PHYSICS

The Gyroscopic Compass

"A Classic Invention"

Sperry Pointed the Axis of Foucault's Gyroscope at The Pole Star and Learned How to Make It a Compass

GYROSCOPIC COMPASS, by Elmer A. Sperry, of Brooklyn, N. Y. Specification forming part of Letters Patent No. 1,279,471, *dated Sept.* 17, 1918. *U. S. Patent Office.*

To all whom it may concern:

BE IT KNOWN that I, Elmer A. Sperry, a citizen of the United States, residing at Brooklyn, in the county of Kings and State of New York, have invented new and useful Improvements in Gyroscopic Compasses, of which the following is a specification.

The gyro-navigation equipment forming the present invention embodies a number of features including master, and may also include repeater, azimuth indicators, one or more of which may be power driven; the employment of an entirely new principle consisting in utilizing a rotating wheel and attached parts, as its journal frame or wheel casing, and in simultaneously controlling its movements in a plurality of movements, these being so effected as to produce on the one hand a practical compass and on the other hand to accomplish a number of other functions essential to the proper operation of the gyroscopic compass, upon moving vehicles. To this end I have introduced a new organization known as an azimuth or azimuth moving unit organized to at once develop the requisite directive power from the rotation of the earth by a new process which I denominate positive orientation which effects a quick settling of the instrument upon the meridian and which also operates by a new method to extinguish oscillation in azimuth by a partial suppression of freedom of the gyro wheel about the vertical axis, thus combining in the present invention means for introducing stresses or movements in both elevation and azimuth and means for quickly reaching true meridional position, substituting mechanical suspension for liquid or mercury floats and affording marked advantages generally in a number of structural and operating details connected with the various features going to make up a practical instrument. One embodiment of my invention, by way of example, will now be specified and shown and the novel features pointed out in the claims.

The work of Leon Foucault in the middle of the last century upon the unique instrument produced by him "after eight years of assiduous superintendence" and to which he gave the name "gyroscope," because as he states, its varied operations "depend upon the rotation of the earth and are but varied manifestations of such rotation," reveals many very interesting and significant statements, upon careful scrutiny, and some far reaching deductions.

The work of this savant on the pendulous gyro with two degrees of freedom is well known and has been followed by many and while a compass on this principle is found to work on land, when placed on a moving body it is found to respond as any pendulum will to acceleration and deceleration pressures and to other numerous disturbances. This latter difficulty and the oscillation which it sets up are very serious draw-backs to its use at sea.

A very significant statement and one which seems to have been wholly overlooked in its bearing on the subject of gyroscopic compasses was communicated by Foucault with regard to his apparatus having 3 degrees of freedom.

This is contained in a document prepared by him in October, 1852, and reads as follows:

"One should understand, from the little that we have said of the construction of the apparatus, that this tore is supported by a sort of Cardan's suspension, analogous to that which supports chronometers and ship's compasses, with this difference only that the two concentric circles, instead of being in the same plane, are normally or in their average position, perpendicular one to the other. One of them plays round a horizontal axis represented by the two knife-edges arranged precisely in one straight line, while the other is movable about a vertical axis represented by a suspension consisting of a torsionless filament. If, at moment we put it in rotation, this body by its axis points at a star in the sky, during the whole time that the movement (spin) lasts this axis will remain pointing toward the same point of the firmament, and this in virtue of the inertia of matter, or for the very good reason that it is incapable of displacing itself or of altering its direction by itself. If, therefore, we select a suitable star, or if we aim at one of the points of the heavens which appear to be moving most quickly, the axis of rotation when carefully examined, will be found to share the same apparent movement and will gave emphatic evidence of the earth's movement. Of course, one should not point the axis in the direction of the polar star, because this star, not having any apparent movement, the instrument would act similarly and not indicate the earth's motion."

The question was long ago asked by me what better compass could one wish than that suggested by the last sentence; it orients perfectly and by adopting this form of suspension, with three degrees of freedom it is found possible at the same time to do away with the evils and errors introduced by "ballistics" and to neutralize the acceleration pressures and also oscillation with one and the same additional device.

