

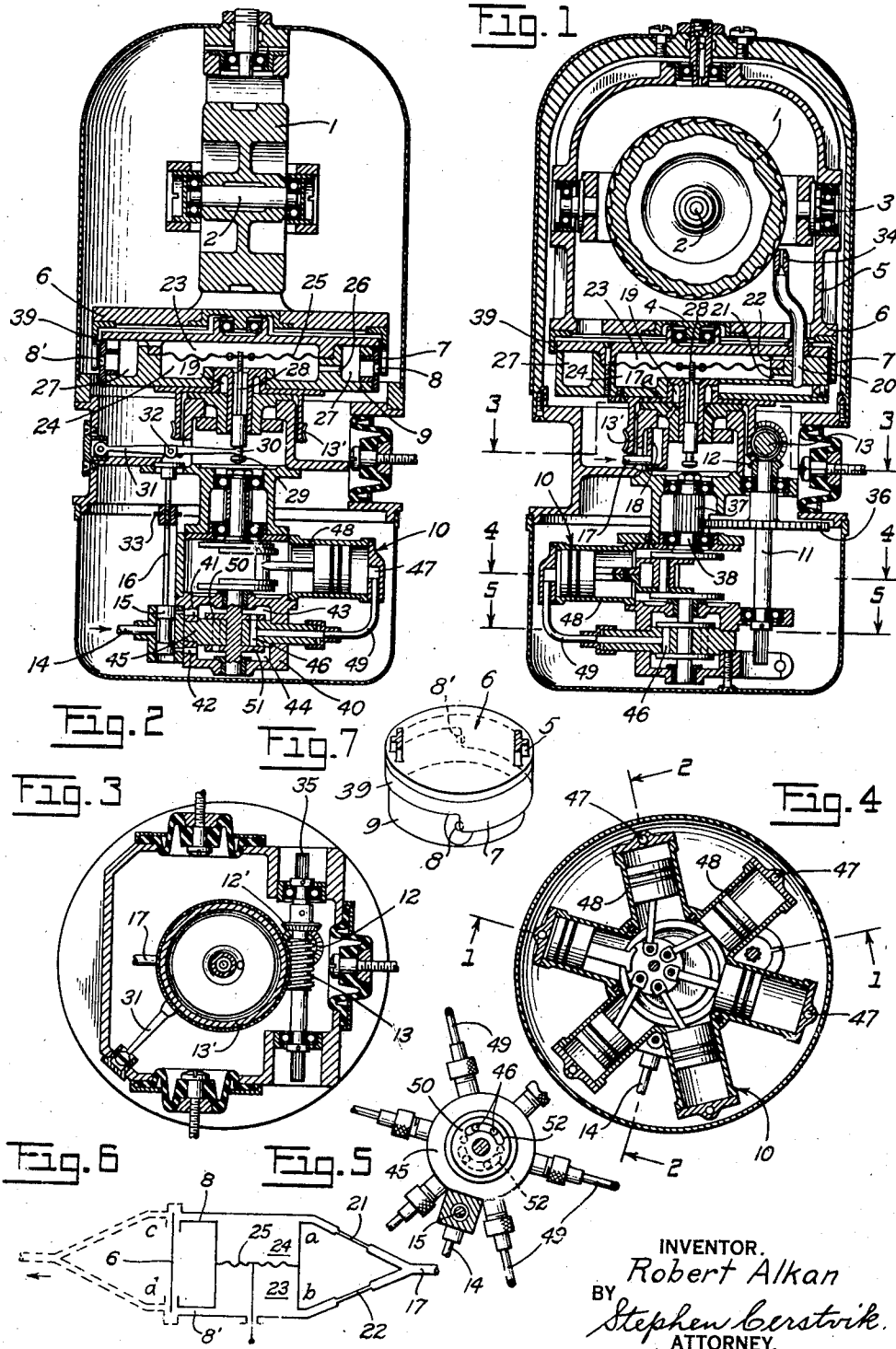
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PNEUMATIC FOLLOW-UP CONTROL

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PNEUMATIC FOLLOW-UP CONTROL

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This invention relates to gyroscopes and namely to directional gyroscopes, i. e., to gyroscopes adapted for use as direction indicators.

Among such gyroscopes, the invention relates more particularly to those in which the energy necessary for rotation of the same and for actuation of follow-up control means thereof is derived from pneumatic means.

