July 7, 1936. J. M. BOYKOW 2,046,998

GYROSCOPIC PENDULUM

Filed Oct. 6, 1934

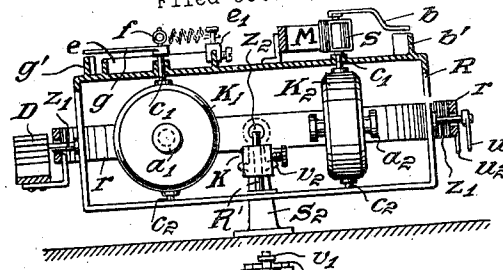


Fig. 1

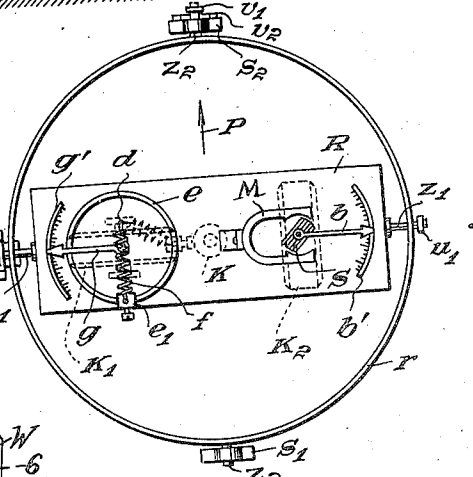


Fig. 2

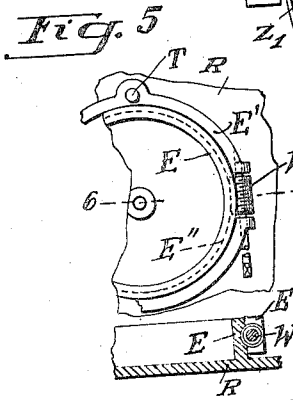


Fig. 5

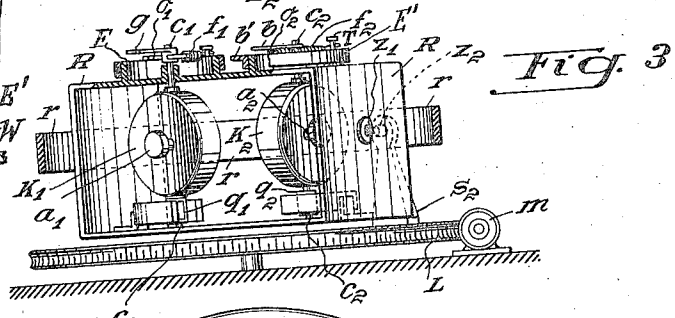


Fig. 3

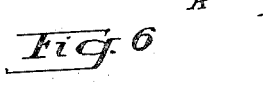


Fig. 6

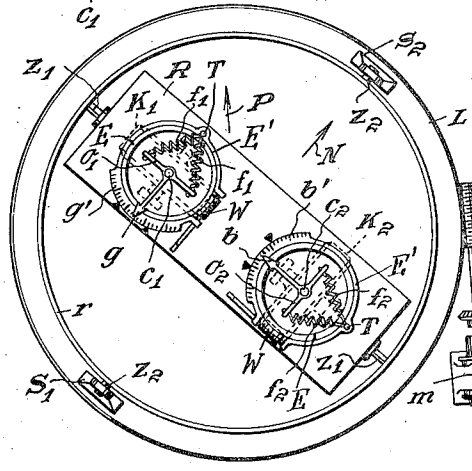


Fig. 4

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GYROSCOPIC PENDULUM

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18 Claims. (Cl. 33—204)

This invention relates to gyroscopic pendulums universally suspended in oscillatory crafts and, more particularly, to means for stabilizing a universally suspended frame by means of two gyroscopes mounted therein.

A further object of this invention is the measurement of the true course and speed of the craft by said two gyroscopes. This may be effected by measuring the true speed over ground by the one of said gyroscopes, and the side slip of the craft in relation to the direction of its longitudinal axis by the other of said two gyroscopes. According to a further feature of this invention, the whole pendulum may be adjustable into the north-south direction by means of a follow-up motor controlled by a compass, or the like, if the course is altered.