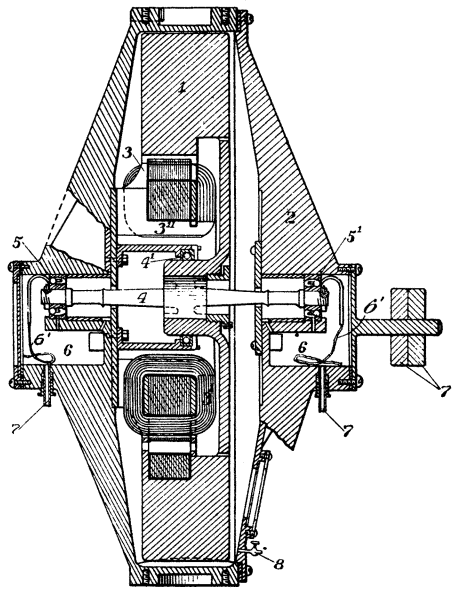
Theoretically, as Foucault pointed out, a spinning gyro mounted for three degrees of freedom maintains constant the

direction of its axis in space; and therefore if the gyro thus mounted, or even when mounted so that its movement about a horizontal axis at an angle to its spinning axis is partially suppressed, be placed with its axis pointing north and south or in the plane of the meridian, it should remain in this position so long as the gyro wheel continues to spin, no matter whether the gyro and its mounting, considered as a whole, be stationary relative to the earth, or in motion. When the gyro apparatus is stationary relative to the earth, the gyro axis does remain fixed in space; but when the gyro apparatus mounted in either of the ways just described is in relative motion, as for example when mounted on a moving vehicle such as a ship, movements of the vehicle acting directly and also acceleration and deceleration pressures caused by the various movements of the vehicle are communicated, by reason of the friction necessarily existing to some extent between the parts of the gyro's mounting, to the gyro wheel itself, upon which the said pressures are thus indirectly impressed in the form of disturbing torques of varying magnitude. These torques tilt the gyro axis and cause precession of the gyro into new positions where, in each instance, the axis assumes and tends to maintain a new direction in space. As a consequence, the gyroscope either having three degrees of freedom, or with one degree partly suppressed as described, will, if left to itself on a vehicle having variable speed, ultimately cease to indicate the meridian or any other chosen direction in which its axis was originally set, and will be erratic and untrustworthy. Moreover, such acceleration and deceleration pressures serve to exaggerate the oscillations which are found in practice to characterize a freely suspended gyro under all conditions; and the periods of these oscillations are so excessively great that apparatus subject to them is almost useless for the purpose of a compass.

However, when a gyroscope mounted for three degrees of freedom is combined, as in the present invention, with means for accomplishing positive orientation and for minimizing oscillations, a practical compass apparatus results which is accurate and dependable under all conditions of service.

In describing the gyro of the present invention as having three degrees of freedom I do not mean to imply that such freedom is absolute, but rather that the gyro may be non-pendulous. As a matter of fact, as will more fully hereinafter appear, freedom of motion about one or more axes is restrained or suppressed to a certain extent for the purpose of developing a positive orienting force. Considered by itself, the gyro of the present invention, in its most advantageous embodiment, may be in indifferent equilibrium; that is, the three axes about which it can move may intersect substantially at its center of gravity. According to the present invention the disadvantages inherent in the ordinary pendulous gyro, due largely to its being directly affected by acceleration pressures, are avoided; and by providing what may be termed latent restraining means for developing a positive orienting force, the erratic performance of the ordinary gyro having three or even only two uncontrolled degrees of freedom is transformed into perfectly dependable indicating action. At the same time all the important advantages of the pendulous gyro having but two degrees of freedom are retained in the present apparatus, and notably the tendency of the gyro always to seek the north. This is brought about by employing means, herein shown as structurally separate from or external to the gyro and its universal movement support but operatively connected thereto, for partially limiting and constraining the gyro axis to movements largely in one plane which, in practice is a horizontal plane. The restraining means, in its most advantageous form, should be normally without effect on the freedom of the gyro, coming into play only when the gyro tends to wander from its proper position. As a matter of fact a gyroscope on a moving vehicle such as a ship does not, in general, point exactly north, the error being variable and depending as I have discovered, upon the speed, course and latitude of the ship. A device for correcting the apparent readings of gyroscopic compasses is described and claimed in my copending application Serial No. 634,595 of even date herewith.

The instrument of the present invention comprises means for developing and applying a positive force tending to tilt the axis of the gyro wheel one way or the other the moment the meridional position is departed from in the slightest degree. I have found how to utilize this means to produce a positive stress which is applied direct to the wheel or its journal frame or casing; not simply about one equivalent axis as has heretofore been the universal practice in attempts to solve this problem, namely the horizontal axis, but simultaneously about two equivalent axes lying normal to each other, the second being the vertical axis of orientation. There are, of course, different methods of carrying this important double function into effect. I shall confine my description to the preferred embodiment of one or two methods, selecting those most easily understood. Let us now suppose that near the suitably suspended gyro wheel casing we provide a suitable rigid part close at hand but structurally separate from the gyro to which first a constantly operating self-centering or centralizing connection is made, and second, a simple device, such as a retractile spring or pair of springs are attached. It is found that the springs or their equivalent means constantly restore the wheel and frame to their central position by utilizing its own motion or tendency to move; and what is probably most important of all, it is found that, by selecting an exact point of attachment and one which is to the correct amount eccentric to the vertical axis, a positive and automatic orientation may be introduced whereby the wheel is very quickly returned in azimuth to the meridian as soon as the axis tends to tilt, all this being brought about by the proper relation of some three forces acting in conjunction. Thus, an entirely new element has been introduced into gyro compass operation, viz: that of forced and positive orientation brought about by an (*Turn Page*)



THE GYRO WHEEL

In vertical section; drawing from Patent No. 1,279,471.

operating mechanism of a predetermined activity and moment connecting the directive factor of the compass with a relatively immovable or stationary part, such part serving as an anchor or abutment for developing the necessary force reactions.

