Sept. 14, 1954 R. ANNEN 2,688,805

GYROSCOPIC APPARATUS

Filed Sept. 23, 1952 2 Sheets-Sheet 1

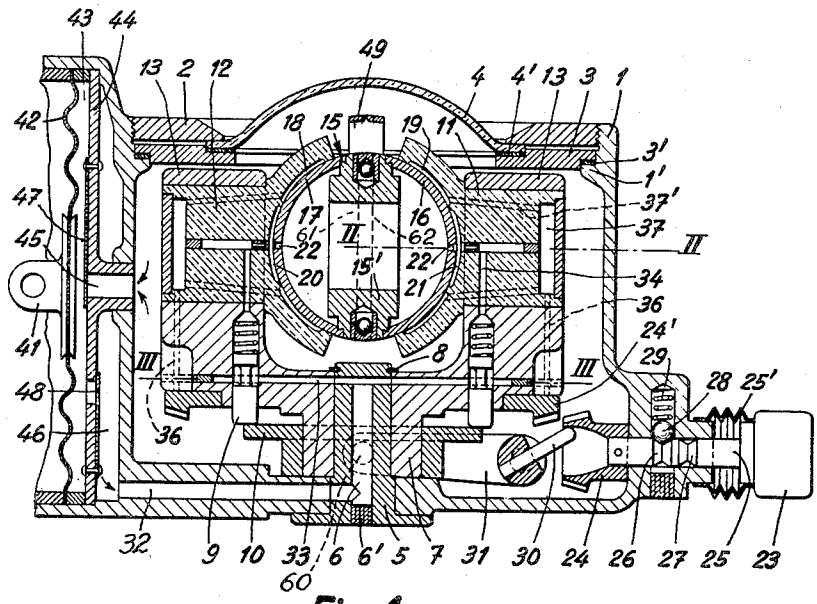


Fig. 1

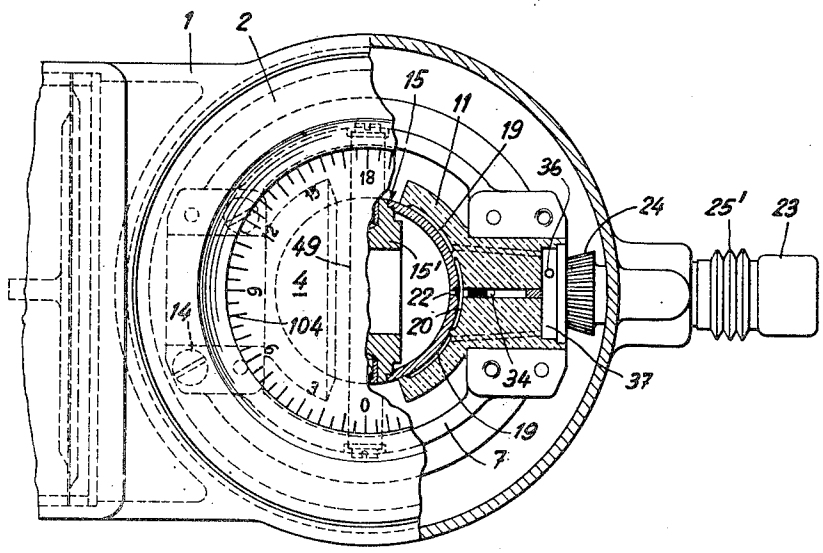


Fig. 2

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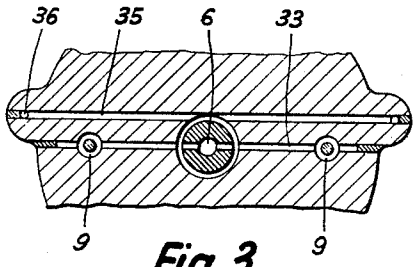