In a preferable form of the invention, the two gyroscopes are arranged with vertical precession axes in a pendulum frame universally suspended in the oscillatory craft in such a way that their spinning axes are horizontal and at right angles to each other. This result may be effected by constraining the gyroscopes by means of springs to zero positions in which the spinning axis of the one gyro is normally parallel to the north-south direction while the spinning axis of the other gyroscope is normally parallel to the east-west direction. If in a well-known manner both gyroscopes are compensated against the influence of the earth's rotation, their precession moments will be proportional to the components of the speed of the craft in the north-south direction and east-west direction, respectively. Hence it is possible to determine the rate and the direction of the true speed over ground e. g. by geometric addition of said components.

Further objects and advantages will be apparent from the following description taken in connection with the accompanying drawing in which

Fig. 1 is an elevation and

Fig. 2 a plan view of an embodiment of a gyroscopic pendulum embodying the invention and attached to a moving craft in a defined relation to the axes of the craft.

Fig. 3 shows in elevation and

Fig. 4 in plan another embodiment which is adjustable in relation to the craft carrying the said embodiment so as to maintain the gyroscope pendulum with its one axis parallel to the north-south line, in consequence of which the gyroscopes of this pendulum as regards their spinning axes will be maintained in the north-south line and in the east-west line, respectively.

Fig. 5 is a plan view, on an enlarged scale, of a detail of the embodiment shown in Figs. 3 and 4, and Fig. 6 is a section on line 6—6 of Fig. 5.

Referring now to Figs. 1 and 2, R is the so-called pendulum-frame, carrying the gyroscopic system and pivoted at z_1, z_1 to the gimbal-ring r, which ring r in turn is pivoted at z_2, z_2 to supports s_1 and s_2, these supports s_1 and s_2 lying, for instance, on a line parallel to the longitudinal axis of the craft. The direction of the longitudinal axis of the craft is that indicated by the arrow P in Fig. 2. The center of gravity of the entire pendulum is at a level below the plane of the pivot axes, and the position of said center of gravity is determined by a weight K adjustable vertically along a guide R' on the frame R. The distance of the centre of gravity of the whole pendulum below the plane of the pivot axes is so dimensioned as to give to the pendulous system an oscillation period of only a few minutes, in consequence of which the system will not respond to short-period accelerations due to the oscillations of the craft around its longitudinal and its transverse axes. The said short oscillation period of the system is advantageous especially for gyroscopic pendulums serving as an artificial horizon for oscillatory crafts, since such gyroscopic pendulums have to be ready for operation within a comparatively short time. The housings of the two gyroscopes K_1 and K_2 are pivoted vertically at c_1, c_2 to the pendulum frame R. The spinning axes a_1 and a_2 of the two gyroscopes are arranged horizontally and at practically right angles to each other. As regards the gyroscope K_2, the influence of the actual earth rotation is compensated in a manner well known per se by means of an electro-magnetic coil S pivoted or swinging between the poles of a magnet, generally a permanent magnet, as shown at M. For instance, the said coil S may be of the type known as a Deprez coil. For the said purpose of compensating the actual earth rotation with respect to the gyroscope K_2, the said coil is excited by a current, which is dependent on the angular speed of the earth and the angle between the course of the craft and the meridian and is proportional to the angular speed of the earth as long as the said angle between the course of the craft and the meridian is maintained. It may be noted that the said compensation is known per se as shown by way of example for instance in United States Patent No. 1,940,387. It will be evident from the above that the gyroscope will not experience a directive force, as long as it is not displaced in relation to the

earth. However, as soon as the gyroscopic pendulum is moved along with the craft in relation to the earth, the gyroscope K_2 will respond to the speed with which the craft moves relative to the earth, which speed in the following may be called the apparent earth rotation. In consequence of the said effect, the spinning axis a_2 of the gyroscope K_2 will execute a turning movement and take up a position in which it is parallel to the axis of the apparent earth rotation, i. e. transverse to the direction of the movement executed by the craft relative to the earth. As long as the direction of the said movement of the craft is parallel to the longitudinal axis of the craft, the spinning axis a_2 of the gyroscope K_2 will be lying in a plane which is at right angles to the direction of the longitudinal axis of the craft. As soon as, however, for any reasons, for instance in consequence of any motion of the medium in which the craft travels, the direction of the movement of craft relative to the earth is deviated from parallelism with the direction of the longitudinal axis of the craft, the spinning axis a_2 of the gyroscope K_2 will deviate from its zero position shown in Figs. 1 and 2 and assume a position in which it includes with the transverse axis of the craft, an angle defined by the line through the pivots z_1, z_1, the size of which angle will be proportional to the amount of the difference between the direction of the movement of the craft and the direction of its longitudinal axis. This angle, the so-called drift angle, is indicated by an indicator b on a scale b', the indicator being fixed to the precession axis of the gyroscope K_2 and the scale b' being provided on the frame R.

