Dec. 1, 1925. 1,563,934

E. A. SPERRY

GYROSCOPIC INCLINOMETER FOR AEROPLANES

Filed Jan. 15, 1918 2 Sheets-Sheet 1

Fig. 1.

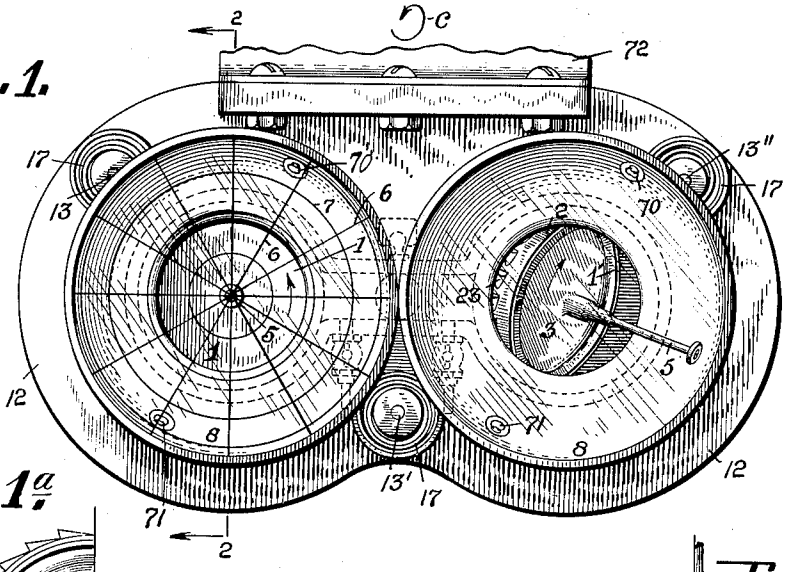

Fig. 1a.

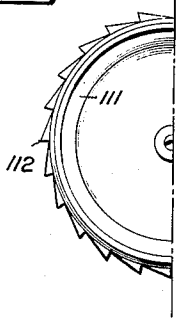

Fig. 1b.

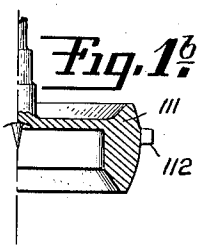

Fig. 2.

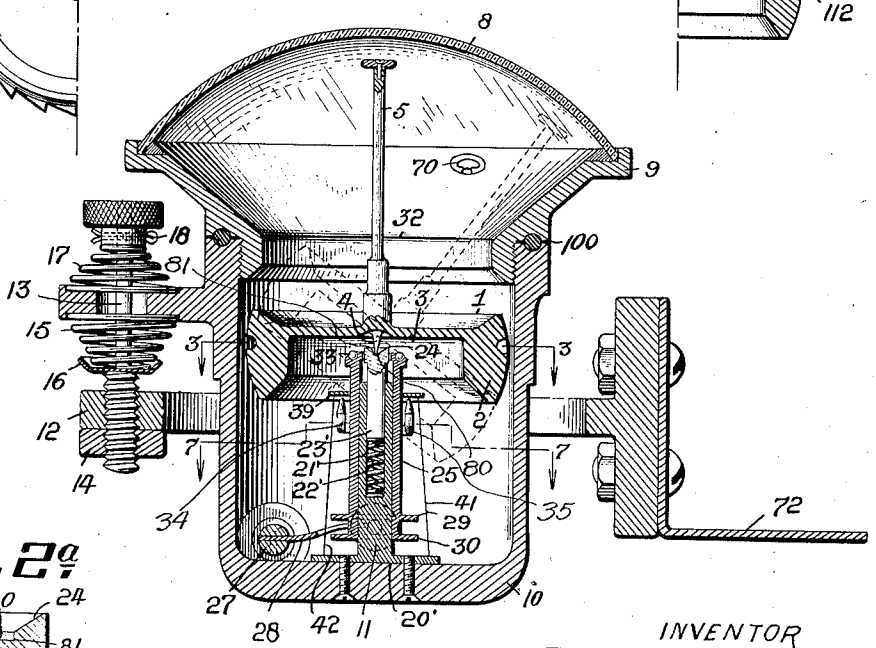

Fig. 2a.

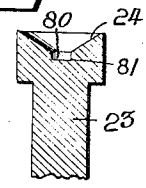

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Fig. 3.