Hitherto, such gyroscopes were generally constituted by a heavy torus or wheel mounted so as to have three degrees of freedom and maintained in rotation about its principal impulse axis under the action of an air jet directed by a nozzle against suitable buckets provided on the periphery of said wheel; the gyroscope thus formed and the mechanism to be controlled thereby were set in a follow-up relation by causing said gyroscope to actuate said mechanism through a servo motor having its control valve or distributor actuated by the support of the gyroscope, upon relative changes in orientation of the latter, with respect to an element of said mechanism which carries with it the casing of said control valve and which is rotatable concentrically about the support of the gyroscopes.

Among the difficulties and the disadvantages which are encountered in the execution and the use of such gyroscopes, there may be mentioned more particularly the perturbations caused in the orientation of the gyroscope by the actuation of the distributor of the servo-motor, by the passive resistances of rotating air-tight connections necessary for feeding the driving nozzle maintaining the rotation of the gyroscope when it is desired that no leakage be produced in these rotating joints, the production of continuous oscillations in the movement of the follow-up mechanism, and the like.

The invention has for its object to eliminate these various disadvantages and to improve the conditions of use and of construction of such gyroscopes.

An object of the invention is to provide a pressure-operated servo-motor for a follow-up element of a directional gyro responsive to precessional movement of the gyro.

Another object of the invention is to provide a manometric differential relay between the follow-up element of a directional gyro and the servo-motor distributor. The relay is operatively connected to the distributor valve of the servo-motor and is so constructed as to undergo variation in pressures responsive to control vanes operatively connected to the gyroscope and preferably having the same properties for fluid pres-

sure as a Wheatstone bridge has for an electric circuit.

A more specific object of the invention is to provide a gyroscope with a manometric differential relay having a yieldable diaphragm and constructed and arranged to form an integral part of the follow-up element of the gyroscope.

A still further object of the invention is to provide a bi-directional yieldable member between the manometric differential relay and the servo-motor distributor so as to urge the assembly toward a position of equilibrium.

A still further object of the invention is to provide a directional gyroscope having a follow-up element and a servo-motor with a spring-held manometric differential relay so as to prevent undesirable oscillation of the relay diaphragm and thereby increase the efficiency of the system.

An additional object of the invention is to provide a nozzle on the follow-up element for the gyroscopic rotor and to supply the nozzle with a pressure medium through an air-tight joint secured to the follow-up element.

A still further object of the invention is to provide a fluid pressure-operated servo-motor for the follow-up element responsive to the precession of the gyroscope and adapted to render remote indication of direction.

Besides the above mentioned principal arrangements which are preferably used together, but which can also be used independently one of another, the invention consists in other arrangements which will be explained more clearly hereinafter.

The invention is concerned more particularly with certain forms of embodiments and, namely, those which are adapted for controlling aiming devices or sights, route tracers or recorders, automatic stabilizers, etc., and it will be better understood from the complementary description which follows as well as from the annexed drawing, it being understood that said complementary description and drawing are given only for the purpose of explanation.

Fig. 1 is a longitudinal sectional view of the device taken substantially along the line 1—1 of Figure 4;

Fig. 2 is a longitudinal central section taken at right angles to the viewpoint of Fig. 1 taken substantially along line 2—2 of Figure 4;

Fig. 3 is a transverse section taken on line 3—3 of Fig. 1;

Fig. 4 is a transverse section taken on line 4—4 of Fig. 1;

Fig. 5 is a transverse segmental section taken on line 5—5 of Fig. 1;

Fig. 6 is a diagrammatical view showing the operation of the manometrical part of the follow-up control means of the same gyroscope; and

Fig. 7 is a detailed view in perspective of the novel vaned drum and follow-up element.

The gyroscope proper is made, as usual, of a heavy torus 1 to which three degrees of freedom are afforded by mounting it in a Cardan suspension for rotation about its principal axis 2—2, an horizontal axis 3—3 and a vertical axis 4—4.

The support 5 of the horizontal axis 3—3 is made integral with a drum 6 the peripheral surface of which is cut out in such a manner that there subsists a part of the wall forming a screen the edges 7 of which can cover ports 8 and 8' provided in the peripheral surface of a second drum 9 which is concentric to the first drum.

There is provided a servo-motor 10 which may be for instance of the type actuated by compressed air, and which is caused to drive the inner drum 9 by means of a shaft 11 carrying a pinion 12 engaging, through the intermediary of a further pinion 12' and a worm 13 splined to shaft 35, a worm gear 13' carried by the drum 9. The servo-motor 10 is supplied with compressed air from a pipe 14 (Fig. 5) through a distributor 15 controlled by a rod 16 and which, when actuated in one or in another direction, causes the operation of the servo-motor respectively in one or in the other direction, as it will appear more clearly hereinbelow.