It is understood that an indication of the said side-slip or drift angle may also be transmitted to other places in the craft, for instance to the pilot's seat.

As in practice the angle of drift will be comparatively small, the gyroscope K_2 will always remain able to maintain the elements in a horizontal plane notwithstanding the oscillations of the craft around its longitudinal axis which is, as will be clear from the above, parallel to the line z_2—z_2.

As regards the gyroscope K_1, the influence of the actual earth rotation is also compensated in a manner known per se, namely by means of a spring f connected at its one end to a lever d fixed to the pivot c_1 of the gyroscope K_1 and connected at its other end to a sleeve e_1 riding on a ring guide e, two different positions of said sleeve being shown in full lines and in dotted lines respectively.

In the zero position of the sleeve e_1 (shown in full lines) in which the direction of the spring force is identical with the longitudinal direction of the lever d, no moment is exercised upon the precession axis of the gyroscope K_1 by the spring f. By displacing the sleeve e_1 on the circular guide e, for instance into the position shown in dotted lines, it is possible to exercise a moment of any desired value on the precession axis of the gyroscope.

The initial value of this moment is, as regards the gyroscope K_1, so dimensioned, as to compensate the directive force exerted upon the spinning axis of the gyroscope by the actual earth rotation in case the spinning axis a_1 is parallel to the direction of movement of the craft, as is shown in Figs. 1 and 2. The said directive force resulting from the actual earth rotation is, once for all, to be measured in any well-known manner. This force is dependent on the angle between the course of the craft and the meridian as well as on the linear velocity of the earth in that geographic latitude in which the craft moves. By means of the spring f not only the influence of the actual but also the influence of a defined amount of the apparent earth rotation may be compensated as regards the gyroscope K_1. To this end, the directive force resulting from the apparent earth rotation has to be calculated as far as the craft travels at its normal speed, i. e. a predetermined value of speed, and the spinning axis a_1 of the gyroscope K_1 is parallel to the longitudinal axis of the craft. The last mentioned directive force corresponding to a predetermined value of the apparent earth rotation may be compensated by the same spring f, by which the actual earth rotation is compensated. Accordingly, the gyroscope K_1 is totally without any directive force as long as the craft has that real speed over ground, say 200 km. per hour, for which the compensation was made. Any difference between the actual speed over ground of the craft and the predetermined or selected value of speed mentioned above, which difference may be caused for instance by a wind or the like, will exert a corresponding directive force upon the gyroscope K_1, which directive force will cause a precession movement of this gyroscope of such an amount that its spinning axis a_1 tends to move into a position in which it is parallel to the direction of the over-ground movement. A precession of this amount is, however, prevented by the action of the spring f, which acts against the directive force of the gyroscope K_1. Therefore, the gyroscope will only precess until the tension of the spring is equal to the directive force, by which the gyroscope is moving around its precession axis. The precession angle obtained in this way or, in other words, the deflection of the spinning axis of the gyroscope from its normal position shown in the drawing will therefore be a correct measure for the said difference between the real speed over ground and that value of the relative speed, according to which the compensating moment had been dimensioned. Accordingly the indicator g fixed to the pivot c_1 of the gyroscope K_1 will indicate the said difference on the scale g' arranged on the pendulum frame R, which scale may be calibrated in degrees of speed.

As long as the craft is moving along a predetermined course, to which end a compass may be used, the spinning axis of the gyroscope K_1 will remain accurately or approximately parallel to the direction of this course and accordingly the spinning axis a_2 of the gyroscope K_2 will accurately or approximately take up a position at right angles to the said course. Therefore, the first named gyroscope will stabilize the system in its horizontal position against oscillations of the craft around its transverse axis and the second gyroscope will stabilize the system against oscillations of the craft around its longitudinal axis. When the course is changed, it is necessary to bring the spinning axis of the gyroscope into the new course direction. This is effected by a moment brought into action upon the gyroscopic pendulum about its axis z_1—z_1. This moment may be generated by a moment generator D which may be of the same character as the compensating device S, M described above, that is to say, it may consist of an electro-magnetic coil pivoted or swinging between the poles of a permanent magnet. By the influence of the said turning