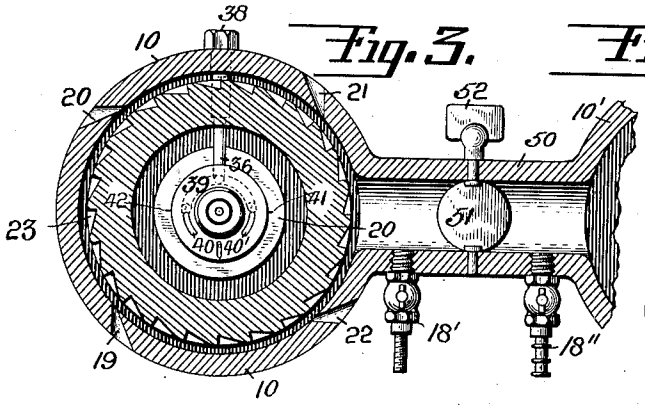


Fig. 4.

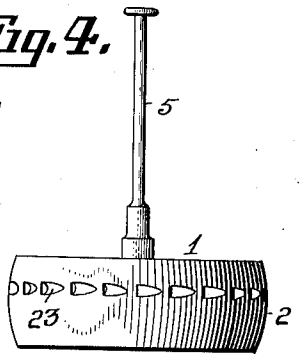


Fig. 7.

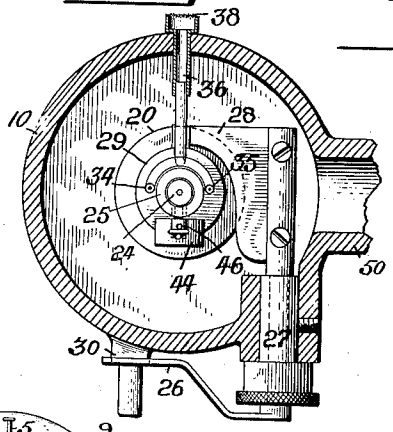


Fig. 5.

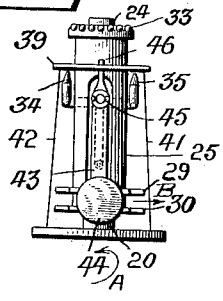


Fig. 6.

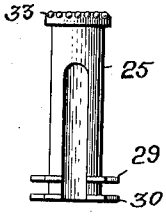
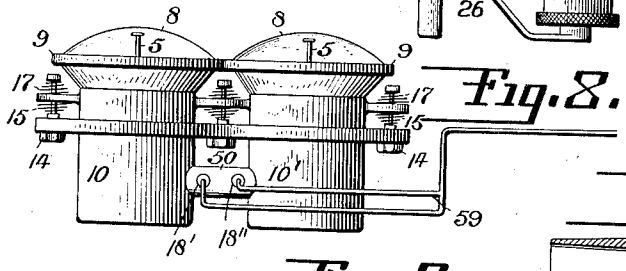


Fig. 8.



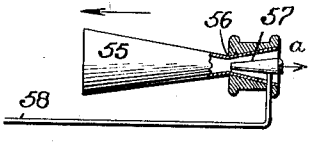


Fig. 11.

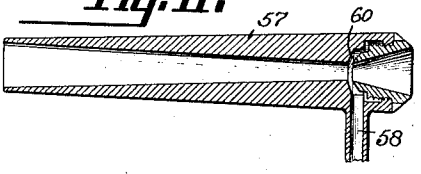


Fig. 10.

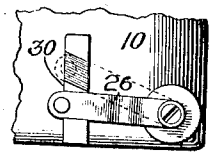
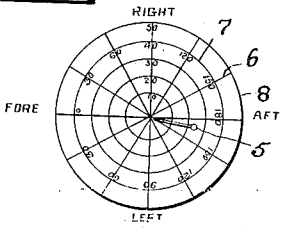


Fig. 9.



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Patented Dec. 1, 1925. 1,563,934

UNITED STATES PATENT OFFICE.

ELMER A. SPERRY, OF BROOKLYN, NEW YORK, ASSIGNOR TO THE SPERRY GYROSCOPE COMPANY, OF BROOKLYN, NEW YORK, A CORPORATION OF NEW YORK.

GYROSCOPIC INCLINOMETER FOR AEROPLANES.

