

E. A. SPERRY & H. L. TANNER.
GYROSCOPIC STABILIZER.
APPLICATION FILED JULY 14, 1914.

1,236,993.

Patented Aug. 14, 1917.
2 SHEETS—SHEET 1.

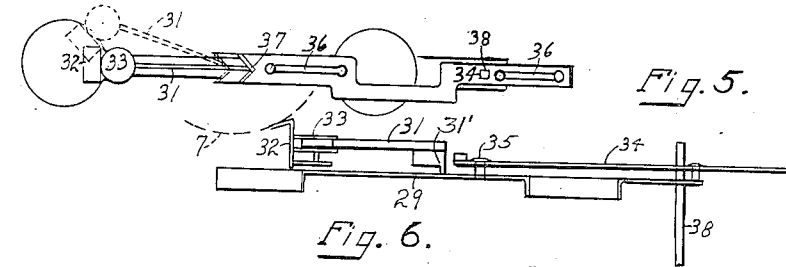
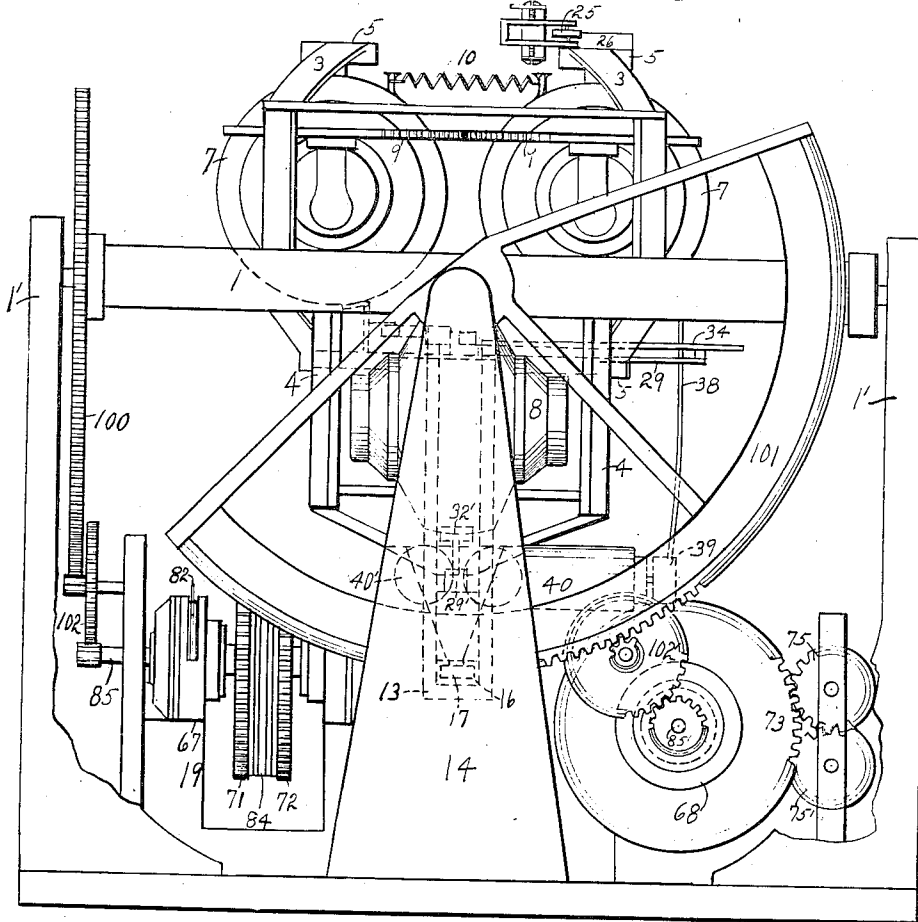


Fig. 7.

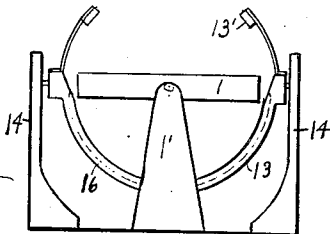


Fig. 1

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E. A. SPERRY & H. L. TANNER.
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2 SHEETS—SHEET 2.

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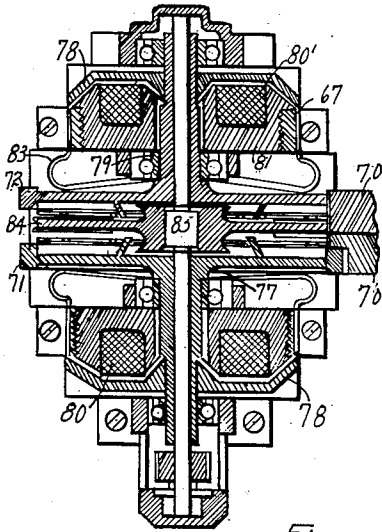


Fig. 4.