Compressed air is also supplied to a pipe 17 secured to a fixed part 18 of a rotatable connection which communicates by way of passage 17a with chamber 19 provided in the central part of the inner drum 9. This central chamber 19 is put into communication with a passage 20 having two ports, 21 and 22, opening into a manometrical chamber separated into two compartments 23 and 24 by a flexible diaphragm 25.

On the other hand, both compartments 23 and 24 of said manometric chamber are in communication by means of passages such as 26, with two cavities 27 respectively, from which the air can flow outwardly through ports such as 8 and 8' provided in the peripheral wall of the drum 9 and in front of which move the screens formed by the peripheral wall of the outer drum 6.

It is easy to see that the flexible diaphragm 25 of the manometric chamber is influenced by the pressure difference which is established between the compartments 23 and 24 supplied by the ports 21 and 22, which pressure difference results from the difference in the degree of closure of the ports such as 8, and 8' by the edges such as 7 of the screens formed by the wall of the drum 6.

This arrangement can be represented diagrammatically in a form similar to a Wheatstone bridge, Figure 6, both branches *a* and *b* of which are constituted by resistances offered to the flow of compressed air by the inlet ports 21 and 22, while the opposed branches *c* and *d* are constituted by the resistances offered to the outflow of air through the ports 8 and 8', which are unequally covered by the edges 7 of the outer drum 6. The portion of Figure 6 which is shown in dotted lines represents the return to a common point which, in practice, is effected through the outlet into the surrounding atmosphere. In a manner similar to the connection of a galvanometer, the differential manometric diaphragm 25 is bridged between the conduits *ac* and *bd*. Sup-

posing the resistances *a* and *b* equal, there will be no pressure differences applied to the diaphragm provided the screen 6 closes the ports 8 and 8' in an equal manner.

This differential manometric device controls the follow-up servo-motor, which preferably will be a motor of the type actuated by compressed air and diagrammatically shown at 10. For this purpose, the diaphragm 25 is provided with a control rod 28 extending through a stuffing box in the trunnion of the drum 9. A double circular bearing 29 is provided at the extremity of the control rod 28 and serves for actuation of a fork 30 integral with an oscillating lever 31 pivotally connected at 32 to the rod 16 of the slide valve of the distributor 15 controlling forward and backward operation of the servo-motor 10 comprising six pressure operated cylinders arranged in the form of a radial engine with the crank shaft coaxial with the vertical axis of suspension of the gyroscope. The servo-motor 10 is provided with a shaft 11 geared to the crank shaft of the motor with a gear ratio smaller than 1:1 and controlling the rotation of the inner drum 9 through the intermediary of pinion 12, 12', the worm 13 and the worm gear 13'.

A gear 36 is splined to shaft 11 and meshes with the gear 37 of the crank shaft 38 of the servo-motor 10. Upon operation of the motor 10 the crank shaft is rotated and in doing so rotates shaft 11 through the intermediary of gears 36 and 37. The rotation of shaft 11 causes consequent rotation of drum 9 and the direction of rotation is determined by the positioning of the valve 15.

In this manner, a follow-up relation is provided between the drum 9 and the movements of the drum 6 and consequently of the gyroscope since, when the mechanism is suitably adjusted, the servo-motor 10 remains at rest so long as the diaphragm 25 is not influenced by any pressure difference, which corresponds to the equal closure of the ports 8 and 8' by the control edges 7. On the contrary, as soon as the gyroscope changes its position with respect to the frame carrying with it the drum 6, the ports 8 and 8' are unequally covered which results in a pressure difference between the compartments 23 and 24 and, hence, in a deflection of the diaphragm 25 which carries with it the rod 28, the oscillating lever 31 and the rod 16 of the distributor 15. The servo-motor 10 immediately sets itself in motion in a direction to re-establish an equal covering of the ports 8 and 8' by the central edges 7 and this movement stops as soon as the pressure equalizes on both sides of the diaphragm.

