drone may not include passengers or other displaceable objects which could displace the center of gravity away from the lift vector. In a full cardan system, on the other hand, such as disclosed in the parent application, a shifting of weight in the cabin would not shift the center of gravity of the craft because all the cabin weight is always carried along the pivot axis of the cabin and then through the successively perpendicular pivot axes to the center of gravity of the system.

In this regard, it should also be noted that the trimming motor disclosed in the parent application for orienting the cabin or, in the case of drones, for orienting only a single ring such as 74, need not be coaxial with the rotational axis B of the rotors. Said motor could, for example, be located on the axis perpendicular to the rotational axis. It is important however that all structure located externally of the cabin be balanced about the center of gravity of the craft in order to avoid unwanted precessive torque.

In the FIG. 11 embodiment the fuel tanks F are mounted on the inner side of rotor 71. Fuel is fed to the engine by a pump. Centrifugal force prevents a shifting of the fuel weight in the tanks as the fuel is consumed.

In the FIG. 12 embodiment, on the other hand, the fuel tanks 87 are located in the engine itself and are properly compartmentized to prevent any change in the fuel weight distribution as the quantity of fuel diminishes pursuant to consumption thereof.

It should be noted that inner rotor 71 or 91 may comprise an imperforate shell enclosing the inner structure or it may comprise stay wires for holding the blade assembly, analogously to the structure of the outer rotor. If the inner rotor does comprise a shell as illustrated in FIGS. 11 and 12, there should be an adequate radial spacing 90 between the inner wall of the blade assembly duct and the surface of the shell. This spacing is needed to separate the induced air flow from the shell surface and thereby avoid the drag which would result if said induced air were to flow along the shell surface. In this regard, it will be noted that frictional drag is proportional to AV^2 where A is the area along which the air flows and V is the velocity of the air.

FIGS. 13 and 14 illustrate a landing gear devised especially for the precessor craft in order to resolve the problem of take-off and landing in a cross-wind or on an uneven terrain. The purpose of this gear is to permit a landing or take-off with the rotational axis of the craft being not necessarily vertical as would be the case if the craft were landing in a cross-wind. In such an instance, the craft would approach ts landing station and hover thereover with its axis tilted to compensate for the wind vector. It is necessary in this case that the landing gear be tiltable relative to the craft's rotational axis so that said gear may squarely engage the landing surface although the rotational axis of the craft may be inclined as it approaches that surface.

The explanation of how the precessor behaves on landing is as follows: when it is in the air, it behaves like a Foucault or free gyro. If it lands perpendicularly without any cross-wind present and on a flat horizontal surface, it becomes on touching ground no longer a free gyro but a balanced gyro, not precessing. But if it lands with its rotational axis inclined to the horizontal (as in a cross-wind or on uneven terrain) it becomes an unbalanced gyro and immediately starts to precess. The same applies in reverse during take-off maneuvers. It is imperative therefore to make the base of the landing gear tiltable in any direction with respect to the rotational axis of the rotors, so that the craft's precession may be counteracted.

Upon impact with the landing surface, a torque is imparted to the craft but is counteracted by the pilot who would at this moment employ "full flap counterprecession".

With reference to FIGS. 13 and 14, it is seen that the landing gear simply comprises a ball and socket joint arrangement 110 interconnecting the landing gear 112 with the first ring 114 corresponding to ring 27 in FIG. 7, ring 74 in FIG. 11 and ring 84 in FIG. 12.

What is claimed is:

1. An aircraft comprising a rotatable propellor means and means for generating a propulsive thrust along the direction of the axis of rotation of the propellor means, the direction of such thrust determining the direction of flight of the craft through the air, said propellor means while rotating constituting the rotor of a Foucault type gyroscope, and including a directional control means for selectively imparting a torque to said propellor means while rotating whereby its axis of rotation will re-orient itself in accordance with the principles of gyroscopic precession, and a drive means for rotating said propellor means without imparting any precessive torque upon same, said propellor means comprising a rotor in the form of an annular axially extending duct defined by radially inner and outer walls, a plurality of fluid-moving blades mounted between said walls in circumferential succesion to each other, said walls and blades forming an integrally rotatable unit, said blades being arranged to impart thrust to a fluid in the axial direction of said duct, said duct being concentrically rotatable about said rotational axis.

2. The craft of claim 1, said walls of said propellor means defining a venturi nozzle therebetween in the axial direction of said duct.

3. The craft of claim 1, said duct being cylindrical and the diameter ration of said inner wall to said outer wall being in the range of 0.55 to 0.75.

4. The craft of claim 1, the axial height of said walls being not in excess of the axial height of the profile of said blades.

5. The craft of claim 1, said propellor means comprising two of said rotors the ducts of which are coaxial with each other and arranged whereby the resultant lift vector thereof passes through the center of gravity of the craft, said drive means being arranged to simultaneously rotate both said rotors in mutually opposite senses and with equal and opposite torque.

6. The craft of claim 5, said drive means being an engine mounted on structure which forms an integral part of one of said rotors, a drive member of said engine being integrally connected with the other of said rotors whereby said engine rotatively drives a one of said rotors and the resultant counter-torque serves to drive the other of said rotors in an opposite sense.

7. The craft of claim 5, comprising an inner member freely pivoted relative to said rotors about the axis of rotation thereof, a drive engine pivotally mounted on said inner member about said axis, a gear means drivingly connecting said engine simultaneously to both said rotors to rotate them in opposite directions in a manner whereby the counter-torque resulting from the driving of one of said rotors serves to drive the other of said rotors in an opposite rotative sense.

8. The craft of claim 5, wherein said drive means comprises an engine drivingly connected simultaneously to both rotors in a manner whereby the counter-torque resulting from driving one of said rotors is fully dissipated in driving the other in an opposite sense to the first.

9. The craft of claim 8, comprising an inner member freely pivoted relative to said rotors about the rotational axis thereof, a servo mounted on said member, means for transmitting signals to said servo, directional control means actuated by said servo for imparting a precessive torque to said propellor means.

10. The craft of claim 9, at least some of said blades including a spoiler flap actuatable to change the lift producing characteristics of the corresponding blade, said directional control means being arranged to actuate said flaps whereby a said precessive torque is imposed upon said propellor means.

11. The craft of claim 10, said directional control means including a light producing means on said inner member, a photosensitive means on one of said rotors arranged to actuate respective ones of said flaps, said servo being arranged to actuate said light producing means and the latter being arranged to transmit a light signal to said photosensitive means which in turn actuates said flaps.

12. The craft of claim 9, including a receiver mounted on said inner member for receiving signals from a distant control station, said receiver being arranged to transmit signals to said servo.

13. The craft of claim 9, including a compass mounted on said inner member and arranged to transmit signals to said servo.

14. The craft of claim 9, including a support structure mounted on said inner member along said rotational axis and extending axially from one pole thereof, reconnaissance equipment mounted on said support structure.

15. The craft of claim 5, including an inner member freely pivoted relative to said rotors about the axis of rotation thereof, a clutching means arranged to selectively drivingly engage said inner member with either of said rotors whereby the orientation of said inner member may be controlled.

16. The craft of claim 1 wherein said propellor means comprise two rotors the ducts of which are coaxial and lie in the same plane.

17. The craft of claim 1 wherein said propellor means comprise two rotors one of the ducts of which is within the bounds of the other.

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