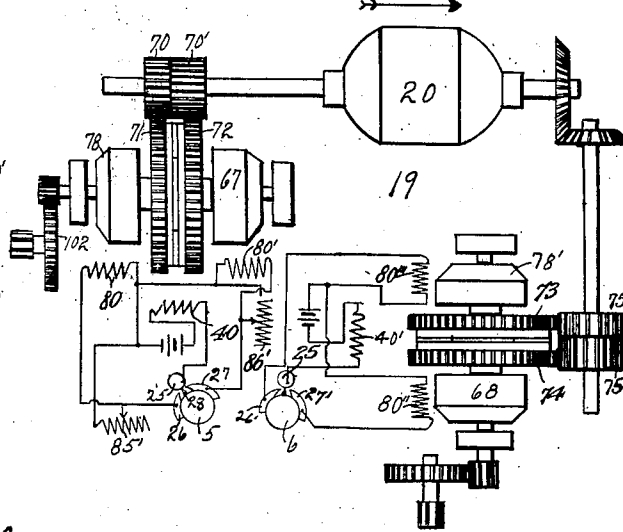


Fig. 3.

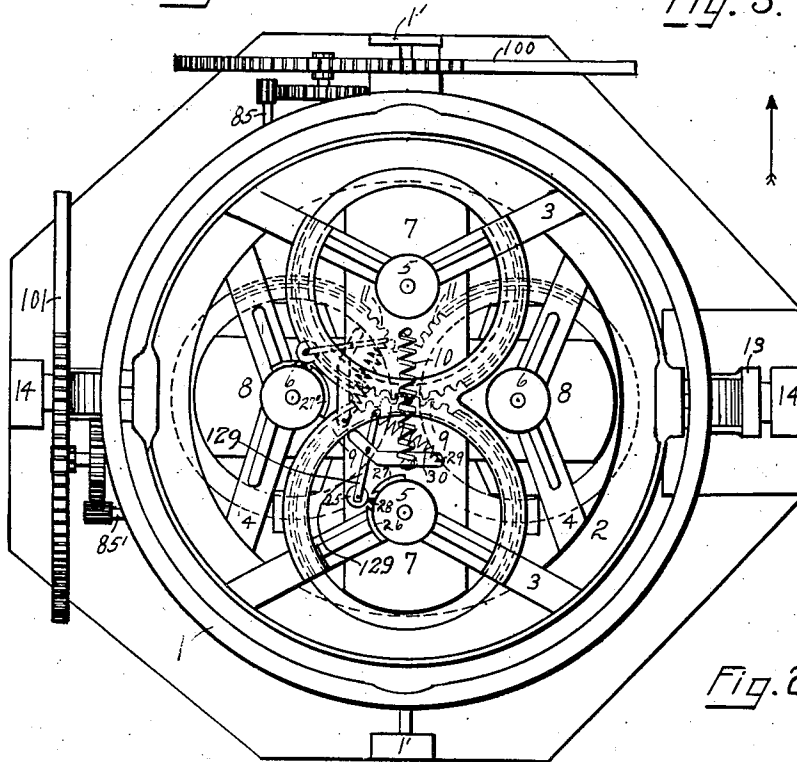


Fig. 2.

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UNITED STATES PATENT OFFICE.

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GYROSCOPIC STABILIZER.

1,236,993.

Specification of Letters Patent.

Patented Aug. 14, 1917.

Application filed July 14, 1914. Serial No. 850,874.

To all whom it may concern:

Be it known that we, ELMER AMBROSE SPERRY and HARRY LAURENCE TANNER, citizens of the United States, residing at Brooklyn, New York, have invented a new and useful Improvement in Gyroscopic Stabilizers, of which the following is a specification.

This invention has for its object the provision of means whereby a reference line or plane may be held at a fixed angle with respect to the surface of the earth under all conditions that may arise. More specifically it relates to means for stabilizing a reference line or plane on an unstable vehicle, whereby the vehicle may be stabilized. Our invention is independent, however, of the means to control the stability of the vehicle from the stabilized plane. Also our invention is not limited to this use, but is equally well adapted for use as an inclinometer and for many other purposes.