Application filed January 15, 1918. Serial No. 211,989.

To all whom it may concern:

Be it known that I, ELMER A. SPERRY, a citizen of the United States of America, residing at 1505 Albermarle Road, Brooklyn, in the county of Kings and State of New York, have invented certain new and useful Improvements in Gyroscopic Inclinometers for Aeroplanes, of which the following is a specification.

This invention relates to gyroscopic appliances for use on aeroplanes. One of the objects of the invention is to provide a simple and compact gyroscopic device of light weight and operated without employing any motor or other machine requiring a source of power on the aeroplane.

Further objects of the invention are to improve upon the construction of gyroscopic apparatus of this character, by providing means for suppressing or overcoming the effect of acceleration pressures thereon, and by improving upon a fluid pressure form of driving means by which no disturbing torques on the gyroscope are produced.

Referring to the drawings in which, what I now consider to be the preferred form of my invention is shown:

Fig. 1 is a plan view of the device constructed in accordance with my invention, the cover of one of the gyroscopes being removed.

Fig. 2 is a cross section of one of the gyroscopic units taken on line 2—2 of Fig. 1.

Fig. 3 is a cross section on approximately line 3—3 of Fig. 2.

Fig. 4 is an elevation of the rotor of the gyroscope which may be referred to as a top, since its characteristics resemble in several respects the ordinary top.

Fig. 5 is a front elevation of the supporting post and sleeve for the top with its associated parts thereto attached.

Fig. 6 is a corresponding view of the sleeve only, the pendulum and other parts being removed.

Fig. 7 is a section on broken line 7—7 of Fig. 2.

Fig. 8 is a diagrammatic view, on a smaller scale, of my invention showing the means used to continuously withdraw air from the interior of the casing.

Fig. 9 is a plan view showing the graduations on cover 8.

Fig. 10 is a detail.

Fig. 11 is an enlarged longitudinal section on the inner portion of the Venturi tube.

Fig. 1ª is a plan view of a rotor provided with a modified form of buckets or vanes.

Fig. 1ᵇ is a vertical section of the same.

Fig. 2ª is an enlarged vertical section of the supporting post for the top.

Perhaps the simplest form of gyroscope, in structure at least, is the ordinary top which, as is known, comprises a rotor that rotates or spins about and is supported on a slightly rounded point; said point acting also as an axis for supporting the top for oscillation about both horizontal axes. While in the ordinary top the center of gravity is located above the point of support, according to my invention, the center of gravity is not necessarily so situated. Preferably it is located very close to and slightly below the point of support so that the top stands substantially in neutral or indifferent equilibrium when at rest whereby a long period of oscillation is secured. The center of gravity may be shifted slightly without materially affecting the operation of the gyroscope, since the physical effect, which causes it to straighten itself up, when spinning, lies in the friction between the point of support and the supporting surface. This causes a torque about substantially vertical axes, causing precession of the top about a horizontal axis to a vertical position.

The top is shown as comprising a rotor or fly-wheel 1, having a heavy ring 2 and a cut-out under portion 3. In the center of the top is a point 4 which supports the top for rotation about a normally vertical axis and at the same time allows the top freedom movement about both horizontal axes intersecting at said point.

The top is preferably provided with a spindle 5 which acts as a pointer or indicator, and cooperates with radial graduations 6 and with circular graduations 7 and 7′ on the transparent cover 8 to indicate both the angle and direction of inclination of the vehicle on which the instrument is mounted. Said cover is secured within a cap 9 threaded into the top of the casing proper 10, the joint 100 being tightly packed. Illuminating means such as lamps 70 and 71 may be provided, if desired. Said cas-

ing surrounds the rotor and supports the same on a post 11 secured to the bottom of the casing. Said casing, together with a companion case 10′ is shown as resiliently supported from a ring or frame 12 by means of a plurality of rods 13, 13′ and 13″ which are adjustably threaded to said ring and locked thereto by lock nuts 14, the casing being supported on said rods by springs 15 resting on washers 16 or the like. Preferably a downwardly acting spring 17 is placed above said ring and acts between the cap 18 and the ring so that jars will not affect the apparatus. Preferably three such supporting rods are provided for the gyroscopic device. A bracket 72 secured to ring 12 may be used to attach the apparatus to the aeroplane or other vehicle.