moment, which is to be manually controlled by the pilot or operator, the axis of the gyroscope K_1 will move into the new direction of travel. This moment on the one hand and the position of the centre of gravity of the gyroscope K_1 in relation to its suspension axis on the other hand are so selected with respect to each other that the precession velocity of the gyroscope K_1, with which the spinning axis goes into the new course direction, is exactly equal to the angular velocity of the craft during its movement from the original course into the new course. In this way the gyroscope K_1 will maintain its position in relation to the pendulum frame R even during a turning of the craft around its vertical axis. Therefore, the pivots c_1, c_1 will not rotate within their bearings while the craft is altering its course, for which reason frictional effects altering the adjustment of the gyroscope will not arise in the said case.

It may be noted that the precession velocity with which the spinning axis a_1 of the gyroscope K_1 moves into the new course may be made equal to the angular velocity of the craft in a very simple manner, because in ships as well as in aircraft the air speed in all cases is nearly constant for a certain type and therefore once for all known. The angular velocity at which the course alterations take place is independent of the speed over ground; it is only dependent on the air speed, which with sufficient accuracy may be assumed as a constant one.

As the speed of the craft will remain constant even during the change of course, it is possible to cause the gyroscope K_2 to assume a precession velocity which is equal to the angular velocity of craft when the craft is altering its course. The moment which causes the precession movement of the gyroscope K_2 during change of the course, results, as is well known, from the centrifugal force acting upon the gyroscopic pendulum while this pendulum or rather the craft is moving along a curved line. This centrifugal moment acts around the line z_2—z_2 of the gyroscopic pendulum and causes a precession movement of the gyroscope K_2, the direction of which movement corresponds to the direction of the travel curve in such a way that the gyroscope K_2 will turn in the same sense as the craft. The distance of the centre of gravity below the plane of the two axis z_1—z_1 and z_2—z_2, which distance may be adjusted by displacing the weight K vertically along the guide R′ provided on the frame R, is so dimensioned that the moment of the centrifugal force acting upon the centre of gravity, which force is proportional to the angular velocity and to the speed of the craft, causes such a precession velocity of the gyroscope K_2 that this gyroscope will remain in its position in relation to frame R. Therefore, by said dimension of the distance of the centre of gravity the precession velocity of the gyroscope K_2 will become as large as the angular velocity of the craft. In consequence of this the pivots c_2 will be prevented from turning within their bearings; therefore, frictions disturbing the position of the gyroscope K_2 will not arise.

The precession angles of the gyroscopes K_1 and K_2, being proportional to the difference between the speed over ground and the normal air speed and to the drift of aircraft respectively, may be indicated directly. In a similar manner the angular movements of the pivots z_1 and z_2 within their bearings, which angular movements correspond to the roll and pitch of the craft respectively, may be indicated by indicators u_1 and v_1 on the scales u_2 and v_2 respectively the indicators being secured to said pivots z_1 and z_2.

In the embodiment shown in Figs. 3 and 4, the two gyroscopes K_1 and K_2 are mounted by means of their vertical precession-axes c_1 and c_2 respectively in the frame R, universally mounted in the craft, in the manner already described in relation to Figs. 1 and 2. In this second embodiment, the supports s_1 and s_2 by which the horizontal pivots z_2 are carried, are, however, no longer in a fixed position on the craft; these supports are arranged on a disk L mounted to turn in a plane parallel to the base of the craft. A motor m operates a worm l engaging the disk, which can thus be rotated in such a manner that the pivots z_2 will always remain in the north-south direction. For this purpose, the motor m is controlled e. g. by the needle t of a magnetic compass, said needle having at its outer end a contact movable between two contacts t_1 and t_2 fixed to the case of the compass. To communicate the rotation of the disk L to the case of the compass any suitable form of connection may be used. In the particular construction illustrated, this connection comprises a bevel gear n and a worm n_1 meshing with teeth on the circumference of the compass case.