The basis of our system is a pendulum, the stability of which is increased by gyroscopes. While pendulums of all types, especially those stabilized by gyroscopes, will maintain a fixed reference plane on a body which is merely tilted or which moves in a straight line at a uniform velocity, they become useless when mounted on a body which moves so as to cause acceleration pressures, such as those due to starting or stopping, turning in azimuth or turning up or down. Our invention overcomes these defects by the means which will now be described in detail:—

Figure 1 is a side elevation of our pendulous system of gyroscopes.

Fig. 2 is a plan view of the same.

Fig. 3 is a diagrammatic view of the force impressor system.

Fig. 4 is a section of one of the clutches of said system.

Figs. 5 and 6 are a plan and elevation of what we term a "decentralizer."

Fig. 7 is a detail.

Broadly, any type of a pendulous gyroscopic system may be employed. The one illustrated is preferred, however, as it lends itself readily to the application of the means we employ to overcome the effect of acceleration pressures. It comprises four rotors or gyroscopic wheels, which are arranged in pairs; one pair stabilizing about each horizontal axis. Both pairs are mounted on a common support, which is shown as a pair

of Cardan rings and pivoted within brackets 1', so as to be free from turning moments about both horizontal axes. Four frames 3, 3 and 4, 4, of special construction are secured to the inner ring 2, frames 3, 3 being secured on top of and frames 4, 4 beneath the ring. These frames we term the precessional frames. They are provided with vertical bearings 5 and 6 in which the rotor frames 7 and 8, or the frames carrying the bearings for the wheels are pivoted. The bearings are normally horizontal and the two pairs are at right angles to each other. The rotors of each pair are designed to rotate in opposite directions. The rotor frames 7 are provided with means to prevent all precession on axes 5, except equal and opposite precession. This means may be of any form and is shown as a segmental gear 9 secured to each frame and intermeshing. A normal centralizing means is also used, which in the embodiment shown takes the form of a spring 10 secured to each frame. The rotor frames 8 are provided with similar gears 11 and a spring (not shown). The rotors are designed to be driven by three phase current and are of the same general type as illustrated in the United States Patent of Elmer A. Sperry, No. 1,186,856, granted June 13, 1916. It will be noted, however, that the rotors in this invention have their axes normally horizontal. In order that the position of ring 2 on its axis may be made use of and controlled, we provide a bail or swinging loop 13, pivoted between brackets 14, and counterpoised by weights 13'. Said bail is provided with a groove 16, in which a roller 17, secured to framework 4, slides.

The apparatus is preferably placed on a vehicle so that one of its axes is parallel to the direction of travel of the vehicle. For purposes of illustration, the vehicle may be considered as going in the direction of the arrows in the figures. The system as a whole is made pendulous by placing the pivots of the ring 1 above the center of gravity. Analysis of the forces acting on the system will show that any force tending to tilt it about a lateral axis, *i. e.*, forces due to pitching of the vehicle, will be resisted by the pair of gyros 8, 8, since they are free to precess in their precessional bearings 6 in frames 4; while any force tending to tilt the system about a longitudinal axis, *i. e.*, forces due to rolling, will be resisted by the pair

of gyros 7, 7, for similar reasons. Torques about the vertical axis will, of course, have no effect upon the equilibrium of the system.

But so far we have only considered the effect of the forces on the system due to friction of the bearings of the gimbal rings, as the vehicle pitches or rolls.

We will now consider the system in a broader aspect: The function of the centralizing springs 10 is to return the gyros to their normal position, after precession. They will perform this function accurately as long as the external forces causing the initial precession are of short duration and are equal and opposite, or, more strictly speaking, as long as the resultant of the forces over a reasonably short period of time is zero. But if a single torque is applied for a time and then released, the effect of the centralizing means is to cause a rotation of the gyroscopic frame in the direction of the applied torque. Such torques are caused by acceleration pressures acting on the pendulous system and tending to displace the pendulous mass from its vertical position. It will be seen that if the system is mounted on a vehicle which is driven around in a circle, a continuous force will be exerted on it, thus causing a continued precession of the gyros, until they will turn to a position where the reactance from their precession will no longer be effective to resist the movement of the pendulous system in the direction of the applied torque. We therefore employ a mechanism which overcomes the effect of acceleration pressures and centralizes the gyroscopes within certain limits by substituting itself automatically for the normal centralizing means. This mechanism comprises essentially means for causing a torque or force to be applied about either or both of the horizontal axes of the system. In the embodiment shown this means comprises a positive force or torque impressing device, which may be termed a force impressor. In addition to the force impressor and cooperating therewith, we may employ a device adapted to overcome the effect of the centralizing spring acting on the gyros, which device we term a decentralizer. The office of the force impressor is primarily to overcome the acceleration pressure by applying a torque about the support of the pendulous system which is opposed to that exerted by said pressure. In its broad aspect, our invention contemplates the employment of any suitable force applying means adapted to exert a torque on either or both of the supports for the gyros. In a preferred form of the invention we have shown a force impressing system 19 (see Fig. 3) adapted to exert a torque about either or both of the horizontal axes of the system. The force impressor comprises a motor 20, which may be constantly driven