The servo-motor is controlled by the valve 15 which controls the admission of air to one or the other side of a distributor casing 40 through the intermediary of opposite passages 41 and 42. When air under pressure is admitted to one of the two opposite chambers 43 and 44 of the distributor casing, the other chamber is vented to the atmosphere, the corresponding passage 41 or 42 being open to the atmosphere. The distributor casing 40 contains a central stationary member 45 divided with a series of transverse bores 46, the number of which corresponds to the number of cylinders, said bores being connected to the inlets 47 of the respective cylinders 48 by the pipes 49. On either side of the stationary member 45 there are provided two distributor plates 50 and 51 which are mounted on the lower extremity of the crank shaft 38 passing through the member 45. The distributor plates are provided, as shown

in Fig. 5, with arcuate slots 52, which are arranged at 180° one from the other and thus control the admission of air under pressure and venting to the atmosphere of cylinders at 180° apart.

5 The ports 8 and 8' are diametrically disposed upon the inner drum 9 as shown in Figure 7 and in a position of equilibrium are equally covered so that the pressures on both sides of the diaphragm 25 are equalized. The coverage of the 10 ports is obtained by the edges 7 of the outer drum 6. The outer drum is provided with a continuous vane or edge 7 running circumferentially 180° as shown in Fig. 7, and has a stepped-up portion 39. Upon angular movement of the gyroscope about 15 its normally vertical axis the outer drum 6 will be rotated in either direction, dependent upon the direction of the angular movement, and will result in covering one port and uncovering the other permitting discharge through the latter 20 port and prohibiting discharge through the former port causing unequal pressure in the relay and operation of the diaphragm. The action of the diaphragm 25 will cause the distributing valve 15 to operate and permit inflow of the pressure 25 medium to the cylinders of the servo-motor 10 which will cause rotation of the crank shaft and resetting of the position of the inner drum 9. At this point a position of equilibrium is again reached wherein the ports 8 and 8' are equally 30 covered by the vane 7 as shown in Fig. 7.

It is possible that, during the very short period of time of the return of the manometric diaphragm 25 to its zero position, the movement of rotation of the servo-motor, of the transmission 35 and of the inner drum 9 may cause the latter slightly to exceed the position in which it should have stopped. In such a case, the servo-motor would re-start immediately in the opposite direction and, with a repetition of the same operation, 40 this may result in a continuous oscillation of the follow-up mechanism about the position of equilibrium which is defined by the orientation of the outer drum 6.

45 In order to avoid the production of such oscillations, there is preferably provided, according to the invention:

A spring such as 33 which is caused to act upon one of the elements providing the connection between the manometric diaphragm 25 and the distributor 15, for instance on the rod 16, so as to urge the distributor toward the position corresponding to the non-operation of the servo-motor. In this manner, the latter can start in 55 one or in the other direction only when the pressure difference between the compartments 23 and 24 attains a predetermined value which is greater than the minimum force necessary for overcoming the force of the spring corresponding to the slight movement which must be imparted to the slide valve of the distributor for causing the motor to start.

This results in a small dead area in the displacement of the outer drum 6 with respect to the 65 inner drum 9 for which the servo-motor will remain inoperative. By suitably proportioning the dimensions of the port 8 and 8' and the radial play between the drums, it will be possible to make this dead area as small as may be desired.

70 If then the stiffness of the springs 33 and the inertia of the elements controlling the slide valve of the distributor are so proportioned that the return to the position imposed by the spring 33, for no pressure difference between the compartments 23 and 24, is effected in a very short time,

smaller than the time which is necessary for the follow-up mechanism to pass over the dead area, the servo-motor will be brought to its inoperative position before the dead area has been traversed and thus any sustained oscillation will be made 5 impossible.

The follow-up relation being thus correctly effected, it will be possible to avail one's self of the synchronism between the movements of the drum 6 and 9 for causing the nozzle 34 supplying 10 the air jet maintaining the rotation of the torus of the gyroscope, to be carried by the drum 9 driven by the servo-motor 10 the power of which will be thus used in overcoming the frictional resistance present in a rotating air-tight connection such as that formed between the plate 18 15 and the inner surface of the drum 9 provided for supplying compressed air to the nozzle 34.

Since the gyroscope is not constrained to drive any rotating air supply connection, it will be possible to make its suspension, more particularly about the vertical axis, as sensitive as it may be desired which, of course, is favourable to the good behaviour of the instrument considered as a directional indicator. 25

By causing the geared shaft 11 of the servo-motor 10 to actuate a transmission mechanism comprising a rotating shaft such as 35, it is possible, with the energy provided by the servo-motor, to remotely actuate various instruments 30 which will be thus put into a follow-up relation with respect to the orientation of the gyroscope.