It will be readily seen that I have thus secured a simple gyro compass and for the first time in the history of the art, a forced and greatly accelerated orientation coupled with perfect freedom from numerous disturbances and errors above pointed out for it is clear that a part for instance in a state of neutral equilibrium or "indifferent equilibrium," as Foucault forcibly puts it, cannot respond to the disturbances named owing to the fact that it is not possessed of ballastic properties which is the source of the difficulty. One detail remains to be added to make the apparatus complete, viz: that the anchor should turn around in azimuth with the gyro wheel so as to be always on hand to operate as a base for the positive orienting, restraining and correcting element. In avoiding mercury floats and employing Foucault's filament suspension, it is also necessary that no torsion should accumulate therein as the ship turns. To provide against this a sensitive and simple following up device has been adopted which instantly responds to the slightest azimuth movement of the wheel and therefore never permanently changes its azimuth relation therewith, thus accomplishing a number of essential functions among which are its use as the anchor for the positive orientation and correction element and at the same time as a support for the torsion suspension whereby the two ends of the torsion element practically always move together, barring a trifling lag existing for an instant between them and before the responding member has caught up, amounting usually to less than one-tenth degree. Therefore no permanent torsion can exist and the suspension is always held in the condition of maximum sensitiveness and in readiness to instantly respond equally to motion in either direction. The rigidity of this supporting and anchoring part will be seen to be more than sufficient for all needs when it is stated that it is geared solidly to a stationary part secured to the supporting body and positively driven as by a power motor.

The acceleration pressures mentioned are due principally to three causes, first, that of getting under headway, or while stopping either forward or backward; second, centrifugal forces in turning, while moving in either direction; and third, the acceleration pressures emanating from oscillation where the compass is located at a distance from the center of such oscillation.

Science News Letter, October 1, 1932

GEOLOGY

Wind May Have Blown Chilean Salts from Rocks and Sea

AGREEMENT is being reached as to the most scientific explanation to account for the formation of the valuable constituents—nitrate and iodine—in the vast natural chemical storehouse that stretches for nearly five hundred miles along the length of the "tapeline" republic of Chile. A plausible theory at first advanced averred that guano, deposited by the birds that inhabit the coastal region, was responsible.

Some scientists then claimed that an upheaval of the sea bed had occurred, resulting in the exposure and decomposition of seaweed—a theory that accounts also for the presence of iodine.

Fixation of atmospheric nitrogen by lightning formed the basis for a third supposition, and still another claimed that the deposits were caused by the action of nitrifying bacteria on alluvial soil.

Then came the suggestion that volcanoes, of which the Andean region has many, were responsible. The contention was raised that nitric acid, formed by the oxidation of released ammonia, combined with alkaline earths from rock formation and resulted in nitrate. This seemed a logical explanation, but it failed to account for the presence of the iodine.

A recent supposition, which seems to meet all objections advanced to date, emphasizes the value of an intimate knowledge of local conditions in a study of this character. A Scandinavian geologist, Bjarne Hofseth, was impressed with the strength and regularity of the winds that commence each day at noon to blow over the pampas, as the stretch of desolate waste is called. He estimated that a daily wind movement occurred of about one hunderd kilometers, carrying minute amounts of dessicated salines, the products of rock decomposition and evaporated sea spray. Basing calculations on the assumption that the deposits have taken 100,000 years to form, Mr. Hofseth shows that a crust of nitrate and other soluble salts accumulating at the rate of only one-tenth of an inch every fifteen years would be sufficient to account for the existing and exploited reserves, the commercial development of which began about a century ago.

A heavy dew characteristic of this region, known as camenchaca, may well have effected dissolution of the salts and their precipitation in the ground. Periodic changes of climate, caused by the conflict of the Humboldt current from the cooler, southern seas, and a warm current from the north, known as El Nino, bring torrential rains at fairly regular intervals of about fifteen years, to vary the monotony of daytime aridity. A concensus of opinion is favoring the assumption that at such periods a further dissolution and recrystallization of nitrate occured; and so the deposit was finally formed as it is now being mined. It is a narrow horizontal stratum, or rarely two or more superimposed strata, usually at a maximum of only a few yards below the surface.

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