Fig. 3

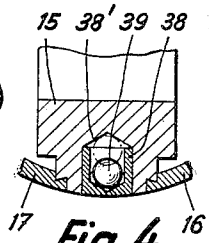


Fig. 4

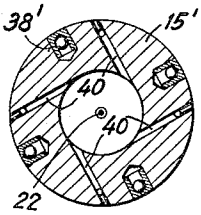


Fig. 5

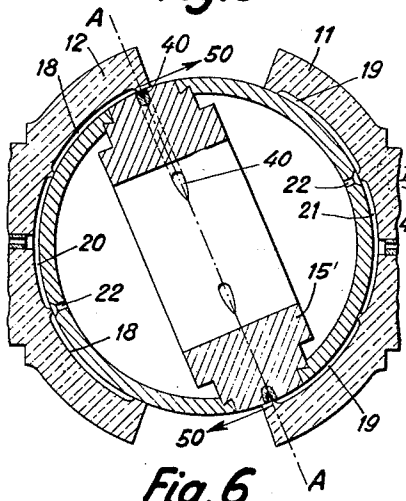


Fig. 6

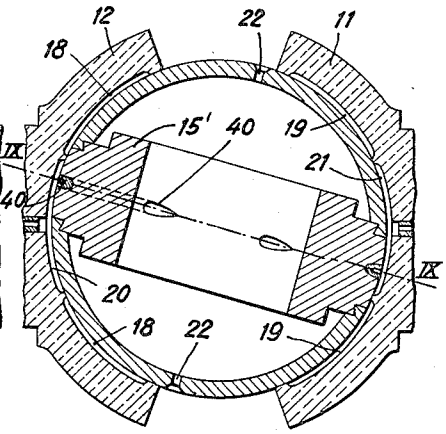


Fig. 8

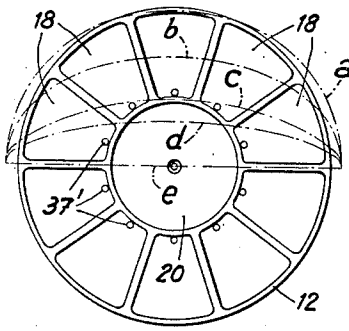


Fig. 7

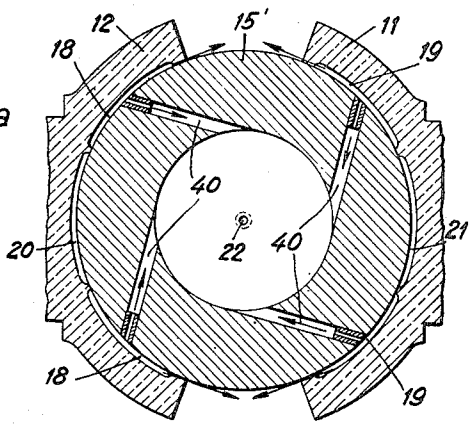


Fig. 9

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GYROSCOPIC APPARATUS

Robert Annen, Bienne, Switzerland

Application September 23, 1952, Serial No. 311,130

Claims priority, application Switzerland
March 17, 1952

7 Claims. (Cl. 33—204)

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The present invention relates to a gyroscopic apparatus.

Two types of gyroscopic apparatus are known, namely the one in which a rotor is driven pneumatically and the other in which a rotor is driven electrically.

In the first type the balancing of the two jets of air driving the rotor and the centering of the latter are very difficult to obtain.

In both types the rotor is always influenced by the frictional resistance of the "anti-friction" bearings carrying the movable parts.

The primary object of the present invention is to do away with these errors.

The invention contemplates the provision of a ball-like rotor spinning in a fluid support bearing having spherical bearing surfaces to which air or another fluid contained in the hermetically closed casing of the instrument is fed, the rotor being adapted to be rotated by the fluid fed to said spherical surface.

Other objects and features will appear from the following description of a constructional embodiment with reference to the accompanying drawings.

In the drawings:

Fig. 1 is a vertical section through the axis of the rotor and that of a control knob, the rotor and the flange provided for its support being intentionally rotated 90° from its normal position to show the air distribution.