by any suitable source of power, and two double clutches 67 and 68; clutch 67 being shown as connected to a gear segment 100 on the gimbal ring 1, while clutch 68 is coupled to a gear segment 101 secured to the bail 13. The large gears 71, 72, 73 and 74 on the clutches are constantly rotated from the motor by means of pinions 70, 70', 75 and 75'. These pinions intermesh so as to drive the units of each pair of gears in opposite directions. As the two clutches are identical in construction, a detailed description of but one of them will be sufficient.

Each gear is provided with a clutch face on its inner side adapted to cooperate with the disk 84, fixed upon a central shaft 85. The gears are formed with sleeve like hubs 77 which are slidable on the central shaft 85 and are secured adjacent their outer ends to armature 78. The inner portion of the ball bearing 79 is fixed to the forward portion of the sleeve so as to form an abutment for a spring 83, which spring is secured to the main frame 67 and acts to hold the armature 78 normally away from the electromagnet 81 and at the same time hold the clutch face on gear 72 away from the disk 84. The electromagnet 81 is provided with a solenoid winding 80', as shown, so that when the solenoid is energized it drives the armature 78 forward, thus closing the clutch. Since the gear 72 is constantly rotated by the motor 20, a torque is immediately exerted on the ring 1 through the gear train 102 and gear sector 100. The construction of the other half of the clutch is identical with that described, so that when the other solenoid 80 is actuated, gear 71 closes the clutch, thereby driving disk 84 in the opposite direction from which it was driven by gear 72. In order that the clutches may be accurately adjusted, the electromagnets are threaded in the main frames, and are provided with pins 82, which serve as handles. The solenoids 80 and 80' of clutch 67 are controlled by means of a trolley switch, the stationary part of which is located upon the top 5 of one of the arms 3; (see Figs. 1, 2 and 3) this part comprises two conducting strips 26 and 27 separated by a space through which projects an insulating knife edge 28; a trolley mechanism is located upon the adjacent rotor frame 7. The trolley mechanism comprises a trolley wheel 25 mounted on a lever 129 (Fig. 2) which is pivotally mounted intermediate its ends on the bracket 29 fixed to an extension (not shown) on the gyro casing. A compression spring 30 extending between the far end of lever 129 and the bracket 29 normally forces the trolley into contact with the conducting strips. The clutch 68 is actuated from a similar trolley mechanism located, as shown, upon the top 6 of one of the frames 4. It comprises conducting strips 26' and 27' and

trolley 25'. When the apparatus is in perfect equilibrium both trolleys rest upon the insulating knife edges. When the equilibrium is only slightly disturbed for a short period of time the trolley mechanism is so constructed that the circuit is not closed, leaving the centralizing springs 10 to return the gyros to their central position. But if a torque is applied for any length of time about the longitudinal axis, tending to tilt that portion of ring 1 to the right of pivots 1' downwardly in Fig. 2, for instance, a large precessional movement of the gyros 7 will occur which will cause the trolley 25 to contact with strip 27, if the rotors are turning toward each other. This will cause solenoid 80' to be energized and thus apply a torque on the ring 1. This torque is designed to overcome the acceleration pressure which is causing the original precession and to cause the gyroscopes to precess back to near their central position. As soon as the trolley leaves the strip 27, however, the circuit will be broken and the torque will cease to be applied, so that if the acceleration pressure is still acting the cycle of movement just outlined will be repeated. It will thus be seen that the action becomes vibratory.

It should also be noted that the force impressor is self-adjusting. That is, it adapts itself automatically to just neutralize the effect of varying acceleration pressures, since the time which the impressor acts is governed by the position of the gyroscopes; thus if the force impressor, roughly speaking, exerts twice the torque on the ring 1 that is exerted by the continuously acting acceleration pressure, the force impressor will be acting approximately about one-half the time.

It will be seen that if the ring 1 is tipped in the opposite direction the trolley will contact with strip 26 and cause the circuit to be closed through solenoid 80, which will apply torque in the opposite direction. It will also be apparent that the action of the trolley mechanism 25', 26' and 27' and clutch 68 is the same about the lateral axis, the torque being applied to ring 2 through gear sector 101 and bail 13. It will at once be seen that the so-called bail 13 or swinging loop furnishes a means of applying torques about the axis of ring 2 which interferes in no way with the movement of the whole pivoted structure about axis 1', 1', since all motions with components about this axis simply cause roller 17 to roll around groove 16.