Obviously any instrument on the board may be controlled by this follow-up mechanism through 35 the intermediary of the geared ends of shaft 35 rotated by bevel gears 12 and 12' as will readily appear to one skilled in the art.

Of course, and as this already results from the foregoing, the invention is by no way limited to the embodiments which have been more specifically described and shown but it covers, on the contrary, all the modifications of the same and more particularly: 40

Those in which the invention is applied to other gyroscopes than those which are to be used as 45 directional indicators;

Those in which the gyroscope is replaced by any other direction indicator or indicator of the axis of reference. 50

Although but one embodiment of the invention has been illustrated and described in detail, it is to be expressly understood that the same is not limited thereto. For a definition of the limits of the invention, reference will be had primarily to 55 the appended claims.

What I claim is:

1. In a flight indicator for aircraft, a directional gyroscope, a follow-up element pivotally 60 mounted to follow the movement of the gyroscope about its normally vertical axis, a pressure actuated follow-up motor connected to drive said element, a valve controlling the admission of pressure to said motor and thus the direction of rotation of said motor, a pressure differential relay 65 comprising means forming two chambers mounted on said element, each chamber having a pressure inlet and a pressure outlet, a diaphragm separating said chambers, means actuated by movement of said gyroscope about its vertical axis equally intercepting the flow of fluid from said outlets when the gyroscope and follow-up are in a predetermined azimuthal relation and causing unequal flow and a pressure difference in said chambers when said relation is departed 75

from, and an operating connection between said diaphragm and said valve.

2. In a flight indicator for aircraft, a directional gyroscope, a follow-up element pivotally mounted to follow the movement of the gyroscope about its normally vertical axis, a pressure actuated follow-up motor connected to drive said element, a distributor having a stationary member and related movable members, a valve mounted for sliding movement in a portion of said distributor for controlling the admission of pressure to said motor through said movable members, a pressure differential relay comprising means forming two chambers mounted on said element, each chamber having a pressure inlet and a pressure outlet, a diaphragm separating said chambers, means actuated by movement of said gyroscope about its vertical axis equally intercepting the flow of fluid from said outlets when the gyroscope and follow-up are in a predetermined azimuthal relation and causing unequal flow and a pressure difference in said chambers when said relation is departed from, and an operating connection between said diaphragm and said valve, said valve being adapted to operate said motor selectively through said movable members of said distributor to permit clockwise or counter-clockwise rotation of the motor depending upon the direction of movement of said gyroscope from said predetermined azimuthal relation.

3. In a flight indicator for aircraft, a directional gyroscope having a rotor mounted for spinning about a normally horizontal axis, a follow-up element pivotally mounted to follow the movement of the gyroscope about its normally vertical axis, a pressure actuated follow-up motor connected to drive said element, a valve controlling the admission of pressure to said motor, and thus the direction of rotation of said motor, a pressure differential relay comprising means forming two chambers mounted on said element, each chamber having a pressure inlet and a pressure outlet, a diaphragm separating said chambers, means actuated by movement of said gyroscope about its vertical axis equally intercepting the flow of fluid from said outlets when the gyroscope and follow-up are in a predetermined azimuthal relation and causing unequal flow and a pressure difference in said chambers when said relation is departed from, an operating connection between said diaphragm and said valve, and a nozzle mounted on said element for directing fluid pressure against said rotor causing spinning thereof about said horizontal axis.

4. In a remote indicating system, a directional gyroscope having a rotor mounted for spinning about a normally horizontal axis, mutually perpendicular gimbal rings mounting said rotor for angular movement about a normally vertical axis, a follow-up element pivotally mounted to follow the angular movement of said rotor about said vertical axis, a pressure actuated reversible servomotor connected to drive said element, a distributor valve controlling the admission of pressure to said motor and thus the direction of said motor, a pressure differential relay comprising means forming a plurality of chambers carried by said element, each chamber having a pressure inlet and a pressure outlet, a resilient member separating said chambers, means actuated during angular movement of said rotor about said vertical axis equally intercepting the flow of fluid from said outlets when the rotor and follow-up are in a predetermined azimuthal relation and

causing unequal flow and a pressure difference in said chambers when said relation is departed from, an operating connection between said resilient member and said distributor valve, and air jet means carried by a portion of said element for directing fluid pressure against said rotor causing spinning thereof about said horizontal axis.