Fig. 2 is a plan view, partly in section along line II—II of Fig. 1.

Fig. 3 is a horizontal partial section through the line III—III of Fig. 1.

Fig. 4 is a partial section of the ball-like rotor along a meridional plane thereof and shows on an enlarged scale a device for restoring the vertical position of the rotor.

Fig. 5 is an equatorial section of a portion of the rotor and shows the air discharge nozzles provided in the latter.

Fig. 6 is a meridional section of the rotor and of the portions of bearing located at immediate proximity thereof.

Fig. 7 is a front view of one of these bearing portions and shows diagrammatically and in projection the paths of the air discharge nozzles in certain working positions of the rotor.

Fig. 8 is a view similar to Fig. 6 and shows the rotor in a position in which its air inlet openings are located between the portions of bearing.

Fig. 9 is a partial section along the axis IX—IX of Fig. 8.

Referring now to the drawing and more particularly to Fig. 1, the gyroscopic apparatus com-

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prises a metallic casing 1 having in general the shape of a cylindrical pot provided at its upper end with a peripheral inner flange 1' supporting an annular cover plate 3. This plate 3 and a similar cover plate 2 screwed into the upper, internally threaded end of the casing 1 serve to hold clamped therebetween a spherically curved window glass 4, sealing rings 3' and 4' being provided so that a hermetic closure is obtained. A circular scale 104 is engraved in the rim portion of the glass 4 which constitutes a transparent portion of the casing.

The bottom of the casing 1 i. e. the portion opposite the glass 4, has a central bore into which a pivot 5 is tightly pressed. This pivot has a longitudinal central bore 6 the lower end of which is hermetically stopped as indicated at 6', this bore forming a passage for the air or other fluid serving to support and to rotate the rotor. A member 7 is rotatably mounted on the pivot 5 and a split ring 8 engaging a groove provided at the upper end of the pivot 5 prevents this member 7 from moving upwardly, whilst the lower support is constituted by the bottom of casing 1. The damping of the rotary movement of member 7 around pivot 5 is effected by spring-loaded pistons 9 frictionally engaging a sleeve 10 which is mounted for axial sliding movement on a lower annular portion of the member 7.

The fluid (air) support bearing comprises two cup-like portions 11 and 12 molded of transparent material and secured to the member 7 by means of clips 13 and of screws 14. The ball-like hollow rotor 15 is held between the cup-shaped bearing portions 11 and 12 so as to be freely rotatable in all directions and positions. In other terms, when the rotor spins around an axis remaining fixed in space, the bearings 11 and 12 may accompany the casing 1 in all movements without disturbing the movement of the rotor. The rotor 15 comprises an equatorial ring 15' and two hemispheres 16 and 17 between which the ring 15' is secured in any appropriate manner. In the embodiment shown in the drawings the hemispheres are fixed to the ring 15' by means of circular shoulders of the ring 15' which are fitted into circular grooves of the hemispheres 16 and 17, as shown at the end of arrow 15.

Each of the bearing cups 11 and 12 is provided on its side facing the rotor 15 with recesses 18 and 19 of small depth which form pressure chambers in which the supporting fluid acts to support the rotor 15. An example of the shape and arrangement of these recesses is shown in Fig. 7. There is a circular central recess 20 which is surrounded by a series of ten sector-like further re-

cesses 18 in the bearing cup 12. The corresponding recesses of the bearing cup 11 are designated by 21 and 19, respectively.

At rest and during normal flying of the plane equipped with the gyroscopic apparatus, the fluid contained in, and fed to, the chambers 20 and 21 generates the rotary movement of the rotor, whilst the fluid contained in the chambers 18 and 19 supports this rotor. This may change, for instance, when the plane flies upwardly or downwardly, i. e. when the openings or air passages 22 located on the spin axis of the rotor come into a position in which they are no longer in communication with the chambers 20, 21, but with one of the chambers 18 and one of the chambers 19, respectively.