It should also be noted that motor 20 may be connected in circuit with the solenoids so as to be actuated when either one of the solenoids is energized if it is desired that the motor should not be kept continuously rotating.

We will now consider the effect and construction of the decentralizing means: As explained before, the action of the normal centralizing means 10 becomes undesirable when a torque is applied for a period of time about one of the major axes. In other words, the action of the centralizing spring should be dispensed with under the same conditions when the force impressor is called into play.

We employ the decentralizer shown in detail in Figs. 5 and 6 to neutralize the effect of spring 10. The base 29 of the decentralizer is secured to the lower hub portion of frame 3. A sliding link 31 has a projection 31' at one end which slides in a slot in the base, and is attached at the other end to a bracket 32 through a swivel joint 33. Bracket 32 is secured to rotor frame 7, so as to be moved as indicated by dotted lines in Fig. 5 by the precession of the gyroscope. A spring-pressed stop 34 is mounted on the base 29 in the rear of link 31, by means of pins fixed in the base, which have heads 35 working in slots 36 in the stop 34, so that the stop is free to slide. The stop is provided with a forked end 37 to embrace the end of link 31. The stop is actuated through a flat spring 38, one end of which passes through a hole in the stop. The position of the spring is controlled by securing said spring to the armature 39 of an electromagnet 40, secured to a portion of the gyroscopic framework support on ring 2. When the magnet is energized, it pulls the spring over to the left in Fig. 1, which carries the stop into engagement with link 31, so that a pressure will be exerted on link 31 and consequently on the rotor frame in the position shown in dotted lines in Fig. 5, such that the force of the centralizing spring will be, in effect, neutralized during the time the acceleration force is acting. Since, as explained above, the force impressor is much more powerful than the average acceleration pressure, it will cause the gyros to precess back to near their central position even while such pressure is acting and thus cause the circuit to be broken, throwing out both the force impressor and the decentralizer by means explained hereinafter. The spring 38 is made in the embodiment shown to exert a greater force than the centralizing spring while it is acting, so that the total resultant of the two forces during the time that the acceleration pressure is being exerted is practically zero for the normal conditions that arise. If, however, the main frame of the apparatus shows a tendency to tilt over in the direction of the applied acceleration force, the strength of the spring may be increased so that an over-balancing torque will be exerted about the precession axis, which will cause the main frame to precess back to the

normal position. Another means of accomplishing this same result will be described hereinafter.

By connecting the magnets 40 in the same circuit with the force impressor 19, that is by controlling it from contactors 25, 26 and 27, means are provided whereby the decentralizing means is actuated only when the force impressor is actuated, so that the two devices coöperate to produce an auxiliary centralizing means, which automatically substitutes itself for the normal centralizing means, at a predetermined point in the precession of the gyro and prevents further precession. While the motor 20 applies a torque about the axis of ring 1, it does not tilt the ring to a perceptible extent, firstly, since the torque it exerts is opposed by the external force (for instance centrifugal force) acting on the pendulous system of gyros which caused the original precession and, secondly, since any torque in excess of the external force is opposed by the precession of the gyros in the opposite direction from the original precession.

The decentralizer 29' for the gyros 8—8, as shown, is identical to the decentralizer described above, so that this detail need not be further specified. It is obvious, however, that either of the force impressing clutches and associated decentralizing means may be dispensed with if it is found that the apparatus under ordinary conditions of use does not bring these into play.

In the wiring diagram in Fig. 3 are shown variable resistances 85' and 86' in circuit with the solenoids 80—80'. The purpose of these is to enable the operator of the machine to cause the main support to work back into the horizontal position in case it becomes displaced. This result is accomplished as follows: A torque applied for a comparatively short time, even though of great force, will have little or no effect in causing the main frame to tilt, since the gyroscopes will rapidly precess away from the influence of the centralizing spring. But if a small torque is applied for a long time it will be seen that the centralizing spring is permitted to exert a torque on the rotor frames for a considerable period of time and, as explained before, this will cause the main frame to gradually tip in the direction of the applied acceleration force. If, however, the strength of the torque applied by the force impressor be lessened by weakening the clutch 67 for instance through variable resistance 86', it will be seen that the time during which it acts, and hence the time during which the decentralizer acts, is increased, thus diminishing the effect of the centralizing spring and increasing the effect of the decentralizer. This will cause the effect of the force exerted by the decentralizer to increase and cause the main support

to precess back to the horizontal position. The variable resistances may also be used to adjust the effect of the auxiliary centralizing means in each direction. Thus, if when the apparatus is being subjected to the usual jolts and jars of a rapidly moving vehicle, but while the general direction of travel is in a straight line, the main rings showed a tendency to tip in one direction, the resistances could be varied until this tendency was overcome.