For revolving the rotor I prefer to provide means for continuously withdrawing air from the interior of said casing, relying upon the entrance of air into the casing in a proper direction and location to revolve the rotor. For this purpose I have provided a valve or other opening 18′ through which the air is exhausted from the casing in any manner, preferably in the manner hereinafter described.

One or more openings shaped in the form of approximately tangential nozzles 19, 20, 21 and 22, are provided in the casing in the plane of the rotor 1. The rotor is provided with buckets or vanes 23 located in the plane of said nozzles and adapted to receive the jets of air issuing therefrom. Preferably said vanes are formed by incisions in the periphery of the rotor. I find it important not to make said incisions of materially greater breadth in the direction of the axis of the rotor than the breadth of the jets and they are preferably substantially less than one-fourth the width of the periphery of the rotor as shown in the drawings. While certain advantages such as increased driving power result from cutting the vanes entirely across the face of the rotor, such construction I find is of great disadvantage, in that when the rotor becomes tilted somewhat the jets striking against the buckets or vanes in their inclined positions cause an unbalanced couple on the gyroscope about one of the horizontal axes and hence precession thereof about the other horizontal axis. Said couple may be caused in part by the fact that the bottoms of the buckets are not parallel to the jets in the inclined position and that the walls of the buckets offer resistance to the jet in an inclined plane. This action, of course, throws the gyroscope or top off and interferes with its accuracy. When said vanes are of limited extent however such trouble is eliminated or reduced to a minimum for all ordinary conditions of the gyroscope, since the periphery thereof may be made spherical and highly polished.

Said post 11 is shown as comprising a central supporting stem 20′ having an axial bore 21′ in which is located a spring 22′ supporting a rod 23′. Said rod is provided adjacent its top with a tapered or concave recess 24 in which the point 4 attached to the top 1 rests. Preferably said recess is flat at the bottom portion 80 at which point the wall 81 is substantially perpendicular for a short distance. On the exterior of said post a slidable sleeve 25 is mounted. Said sleeve normally stands in the lower position as indicated in Figs. 2 and 5, but may be raised to an elevated position to lift the point of support of the top off the rod 24. This may be accomplished by means of handle 26 secured to a rod 27 journaled adjacent the bottom of the casing 10 and provided at its inner portion with an inwardly extending arm 28. Said arm engages between flanges 29—30 located near the lower portion of the sleeve 25. It will be readily apparent that by rotation of the handle 26 sleeve 25 may be raised to lift the rotor off the delicate bearing or point of support. The handle 26 may be made of resilient material so as to spring past and catch over a lug 30 (Fig. 10) on the exterior of the casing to hold the sleeve in the raised position at will.

Preferably means are provided to limit the extent of inclination of the gyroscope with respect to the casing. While the rod 5 will perform this function by striking against the inner edge 32 of the top 9, I prefer to provide anti-friction means for this purpose so as not to retard the rotation of the top more than necessary. This means is shown as a series of balls 33 mounted for rotation adjacent the top of sleeve 25 so that when the gyroscope tilts over a predetermined amount, the bottom of the top will strike against the balls and prevent further inclination as indicated in the dotted lines in Fig. 2.

While the structure so far described operates with a fair degree of accuracy, I prefer to provide in addition a damping means or more strictly speaking, a means for preventing or equalizing the disturbing effects of acceleration forces of the top. Said means is shown as comprising a plurality of nozzles 34 and 35 to which air is introduced by means of a common pipe 36 leading to the exterior of the casing 10. The entrance to said pipe is shown as covered by fine wire gauze 38 to prevent the entrance of dust. Immediately over but spaced a greater or less distance from said nozzles is located a baffle plate or disk 39 having an inner slot or slots 40 and 40′ extending around a predetermined portion of the disk. Normally the slots are positioned so that the