5. In a flight indicator for aircraft, a directional gyroscope comprising a rotor mounted for spinning about a normally horizontal axis, a gimbal mounting said rotor for precession about a horizontal axis perpendicular to said spin axis, a second gimbal mounting said first gimbal and said rotor for angular movement about a vertical axis mutually perpendicular to said first and second axes, a follow-up element pivotally mounted to follow the angular movement of the rotor about said vertical axis, a pressure actuated follow-up motor connected to drive said element, a valve controlling the admission of pressures to said motor and thus the direction of rotation of said motor, a pressure differential relay comprising means defining a plurality of chambers carried by said element, each chamber having a pressure inlet and a pressure outlet, flexible means separating said chambers, means carried by a portion of said second gimbal adjacent said relay and actuated during angular movement of said rotor about said vertical axis equally intercepting the flow of fluid from said outlets when the rotor and follow-up are in a predetermined azimuthal relation and causing unequal flow and a pressure difference in said chambers when said relation is departed from, and an operating connection between said flexible means and said valve.

6. In a flight indicator for aircraft, a directional gyroscope comprising a rotor mounted for spinning about a normally horizontal axis, a gimbal mounting said rotor for precession about a horizontal axis perpendicular to said spin axis, a second gimbal mounting said first gimbal and said rotor for angular movement about a vertical axis mutually perpendicular to said first and second axes, a follow-up element pivotally mounted to follow the angular movement of the rotor about said vertical axis, a pressure actuated follow-up motor connected to drive said element, a valve controlling the admission of pressure to said motor and thus the direction of rotation of said motor, a pressure differential relay comprising means defining a plurality of chambers carried by said element, each chamber having a pressure inlet and a pressure outlet, flexible means separating said chambers, a drum member secured to a portion of said second gimbal and movable therewith, means carried by and depending from said drum member adjacent said chamber outlets equally intercepting the flow of fluid from said outlets when the rotor and follow-up are in a predetermined azimuthal relation and causing unequal flow and a pressure difference in said chambers during angular departure of said rotor from said predetermined relation about said vertical axis, and an operating connection between said flexible means and said valve.

7. In a flight indicator for aircraft, a directional gyroscope, a follow-up element pivotally mounted to follow the movement of the gyroscope about its normally vertical axis, a pressure actuated radial servo-motor connected to drive said element, said motor having a power output shaft coaxial with the vertical axis of said gyro-

scope, a valve controlling the admission of pressure to said motor and thus the direction of rotation of said motor, a pressure differential relay comprising means forming a plurality of chambers carried by said element, each chamber having a pressure inlet and a pressure outlet, a diaphragm separating said chambers, means actuated by movement of said gyroscope about its vertical axis equally intercepting the flow of fluid from said outlets when the gyroscope and follow-up are in a predetermined azimuthal relation and causing unequal flow and a pressure difference in said chambers when said relation is departed from, and an operating connection between said diaphragm and said valve.

8. In a flight indicator for aircraft, a directional gyroscope, a follow-up element pivotally mounted to follow the movement of the gyroscope about its normally vertical axis, a pressure actuated follow-up motor connected to drive said element, a reciprocally mounted valve for controlling the admission of pressure to said motor and thus the direction of rotation of said motor, a pressure differential relay comprising means forming two chambers mounted on said element, each chamber having a pressure inlet and a pressure outlet, a diaphragm separating said chambers, a circular drum member actuated by and during movement of said gyroscope about its vertical axis, a sector member carried by and depending from said drum member adjacent said chamber outlets equally intercepting the

flow of fluid from said outlets when the gyroscope and follow-up are in a predetermined azimuthal relation and causing unequal flow and a pressure difference in said chambers during angular departure of said gyroscope from said predetermined relation about said vertical axis, and an operating connection between said diaphragm and said valve.

9. In a flight indicator for aircraft, a directional gyroscope, a follow-up element pivotally mounted to follow the movement of the gyroscope about its normally vertical axis, a pressure actuated follow-up motor, connections from said motor to said follow-up element for driving the element, said connections including a shaft having a plurality of power ends, a reciprocally mounted valve for controlling the admission of pressure to said motor and thus the direction of rotation of said motor, a pressure differential relay comprising means forming two chambers mounted on said element, each chamber having a pressure inlet and a pressure outlet, a diaphragm separating said chambers, means actuated by movement of said gyroscope about its vertical axis equally intercepting the flow of fluid from said outlets when the gyroscopes and follow-up are in a predetermined azimuthal relation and causing unequal flow and a pressure difference in said chambers when said relation is departed from, and an operating connection between said diaphragm and said valve.

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