Another effect that may be secured by varying the strength of the clutches is secured when their strength is increased to a maximum, so that the force impressor virtually delivers sharp blows on the main frame. The effect of this is apparently to move the main frame in the direction of the applied force before the inertia of the gyroscopes around their precession axes has been overcome so that the reaction from their precession can become effective. Since the tendency of the centralizing spring is to move the main frame in the opposite direction, it will be seen that by carefully adjusting the inertia of the gyros and the sharpness of the blows, the function of the decentralizer may be performed in whole or in part.

Another use for the variable resistances is found in adjusting the strength of the force impressor clutches to the ballistic of the gyro-pendulum about each axis. With Cardan mountings for pendulous devices, the ballistic about the two horizontal axes is apt to be different, especially where a swinging loop such as loop 13 is employed, so that it becomes desirable to vary the strength of the clutches accordingly.

The operation of the device will be apparent from the foregoing detailed description and explanation.

In accordance with the provisions of the patent statutes, we have herein described the principle of operation of our invention, together with the apparatus which we now consider to represent the best embodiment thereof, but we 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.

Having described our invention, what we claim and desire to secure by Letters Patent is:

1. The combination with a gyroscope, of external means brought into action by the precession of the gyroscope for causing a torque to be applied on said gyroscope.
2. The combination with a gyroscope, of

external means brought into action by movement of the gyroscope about one axis for causing a torque to be applied about a second axis of the gyroscope.

5 3. Means for stabilizing a plane on a freely movable body, comprising a support fixed on said body, a plurality of gyroscopes mounted on said support for concerted oscillation about one or more axes, and precessional movements about other axes, means to limit said precessional movement, comprising means adapted to exert a torque about one of said first mentioned axes, and controlling means for said torque applying means adapted to be actuated by a predetermined precessional movement of a gyroscope.

4. Means for stabilizing a plane on a freely movable body, comprising a support fixed on said body, a system of gyroscopes mounted on said support for concerted oscillation about one or more axes, said system comprising one or more pairs of oppositely rotating wheels, bearing frames for each of said wheels, coupled for opposite precession and pivoted on axes at right angles to said first mentioned axes, means to limit said precessional movement, comprising a force-impressor adapted to exert a torque about one of said first mentioned axes and controlling means for said force-impressor adapted to be actuated by a predetermined precessional movement of a gyroscope.

5. Means for stabilizing a frame on a freely movable body, comprising a support fixed on said body, a system of gyroscopes mounted on said support for concerted oscillation about one or more axes, said system comprising one or more pairs of oppositely rotating wheels, bearing frames for each of said wheels, coupled for opposite precession and pivoted on axes at right angles to said first mentioned axes, means to limit said precessional movement, comprising a force-impressor adapted to exert a torque about one of said first mentioned axes, a centralizing means for said frames, controlling means for said force-impressor adapted to be actuated by a predetermined precessional movement of a gyroscope and means also actuated by said controlling means adapted to destroy the effect of said centralizing means.

6. In a gyroscope supported for oscillation about an axis and for precession about a second axis at an angle thereto, means whereby the gyroscope is normally centralized about its precession axis, a device for overcoming the effect of excessive acceleration forces, comprising a controlling means adapted to be actuated by a predetermined precession of the gyroscope, a means controlled by said controlling means and adapted to exert a torque about an axis at right angles to said precessional axis, and a decentralizing means adapted to neutralize

said centralizing means when said torque applying means is energized.

7. In a device for stabilizing a plane, a Cardan ring support including a pivoted ring, a pair of oppositely facing frames with vertical bearings secured above said ring, and a pair of oppositely facing frames with vertical bearings secured below said ring, a frame pivoted in each set of bearings, gearing and a centralizing spring connecting the frames of each pair and a rotor revolvably mounted in each frame on horizontal axes, the axes of one pair being at right angles to the axes of the other pair, the two rotors of each pair being adapted to be oppositely rotated.

8. In a gyroscope comprising a support pivoted about an axis, a rotor-bearing frame pivoted for precession on said support, a contact switch, the two parts of which are secured respectively to said frame and to said support, and electrical means controlled by said switch for causing a torque to be exerted about the pivotal axis of said support.