jet issuing from either nozzle will not strike the under surface of the top. Upon a slight rotation in one direction, however, one jet is uncovered, while upon similar rotation in the other direction the other jet is uncovered. Said disk is turned by means of a pendulous device 43 which, as shown comprises a pendulum 44 pivoted at 45 on stem 20. The pendulum is provided with an upstanding pin 46 which engages a hole or slot in the disk 39 so that as the pendulum is swung in one direction it will revolve the disk in the opposite direction. Said pendulum is, of course, responsive to acceleration forces exerted thereon so that if the axis of the pendulum is fore and aft of the aircraft and if the aircraft is turned in the direction indicated by the arrow A at the bottom of Fig. 5, the pendulum will be moved in the direction indicated by the arrow B in Fig. 5 and thereby rotate disk 39 in a clockwise direction, as viewed in Fig. 3. This, it will be seen, will uncover the nozzle 34, and cause an upward pressure of air to be maintained against the under surface 3 of top 1 thereby exerting a force which is opposed to the acceleration force acting on the gyroscope at the time, assuming that the gyroscope is pendulous or in other words has its center of gravity below its point of support. While the axis of the pendulum may be placed in any position on the aircraft, I prefer to place it in such position that the pendulum will be affected by the most frequent and persistent acceleration forces occurring in said vehicle. It is, of course, obvious that a pendulum may be provided about each axis if desired, but a position allowing transverse oscillation is preferred.

As above stated, I prefer to employ a plurality of such tops 1 and 1′ which are driven in opposite directions as indicated by the arrows in Fig. 1. The reason for preferring two oppositely rotating tops is to insure having at least one of the tops correct at all times. For instance, if the aeroplane on which the apparatus was mounted was turning in the direction of arrow C (Fig. 1) top 1′, which is shown as rotating in the opposite direction, would have a tendency to flop over, as indicated, while top 1 would remain unaffected. Similarly, if the aeroplane were turning in the other direction, top 1′ would straighten up, while top 1 would tend to turn over. The casings 10 and 10′ enclosing the two tops may be formed as one or connected by pipe 50. Each casing may be provided with an outlet valve 18′ and 18″, each or either of which may be connected to the air exhausting device. Preferably a valve or other obstructing device 51 is employed between the two casings, so that if desired one gyroscope only may be operated the full force of the exhausting device being exerted on said gyroscope. It will be readily apparent that said valve may be turned cross-wise in the pipe 50 by means of thumb piece 52, shutting one casing off from the other.

For exhausting the air from the casings, I prefer to employ a device 55 somewhat similar to a Venturi tube. Said device may comprise a tubular member with a restricted passage 56 therein, each end of the member tapering outwardly, Fig. 8. If the aircraft is flying in the direction indicated by the arrow *a* in said figure, the air will flow with great speed through the said tube and restricted passage, thereby reducing the pressure to a marked extent adjacent said passage. At or adjacent said restricted passage is located a second small tube 57 which is connected to either or both of the valves 18′ and 18″ by means of a pipe 58 having a branch pipe 59. Pipe 58 is shown as tapped into tube 57 adjacent a restricted passage 60 therein as indicated in Fig. 11, whereby a double rarifaction of air, so to speak, is produced.

In accordance with the provisions of the patent statutes, I have herein described the principle of operation of my invention, together with the apparatus, which I now consider to represent the best embodiment thereof, but I desire to have it understood that the apparatus shown is only illustrative and that the invention can be carried out by other means. Also, while it is designed to use the various features and elements in the combination and relations described, some of these may be altered and others omitted without interfering with the more general results outlined, and the invention extends to such use. Thus the buckets on the rotor may be formed by providing the rotor 111 with an annular flange (Figs. 1ª and 1ᵇ) 112 and cutting or forming vanes therein similar to sawteeth. It should be noted that the damping action of jets 34 and 35 is rendered effective not only when pendulum 44 becomes inclined, due to acceleration forces and the like, but also when the casing 10 becomes inclined with respect to the pendulum, or in other words when the aeroplane is on an uneven keel. This action is advantageous rather than otherwise since whatever disturbing effect is introduced by the oblique action of the jets 19, 20, 21 and 22 is offset by one of jets 34 or 35.

Having described my invention, what I claim and desire to secure by Letters Patent is:

1. In gyroscopic apparatus, the combination with a top, means for blowing air on said top in such direction as to exert a couple thereon, and means for rendering effective said blowing means upon a predetermined event.

2. The combination with a gyroscope mounted for oscillation about an axis, of a pendulous device mounted adjacent thereto, means for applying a torque on said gyroscope about said axis, and means responsive to inclination of the device about an axis parallel to said axis for bringing into action said torque applying means.