The device for adjusting the instrument comprises the actuating knob 23 and the pinion 24 rigidly connected therewith by means of the axle 25. These three members are shiftable axially and may take two extreme positions which are determined by a ball 28 loaded by a coil spring 29 and adapted to engage either one of two peripheral grooves 26 and 27 of the axle 25.

The bevelled pinion 24 is made with a cup-like recess the wall of which is adapted to engage a pin 30 fastened to a lever 31 which is swingably mounted in casing 1 and operatively connected with sleeve 10 by means of a pin 60 shown in dotted lines, which engages the bottom of the sleeve. When the knob 23 is pushed to the left from the position shown in Fig. 1, the lever 31 is swung in clockwise direction and the sleeve 10 is lifted. Consequently, the pistons 9 which are adapted to operate as control members, are lifted too and close the air passages 33. The flexible tube 25' prevents air and dust from getting into the space enclosed by casing 1.

The arrangement of certain air passages, including the air passages 33, is shown by Fig. 3. It becomes obvious from this figure that the air for supporting and driving the rotor can flow to the chambers 18 and 19 through the passages 32, 6, 35, 36, 37 and 37' and to the chambers 20 and 21 through the passages 32, 6, 33, 34.

Fig. 4 shows on an enlarged scale the manner in which the halves 16 and 17 of the spherical rotor 15 are fixed to the ring 15'. It shows furthermore that in each of four blind radial holes 38' which according to Fig. 5 are arranged at 90° from one another in the equatorial plane, a pressed-in pot-like bushing 38 is provided in the axial bore of which a ball 39 is freely movable in the radial direction of ring 15'. If the rotor does not spin or if it spins only slowly, the balls 39 therefore being subject to only a small centrifugal force or to no centrifugal force at all, it comes into the normal or "vertical" position shown in Fig. 1 because the ball 39 enclosed in the downwardly directed hole will rest on the bottom of the correspoding bushing and be located at a greater distance from the axis of ring 15' than the ball 39 enclosed in the upwardly directed hole 38' and resting on the bottom of this hole. The center of gravity of the rotor is then positioned somewhat below the geometrical center and the ball-like rotor comes to occupy a position of stable equilibrium which is the normal or starting position in which the equatorial plan is vertical. In Fig. 1 the rotor is supposed to rotate rapidly and the two balls 39 which are visible rest on the bottoms of their respective bushings as do the other two balls which are not visible. The center of gravity of the rotor then coincides with the geometrical center.

Other systems might be provided for restoring the correct starting position of the spherical rotor. A plurality of small permanent magnets could, for example, be so imbedded in the ring 15' that their like poles would be directed outwardly. A further permanent magnet would be arranged in the bore 6 and operatively connected with sleeve 10 so as to be shiftable against the rotor. The latter would then be decelerated and erected, i. e. its normal or starting position restored.

Fig. 5 shows four passageways 40 which act normally (as set out later on) as discharge nozzles for the air or other fluid entering the rotor through the passageways 22. The passageways 40 extend in the equatorial plane perpendicular to the spin axis coinciding with the common axis of the passageways 22. They are inclined at the same angle to the peripheral surface of the rotor.

The operation of the gyroscopic apparatus is as follows:

A small electric or other motor not represented on the drawings reciprocates the connecting piece 41 which actuates the annular bellows 42 correspondingly. The fluid, e. g. the air contained in the casing 1 with a slight overpressure is sucked through passage 45 and discharged into the reservoir 46. Resilient tongues 47 and 48 fixed to the partition 44 act as automatic valves. From the reservoir 46 the fluid, e. g. the air, flows through the passages mentioned in connection with Fig. 3 and feeds the pressure chambers 18, 19, 20 and 21 where it acts in supporting and driving the rotor, the manner in which the driving action takes place being explained later on. At any rate it may be stated that the air or other fluid is discharged by the pressure chambers back into the inner space of the casing 1 surrounding the rotor. The flow circuit is thus closed. The fluid has therefore an approximately constant temperature. It is somewhat heated up by the pump constituted by the bellows 42.