In Fig. 4 the arrow P indicates the direction of travel, whilst the arrow N indicates north-south direction. Each gyroscope K_1 and K_2 is provided with an electromagnetic device q_1 and q_2 respectively for compensating the directive moment resulting from the rotation of the earth. This compensation is well known. In consequence of this, the gyroscopes have no directive force as long as the craft is not in motion. Each of the devices q_1 and q_2 may be of the same character as the moment generator D and the compensator S, M, that is to say, such device may consist of an electro-magnetic coil pivoted or swinging between the poles of a permanent magnet, as shown best in Fig. 2 with respect to the compensator S, M. When the craft is travelling in the direction shown by the arrow P, the gyroscopes K_1 and K_2 are influenced by a directive moment caused by gravitation. Due to the influence of said moment, the gyroscopes tend to assume a position in which their spinning axes a_1 and a_2 are transverse to the direction of travel over ground. The gyroscopes are, however, prevented from assuming said position by springs f_1 and f_1 whose one end is attached to the frame R as described below and whose other end is attached to a two-armed lever o_1 and o_2 respectively secured to the precession axis of each gyroscope. By the springs f_1 the spinning axis of the gyroscope K_1 is constrained to the north-south direction, whilst the spinning axis of the gyroscope K_2 is constrained by the springs f_2 to the east-west direction. The constraining force of the springs f_1 and f_2 may be comparatively low. During travel the gyroscope K_1 will be influenced by a directive force proportional to the speed rate in the north-south direction, whilst the gyroscope K_2 is influenced by a directive force proportional to the speed rate in the east-west direction. In consequence of this, the gyroscope K_1 will assume a precession angle corresponding to the speed rate in the north-south direction and the gyroscope K_2 will assume a precession angle corresponding to the speed rate in the east-west direction. These angles are indicated on the scales g' and b' by means of the

indicators g and b secured to the precession axes c^1, c^2 of the respective gyroscopes.

It may be understood that the directive force resulting from the rotation of the earth which is to be compensated in the embodiment according to Figs. 3 and 4 is independent of the course relative to the meridian, as the gyroscopes have a fixed position in relation to the north-south and to the east-west directions.

For a good stabilization of the artificial horizon it is necessary that the spinning axes a_1 and a_2 of the gyroscopes will always remain at practically right angles to each other. In order to ensure this, the normally stationary ends of the springs constraining the gyroscopes to a normal zero position, may be mounted for adjustment along ring guides E of the same general character as the one shown at e in Figs. 1 and 2. These ring guides E (like the ring e) are rigid with the frame R, and along them the slides or members E' are movable circumferentially, for instance by the rotation of worms journaled on said members E' and meshing with worm teeth E'' on the respective ring guides. The shafts of the worms are provided with squared ends for the reception of a suitable operating crank or key. The adjacent ends of the two springs f_1 are attached to a stud T on one of said adjustable members E', while the adjacent ends of the springs f_2 are similarly attached to the other member E'. Each of said members E' also carries one of the scales g' and b' mentioned above. Assuming that, according to a certain speed in the north-south direction, the gyroscope K_1 may have a precession angle of about 15° in the counter clockwise direction. If, for instance, the indicator g should be deflected through an angle of 15° from its zero position, the operator will know that he must shift the member E'' connected with the springs f_1, circumferentially of the ring E, through an angle of 15°, in such a direction that the gyroscope K_1 will be brought back to its original position relatively to the frame R. That is to say, assuming counter clockwise precession of the gyroscope K_1, the member E' to which the springs f_1 are attached will be displaced along the guide E through an angle of 15° in the clockwise direction to readjust the gyroscope K_1 into its zero position. At the same time the scale g' will be shifted by an angle of 15° along said ring guide E in the clockwise direction, owing to the fact that the member E' and the scale g' are rigidly connected with each other. Hence, the indicator g will always indicate on its scale the real speed rate in the north-south direction, though the gyroscope may have been readjusted into its zero position. Similar remarks will apply to the indicator b provided for the east-west gyroscope K_2.

I claim:

1. A gyroscopic apparatus including a frame, means pendulously and universally mounting said frame on a craft, two gyroscopes with horizontal spin axes pivoted on vertical precession axes in said frame, means for applying torques about said precession axes to nullify the influence of earth rotation on each of said gyros, means for yieldingly constraining one of said gyros to a definite position of its spin axis relatively to said frame, said means being connected to the precession axis of said gyro and to said frame, and means for adjusting the power of said constraining means corresponding to a predetermined normal ground speed of the craft.