3. In gyroscopic apparatus, the combination with a top, means for blowing air on said top in such direction as to exert a couple thereon, a pendulous device, and means responsive to inclination of said device for rendering effective said blowing means.

4. The combination with a gyroscope mounted for oscillation about an axis, of a pendulous device mounted adjacent thereto, means for applying a torque on said gyroscope about said axis, and means responsive to inclination of the device about an axis substantially parallel to said axis of oscillation for bringing into action said torque applying means.

5. The combination with a gyroscope mounted for oscillation about a plurality of axes, of a pendulous device pivoted about an axis and means responsive to inclination of the device for causing a torque on the gyroscope about an axis substantially parallel to the axis of the pendulum.

6. The combination with a gyroscopic top mounted for oscillation about an axis, of a device responsive to acceleration forces mounted adjacent thereto, and means rendered effective by said device for exerting a torque on the gyroscope in a counter direction to the torque produced thereon by the acceleration force causing actuation of said device.

7. The combination with a gyroscopic top, of a support therefor, and means for limiting the extent of inclination of the top with respect to the support comprising an antifriction bearing member carried by said support and adapted to engage the under surface of the top on inclination thereof.

8. The combination with a gyroscopic top, of a support therefor, and means for limiting the extent of inclination of the top with respect to the support comprising a member adapted to engage the top when its inclination exceeds a predetermined amount, and antifriction means between said member and top.

9. The combination with a gyroscopic top, of a support therefor, and means for limiting the extent of inclination of the top with respect to the support comprising a member carried by said support and adapted to engage the under surface of the top on inclination thereof beyond a predetermined amount, and antifriction means between said member and top.

10. In gyroscopic apparatus, a rotor, a pivotal point of support for said rotor located close to its center of gravity and a resiliently mounted member upon which said point of support is adapted to spin.

11. In gyroscopic apparatus, a rotor, a pivotal point of support for said rotor located close to its center of gravity, a resiliently mounted member upon which said point of support is adapted to spin, and means for lifting said rotor and point off said member.

12. In combination, a casing, a gyro rotor mounted therein, means for exerting an upsetting couple on said rotor, said means comprising a nozzle adjacent the side of said rotor and communicating with the exterior of said casing, and means for withdrawing air from said casing to cause an inflow of air through said nozzle.

13. In combination, a casing, a gyro rotor mounted therein, means for exerting an upsetting couple on said rotor, said means comprising a nozzle adjacent the side of said rotor and communicating with the exterior of said casing, means for withdrawing air from said casing to cause an inflow of air through said nozzle, means covering said nozzle, and means responsive to tilting of said casing for uncovering said nozzle.

14. In a gyroscopic apparatus, a supporting post, a gyroscopic top adapted to rotate on said post and a plurality of bearing balls mounted on said post and adapted to be engaged by the top when the latter precesses.

15. In combination, a casing, a gyro rotor mounted therein, means for exerting a couple on said rotor, said means comprising a plurality of nozzles adjacent opposite sides of the rotor, means for causing flow of air through said nozzles, means normally covering said nozzles, and means responsive to tilting of the casing for uncovering certain of said nozzles.

16. In combination, a casing, a gyro rotor mounted therein, means for exerting a couple on said rotor, said means comprising a pair of nozzles adjacent opposite sides of said rotor, means for causing flow of air through said nozzles, means normally covering said nozzles, and means responsive to tilting of the casing for uncovering one of said nozzles.

17. In combination, a casing, a resilient mounting for said casing, a rotor, and a resiliently mounted member upon which said rotor is adapted to spin.

18. In a gyroscopic apparatus, a rotor, a resiliently mounted supporting member, means whereby said rotor is pivotally mounted on said member, and means for lifting said rotor off said member.

19. In gyroscopic apparatus, a closed casing, means for withdrawing air therefrom, a gyro-wheel in said casing, a nozzle for driving the same adjacent thereto and con-

nected to the outer air, and a second nozzle for damping the gyroscope also connected to the outer air.

20. In gyroscopic apparatus for aeroplanes, a closed casing, means operable by the passage of the aeroplane through the air for withdrawing air therefrom, a gyro-wheel in said casing, a nozzle for driving the same adjacent thereto and connected to the outer air, and a second nozzle for damping the gyroscope also connected to the outer air.

In testimony whereof I have affixed my signature.

ELMER A. SPERRY.