Before he starts the motor driving the air pump, the pilot puts the rotor into a position indicating the flying direction. When a plane is started, its longitudinal axis rarely corresponds with the general flying direction which is to be maintained. During the landing too its longitudinal axis most probably must depart from the general flying direction. It results therefrom that the white and black lines indicated by the dotted lines 61 and 62 respectively, usually provided on the rotor take any position with regard to the zero on the scale of the instrument.

Assume that the longitudinal axis departs by x degrees from the general flying direction. The pilot then sets the two lines 61 and 62 of the non-rotating rotor at x degrees on the scale 104, this being performed by rotating the member 7 provided with the toothed crown 24' by means of the knob 23, of the axle 25 and of the bevelled pinion 24, these parts having previously been shifted leftward in Fig. 1. When the setting has been carried out these parts are shifted back into the position of Fig. 1. Then the pump is put into operation. The plane of rotation of the rotor, i. e. that of the white and black marking lines on the rotor is placed, at least temporarily, exactly in alignment with the indication of x degrees on the scale 104 on the stator, but the member 7 occupies any random position.

After a few minutes, when the rotor spins with its normal working speed, the pilot may correct the position of the member 7 so that the marking line usually provided on the transparent sector 49 fixed to the member 7 will be placed opposite

to the "0"-indication of the scale **104** on the stator.

The plane is flying in the desired direction when the two marking lines on the rotor frame the marking line provided on the sector **49**.

It is evident that this setting of the instrument can be carried out while the plane is flying.

When it is desired to stop the rotor, the button **23** has merely to be shifted to its left extreme position. The pinion **24** is thereby put into engagement with the toothed crown **24'** and at the same time the sleeve **10** is moved upwardly together with the slide valve members **9**. The outlets of the passages **33** are consequently stopped and the principal feeding source of fluid is no longer in communication with the pressure chambers **18–21**. The rotor slows down and finally stops.

The pump **41** or rather its driving motor may then be stopped. As the rotor is no longer supported on a film or air it will come at rest on the bearing portions **11** and **12**.

The parallel circles engraved along a diametrical plane of the rotor are intended to indicate to the pilot whether or not the plane has departed from a given flying direction and whether the angle of departure is more or less than 180°, and will be marked as usual, the one being colored in white, the other one in black, for example. These circles play the rôle of an indicating hand; they are visible through the transparent segment **49** over a length substantially equal to an equatorial diameter of the spherical rotor. The segment **49** is provided over substantially its whole length with a fine index line which faces the zero of the scale of the stator; it permits an accurate reading of the indications furnished by the black line and the white line on the rotor.

The outer surface of the spherical rotor is perfectly smooth and polished. Only the small air inlet ports **22** and certain other small ports still to be described are visible. The aforementioned black and white lines are engraved into its surfaces, are very near to each other, filled with enamel and polished as is the remaining outer surface of the rotor.

The air inlet ports **22** and air discharge nozzles indicated at **40** are so calibrated that the pressure inside the rotor is practically the same as that in the pressure chambers **18** and **19**.

The rotor of a modern gyroscope must be able to be started, speeded-up and keep its working speed in all positions of its spin axis with regard to the bearing portions provided for its support.

The previously supposed "x°" of departure from the general flying direction may vary from 0° to 180°. If the axis of the bearing of the rotor may rotate in the horizontal plane between 0° and 90° without disturbing the position of the spin axis of the rotor, it may obviously take any position without disturbing that of the spin axis.

Four principal positions will now be considered.

The first position which is shown in Fig. 1, is that in which the air inlet ports **22** feeding the discharge and driving nozzles **40** remain in the field of the chambers **20** and **21**. In this working position the outlets of the discharge nozzles remain always between the rims of the bearing portions **11** and **12**. The rotor spins normally.