9. In a gyroscope comprising a support pivoted about an axis, a rotor-bearing frame pivoted for precession on said support, yielding means for centralizing said frame, a contact switch, the two parts of which are secured respectively to said frame and to said support, electrical means controlled by said switch for causing a torque to be exerted about the pivotal axis of said support, and other means also controlled by said switch for rendering said centralizing means inoperative.

10. In a gyroscopic system, a pair of rotors adapted to be oppositely rotated, bearing frames for said rotors and precessional frames for said bearing frames, a positive connection between said bearing frames, whereby equal and opposite precession about one axis only is permitted, a centralizing means for said frames, and a decentralizing means positioned and arranged to engage one of said bearing frames when a predetermined precession has occurred and to exert a force opposing and counteracting the effect of said centralizing means.

11. Means for stabilizing a plane on a freely movable body, comprising a frame fixed on the body, a support pivoted on said frame so as to be substantially unaffected by the rotation of the body about either horizontal axis, a pendulous system of gyroscopes mounted on said support comprising a plurality of rotor frames pivoted on said support for precession independent of said support about vertical axes, and a plurality of rotors mounted on horizontal axes in said frames, a portion of said rotors being mounted with their axes normally at right angles to the others of said rotors.

12. A decentralizing device for a gyro-

scope, normally centralized about its precessional axis, comprising a bracket adapted to be connected to the rotor frame, a base plate, a link having one end pivoted on said bracket and its other end slidably mounted on said base plate, a stop slidably mounted on said base plate and adapted in one position to engage said link, and in another position to be spaced from said link, means to control the position of said stop, and a spring connecting said means and stop and adapted to exert enough pressure on said link through said stop, when said stop is in the engaged position, to decentralize the gyroscope.

13. In a gyroscopic apparatus, a main frame mounted upon a support for oscillation relative thereto, a pair of precessional frames mounted on said frame, a rotor frame pivoted in each precessional frame with their axes parallel, a rotor journaled in each frame with its spinning axis at a substantial angle to said precessional axes, a connection between said frames permitting opposite precession only, and means for centralizing the two rotor frames comprising a continuously operative means and an auxiliary means actuated only upon a predetermined movement of the apparatus and adapted to counteract the effect of said continuously operative means.

14. In a gyroscopic apparatus, a frame mounted upon a support for oscillation relative thereto, a gyroscope mounted upon said frame for precession and rotation relative thereto, means for centralizing the gyroscope comprising a continuously operative means, means actuated only upon a predetermined precession of the gyroscope and co-operative means adapted to counteract the effect of said continuously operative means.

15. In a gyroscopic apparatus, a main frame mounted upon a support for oscillation relative thereto, a pair of precessional frames mounted on said frames, a rotor frame and rotor pivoted in each precessional frame with their axes parallel, the said axes being at a substantial angle to the spinning axis of each rotor, a connection between said frames permitting opposite precession only, means for centralizing the gyroscopes upon their precession axes comprising a spring attached to each rotor frame, a force impressor system adapted to be actuated upon a predetermined movement of the apparatus and arranged to exert a torque on said main frame, and a spring stop adapted to be thrown into operative engagement with one of said rotor frames in conjunction with said force impressor, and arranged to overcome the centralizing effect of said spring.

16. In a gyroscopic system, a pair of rotors adapted to be oppositely rotated, bearing frames for said rotors and precessional frames for said bearing frames, a positive

connection between said bearing frames, whereby equal and opposite precession about one axis only is permitted, a spring connecting and adapted to centralize said bearing frames, and a decentralizing means positioned and arranged to engage one of said bearing frames when a predetermined precession has occurred and to exert a force opposing and counteracting the effect of said centralizing means.

17. In an apparatus for stabilizing a pivotally supported frame on a freely movable body, a pendulous, gyroscopic system mounted on said frame, comprising a pair of interconnected gyroscopes mounted with their spinning axes at an angle to their precession axes, and a torque applying means adapted to exert a torque on said main frame, whereby said gyros are centralized.

18. In a gyroscopic stabilizing system comprising a frame mounted for oscillation about an axis, a gyro supported on said frame for precession at an angle to said axis, mechanism adapted to precess the gyro by causing a torque to be applied to the frame about its axis, said mechanism being called into action by the precession of said gyro.

19. In a gyroscopic stabilizing system comprising a frame mounted for oscillation, means for opposing the said oscillations, comprising a gyro supported by said frame, mechanism adapted to precess the gyro by causing a torque to be applied to the frame, said mechanism being called into action by the precession of said gyro.

20. In a gyroscopic stabilizing system comprising a pendulous frame mounted for oscillation, a gyro supported by said frame for precession relative thereto, mechanism adapted to precess the gyro by causing a torque to be applied to the frame, said mechanism being called into action by the precession of said gyro.