2. A gyroscopic apparatus including a frame, means pendulously and universally mounting said frame on a craft, two gyroscopes with horizontal spin axes pivoted on vertical precession axes in said frame, means for applying torques about said precession axes to nullify the influence of earth rotation on each of said gyros, a spring for constraining one of said gyros to a position with its spin axis lengthwise of the craft, a lever fixed to the precession axis of said gyro, said spring being attached at one end to said lever and at its other end to said frame, and means for adjusting the tension of said spring corresponding to a predetermined normal ground speed of the craft.

3. A gyroscopic apparatus including a frame, means pendulously and universally mounting said frame on a craft, two gyroscopes with horizontal spin axes pivoted on vertical precession axes in said frame, means for applying torques about said precession axes to nullify the influence of earth rotation on each of said gyros, a spring for constraining one of said gyros to a position with its spin axis lengthwise of the craft, a lever fixed to the precession axis of said gyro, said spring being attached at one end to said lever, a ring guide carried by said frame, and a sleeve adjustable along said guide, the other end of said spring being attached to said sleeve, whereby movement of the sleeve along said guide will change the tension of the spring, to permit such tension to be adjusted corresponding to a predetermined normal ground speed of the craft.

4. A gyroscopic apparatus including a frame, means pendulously and universally mounting said frame on a craft, two gyroscopes with horizontal spin axes pivoted on vertical precession axes in said frame, an electromagnetic device for applying a torque to the precession axis of one of said gyros to nullify the influence of earth rotation on such gyro, a lever secured to the precession axis of the other gyro, a spring attached at one end to said lever and connected at its other end to said frame, and means for adjusting the tension of said spring corresponding to the influence of earth rotation and to a predetermined normal ground speed of the craft.

5. A gyroscopic apparatus including a frame, means pendulously and universally mounting said frame on a craft, two gyroscopes with horizontal spin axes pivoted on vertical precession axes in said frame, an electromagnetic device for applying a torque to the precession axis of one of said gyros to nullify the influence of earth rotation on such gyro, a lever secured to the precession axis of the other gyro, a spring attached at one end to said lever, a ring guide carried by said frame, and a sleeve to which the other end of said spring is attached, said sleeve being adjustable along said ring guide to vary the tension of said spring corresponding to the influence of earth rotation and to a predetermined normal ground speed of the craft.

6. A gyroscopic apparatus including a frame, means pendulously and universally mounting said frame on a craft, two gyroscopes with horizontal spin axes pivoted on vertical precession axes in said frame, means for applying a torque about the precession axis of one of said gyros to nullify the influence of earth rotation on such gyro, means for constraining the other gyro to a position with its spin axis lengthwise of the craft and for nullifying the influence of earth rotation on such second gyro, and an electromagnetic device having a movable member attached to said frame, to exert a moment on said frame so as to maintain the second mentioned gyro in its position relative

to such frame, when the craft is altering its course.

7. A gyroscopic apparatus including a frame, means pendulously and universally mounting said frame on a craft, two gyroscopes with horizontal spin axes pivoted on vertical precession axes in said frame, means for applying torques about said precession axes to nullify the influence of earth rotation on each of said gyros, and an electromagnetic device having a movable member attached to said frame, to exert a moment on said frame so as to maintain one of said gyros in its position relative to such frame, when the craft is altering its course.

8. A gyroscopic apparatus including a frame, means pendulously and universally mounting said frame on a craft, two gyroscopes with horizontal spin axes pivoted on vertical precession axes in said frame, means for applying torques about said precession axes to nullify the influence of earth rotation on each of said gyros and for constraining one of said gyros to a position with its spin axis lengthwise of the craft, indicators secured to the precession axes of the respective gyros, and scales carried by said frame and co-operating with said indicators to indicate drift and speed respectively.

9. A gyroscopic apparatus including a frame, means pendulously and universally mounting said frame on a craft, such universal mounting having one pivot axis lengthwise of the craft and the other athwartship, two gyroscopes with horizontal spin axes pivoted on vertical precession axes in said frame, means for applying torques about said precession axes to nullify the influence of earth rotation on each of said gyros and for maintaining the spin axes of said gyroscopes at right angles to each other, and two indicating devices co-operating with said longitudinal and transverse pivots of said universal mounting, to indicate pitching and rolling angles of the craft respectively.