The second position, shown in Fig. 6, is that in which the air inlet ports **22** face the very narrow partitions which separate the central chambers **20, 21** from the chambers **18, 19**, respectively.

Though the ports **22** are shown to have a diameter at least equal to the width of the said partitions, they have a bevelled inlet or outer end in order to facilitate the passage of air. The discharge nozzles **40** are then fed by the chambers **18** and **19** as well as by the chambers **20** and **21**. The feeding is nevertheless slightly diminished, but still largely sufficient.

In the working position of the spin axis of the rotor and of the inlet ports **22**, shown in Fig. 6, the nozzles **40** move along a circle the uppermost portion of which is located slightly inside the uppermost chamber **18** and the lowermost portion of which is located slightly inside the lowermost chamber **19**. This is diagrammatically illustrated in Fig. 7, by the line a. Some supporting fluid escapes from the uppermost chamber **18** and from the lowermost chamber **19**, the escaping direction being indicated by the arrows **50**. Some air is discharged by the nozzles **40** in the plane of rotation (equatorial plane) A—A of the rotor, as shown in Fig. 6.

It has been said heretofore that the fluid pressure inside the rotor is substantially equal to that in the pressure chambers. It is, however, true that the pressure of the air discharged from the nozzles **40** is somewhat lower than the pressure inside the pressure chambers. There is consequently at the outlet of the nozzle or nozzles **40**, at the moments when they pass inside the pressure chambers, a very low resulting pressure or thrust directed towards the center of the rotor. This resulting small thrust has for its effect to cause a very tiny precession movement of the rotor.

If the rotor spins at a reduced velocity of 6000 R. P. M., the four nozzles **40** pass alternatively through the diametrically opposite critical positions in $\frac{1}{400}$ of a second.

The very small precession movement produced at the right side after the passage of either one of the nozzles through an upper pressure chamber will be completely compensated after the passage of the same nozzle through the lower critical position.

The above is true not only for the working position of Fig. 6, but also when the spin axis of the rotor (in a relative movement) oscillates away from the longitudinal axis of the bearing portions towards a position in which the spin axis is perpendicular to this longitudinal axis. In the course of such oscillating movement, the paths of the nozzles **40** would be successively indicated by lines as b, c, d and e in Fig. 7.

In the operative range between the lines c and e the air inlet ports **22** are located between the bearing portions **11** and **12** as shown in Fig. 8. The feeding of driving fluid into the rotor through the ports **22** has then ceased. But the rotation of the rotor continues owing to the periodic action of the fluid present in the pressure chambers onto each pair of nozzles **40** during their passage through the pressure chambers, in a manner illustrated in Fig. 9 which is a sectional view along the line IX—IX of Fig. 8. This driving action takes place as follows:

The air escaping from the pressure chambers **18** and **19** (Fig. 9) acts upon the nozzles **40** as if the latter were blades of a turbine. These intermittent driving impulses are sufficient to keep the rotor in rotary movement during an undetermined period of time. Tests which have been made on such a gyroscope have proved that the rotary speed of the rotor in the positions, as that indicated at d, corresponding to the field

comprised between the lines c and e of Fig. 7 is not substantially lower than the speed in the normal working position of Fig. 1, in which air flows into the rotor through the ports **22** facing the central pressure chambers **20** and **21**.

If the spin axis oscillates still further, the rotor passes through working positions similar to those explained hereabove and shown by Fig. 7 reversed top to bottom together with the lines *e, d, c, b* and *a*, and finally the rotor would again be in a working position in which air flows from the central chambers **20, 21** into the rotor and escapes from the latter through the nozzles.

During normal flying the black and the white marking lines on the rotor are constantly located between the two bearings. Working positions as those represented by the lines *a, b, c, d* and *e* of Fig. 7 occur only accidentally and during acrobatic flying, and then only for a few moments.

It has already been said that the inside of casing 1 is hermetically closed. When the parts of the instrument are assembled together, a neutral gas, e. g. dry air, is advantageously pumped into the inner space with an overpressure of about 1 kg. per cm.^{2}. The pressure of this gas should be periodically measured and restored if necessary. As during the operation the fluid flows in a closed circuit it need not be filtered.