10. A gyroscopic apparatus including a frame, a rotatable member mounted on a craft, means pendulously and universally mounting said frame on said member, two gyroscopes with horizontal spin axes pivoted on vertical precession axes in said frame, means for applying torques about said precession axes to nullify the influence of earth rotation on each of said gyros, means for maintaining the spin axes of said gyros at right angles to each other, a motor for turning said member relatively to said craft, and a compass controlling said motor for automatically maintaining the orientation of said member when the craft is altering its course.

11. A gyroscopic apparatus including a frame, a rotatable member mounted on a craft, means pendulously and universally mounting said frame on said member, two gyroscopes with horizontal mutually normal spin axes pivoted on vertical precession axes in said frame, means for applying torques about said precession axes to nullify the influence of earth rotation on each of said gyros, means for maintaining the spin axis of one gyro in the north-south direction and the spin axis of the other gyro in the east-west direction, said means comprising a motor for turning said member relatively to said craft, and a compass controlling said motor for automatically maintaining the orientation of said member when the craft is altering its course.

12. A gyroscopic apparatus including a frame, a rotatable member mounted on a craft, means pendulously and universally mounting said frame on said member, two gyroscopes with horizontal spin axes pivoted on vertical precession axes in said frame, means for applying torques about said precession axes to nullify the influence of earth rotation on each of said gyros, levers secured to the precession axes of the respective gyros, springs for constraining the spin axes of the gyros to north-south and east-west directions respectively, each spring being attached at one end to a respective lever and at the other end to said frame, a motor for turning said member relatively to said craft, and a compass controlling said motor for automatically maintaining the orientation of said member when the craft is altering its course.

13. A gyroscopic apparatus including a frame, a rotatable member mounted on a craft, means pendulously and universally mounting said frame on said member, two gyroscopes with horizontal spin axes pivoted on vertical precession axes in said frame, means for applying torques about said precession axes to nullify the influence of earth rotation on each of said gyros, levers secured to the precession axes of the respective gyros, springs for constraining the spin axes of the gyros to mutually normal positions relatively to said frame, each spring being attached at one end to a respective lever and at the other end to said frame, indicators secured to the precession axes of the respective gyros, scales on the said frame, co-operating with said indicators to indicate speed, a motor for turning said member relatively to said craft, and a compass controlling said motor for automatically maintaining the orientation of said member when the craft is altering its course.

14. A gyroscopic apparatus including a frame, means pendulously and universally mounting said frame on a craft, two gyroscopes with horizontal spin axes pivoted on vertical precession axes in said frame, means for applying torques about said precession axes to nullify the influence of earth rotation on each of said gyros, and means for yieldingly constraining at least one of said gyros to a definite position of its spin axis relatively to said frame, said means being connected to the precession axis of said gyro and to said frame.

15. A gyroscopic apparatus including a frame, means pendulously and universally mounting said frame on a craft, two gyroscopes with horizontal spin axes pivoted on vertical precession axes in said frame, and means for applying torques about the precession axis of each of the gyros to nullify the influence of earth rotation on said gyros, and a torque about the precession axis of at least one of the gyros to yieldingly constrain this gyro to a definite zero position of its spin axis relatively to said frame, said zero position being so selected that the spin axis of one of the gyros in its zero position is at an angle to the spin axis of the other gyro.

16. A gyroscopic apparatus as claimed in claim 15, in which the spin axis of the one gyro in its zero position is at right angles to the spin axis of the other gyro in its zero position.

17. A gyroscopic apparatus including a frame, means pendulously and universally mounting said frame on a craft, two gyroscopes with horizontal spin axes pivoted on vertical precession axes in said frame, and means for applying torques about the precession axes of said gyros to nullify the influence of earth rotation on said gyros and furthermore a torque of such rate about the precession axis of at least one of the gyros that the spin axis of this gyro is parallel to the

direction of the craft's movement at a predetermined normal ground speed.

18. A gyroscopic apparatus including a frame, a rotatable member mounted on a craft, means pendulously and universally mounting said frame on said member, two gyroscopes with horizontal spin axes pivoted on vertical precession axes in said frame, means for applying torques about the precession axes of said gyros to nullify the influence of earth rotation on said gyros and furthermore such torques about the precession axes of said gyros that their spin axes normally are at an angle to each other, a motor for turning said member relatively to said craft, and a compass controlling said motor for automatically maintaining the orientation of said member when the craft is altering its course.

JOHANN MARIA BOYKOW.