The support afforded by the film of supporting fluid is sufficiently strong to damp possible accelerations and shocks.

The play of the spherical rotor between its bearings should normally be comprised between about 0.02 and 0.03 mm.

It should be noted that since the casing is hermetically closed, variations of the outer pressure have no effect on the instrument.

The fluid support bearings exert practically no resistance to the rotation of the rotor; hence, precession and drift are practically nil.

Amongst a number of modifications, an important one would consist in arranging the bearing portions at a position at 90° from that shown in Fig. 1, the axis of the bearing being then vertical. The gap between the bearing portions would then be horizontal and an aperture should be provided so as to render easily visible the marking circles of the rotor.

I claim:

1. A gyroscopic apparatus comprising a closed casing, a ball-like rotor, a fluid-support bearing for the rotor, moving bodily with said casing during operation and having two opposite, cup-like spherical support surfaces located on either side of the rotor, means for feeding to said surfaces a fluid contained in the casing, said rotor having intercommunicating passageways for the fluid, namely a pair of passageways extending along a diameter which coincides with the spin axis of the rotor and serving during normal operation as inlets to the rotor for the fluid fed to the support surfaces, in one position of the axis of said rotor relative to said surfaces, and serving as outlets in another position of said rotor, and a series of passageways extending in a plane perpendicular to said diameter and serving during normal operation as outlets for said fluid while said rotor is in said one position, but as inlets when in said other position, with outer portions of said series of passageways being all inclined by the same angle relative to the peripheral surface of the rotor, all these passageways being adapted to keep the rotor spinning and to keep its spin axis fixed in space during all movements of said casing, indicating means on said rotor, visible through the casing, and other indicating means on the casing, for indicating the variations of position of said casing with regard to the spin axis of the rotor.

2. The gyroscopic apparatus of claim 1, in which the casing includes a transparent portion, said indicating means on the casing being constituted by a circular scale engraved in the transparent portion of the casing, and the indicating means on the rotor being constituted by at least one marking circle engraved along the equator of the rotor.

3. The gyroscopic apparatus of claim 2, in which said support surfaces are provided on two separate portions of the bearing and which comprises a pivot fixed to a portion of the casing opposite to the transparent portion thereof, said pivot extending in a direction perpendicular to the plane of said circular scale, a member rotatably mounted on said pivot, to which the portions of the bearing are secured, their common longitudinal axis extending substantially in a plane parallel to the plane of said circular scale, means for normally retaining said member from rotating around said pivot, means operable by hand for adjusting the angular position of said member by rotation thereof around said pivot, and indicating means on said member, movable together with this member below said circular scale.

4. The gyroscopic apparatus of claim 3, in which the portions of bearing are molded of transparent material.

5. The gyroscopic apparatus according to claim 4, which in said feeding means comprise a pump operable for circulating the fluid contained in said casing, which is hermetically closed, back to the support surfaces of the fluid support bearing.

6. The gyroscopic apparatus according to claim 5, in which said feeding means furthermore include passages provided in said casing, said pivot, said member and said portions of bearing, and adapted to connect the pump with the support surfaces, in which said means for normally retaining said member from rotating include a non-rotatable sleeve concentric to said pivot and spring-loaded pistons guided in said member and resting on said sleeve, an operative connection being provided between this sleeve and the means for rotating said member, so that these means are also operable for shifting the sleeve independently of the rotation of the member, and said spring-loaded pistons being adapted and arranged to act as valves controlling the flow of fluid through said passages from said pump to the support surfaces.

7. The gyroscopic apparatus according to claim 6, in which said rotor has a plurality of chambers extending radially in its equatorial plane near the outer surface thereof, a ball being movable in each of said chambers, these balls being operative, when the rotor does not spin, in bringing this rotor back into a normal rest position in which its equatorial plane is vertical.

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