21. In a gyroscopic stabilizing system comprising a frame mounted for oscillation, a gyro supported by said frame for precession relative thereto, mechanism adapted to precess the gyro by causing a torque to be applied to the frame in different directions, said mechanism being called into action by the precession of said gyro.

22. In a gyroscopic stabilizing system comprising a frame mounted for oscillation, a gyro supported by said frame for precession relative thereto, mechanism adapted to precess the gyro by causing a torque to be applied to the frame in opposite directions, said mechanism being called into action by the precession of said gyro.

23. In a gyroscopic stabilizing system comprising a frame mounted for oscillation, two or more coupled gyros mounted on said frame, a normal centralizing means for the gyros, and mechanism adapted to precess

the gyros by exerting a torque on the frame, said mechanism being called into action by the precession of said gyros.

24. In a gyroscopic stabilizing system comprising a frame mounted for oscillation, two or more coupled gyros mounted on said frame, and means for returning the gyros to a predetermined relation with the oscillating frame, said mechanism being called into action by the precession of said gyros.

25. In a gyroscopic stabilizing system comprising a gyro adapted to spin on a horizontal axis, a frame supporting said gyro, said frame being mounted for oscillation about a horizontal axis at a substantial angle to the spinning axis of the gyro, and mechanism adapted to precess the gyro about its vertical axis by forces applied to the frame, said forces being called into action by said precession of said gyro.

26. In gyroscopic apparatus, a main, pivoted support, which together with its contained parts, is pendulous, a rotor and rotor bearing frame pivoted on said support for precession relative thereto, and means responsive to the exertion of a pressure on the main support for eliminating the effect of such pressure.

27. In a gyroscope having at least two degrees of freedom, yielding means whereby the rotor bearing frame is caused to assume a normal position with respect to its support, and means brought into action by movement of said frame against said yielding means for eliminating the effect of said means.

28. In mechanism for establishing a base line on moving objects, a pendulum, a gyroscopic stabilizer for the pendulum, mechanism coöperating therewith for preventing lateral pressures acting upon the ballistic mass of said pendulum from altering its angular position with reference to the earth, the said pendulum being supported on said object.

29. In mechanism for establishing a base line on moving objects, a pendulum supported on said object, an oscillating gyroscopic stabilizer for the pendulum, mechanism anchored to the pendulum support and coöperating with said pendulum for preventing lateral pressures acting upon the ballistic mass of said pendulum from altering its angular position with reference to the earth, and a centralizing device for the oscillating gyroscopic stabilizer.

30. In mechanism for establishing a base line on moving objects, a pendulum supported on said object, an oscillating gyroscopic stabilizer for the pendulum, mechanism anchored to the pendulum support and coöperating therewith for preventing lateral pressures acting upon the ballistic mass of said pendulum from altering its angular

position with reference to the earth, a centralizing device for said stabilizer and means for periodically overpowering said centralizing device.

31. The combination with a universally mounted support, of a plurality of gyroscopes supported thereon for precession with respect thereto, means brought into action by precession of one of the gyroscopes for causing a torque to be applied about one of the principal axes of said support and means brought into action by precession of another of said gyroscopes for causing a torque about the other principal axis of said support.

32. In mechanism for stabilizing a plane on moving vehicles, a universally mounted pendulous device adapted to be mounted on a vehicle and means responsive to a tendency of the device to depart from its vertical position whereby a counteractive force is applied thereto.

33. In apparatus for the automatic control of the stability of vehicles, a pendulous support, a plurality of pairs of oppositely rotating gyros mounted thereon adapted to stabilize the support about a plurality of axes, each pair being in static equilibrium within the pendulum, and mechanism adapted to cause such support to be practically unaffected by translated forces of the pendulum.

34. In apparatus for the automatic control of the stability of vehicles, a pendulous support, a plurality of pairs of oppositely rotating gyros mounted thereon adapted to stabilize the support about a plurality of axes, each of said pair having parallel precession axes and being in static equilibrium within the pendulum, and mechanism adapted to cause such support to be practically unaffected by translated forces of the pendulum.

35. In apparatus for the automatic control of the stability of vehicles, a pendulous support, a plurality of pairs of oppositely rotating gyros mounted thereon adapted to stabilize the support about a plurality of axes, each of said pair having parallel precession axes and being in static equilibrium within the pendulum, mechanism adapted to cause such support to be practically unaffected by translated forces of the pendulum, and means for centralizing the pairs within the pendulum.

36. In gyroscopic apparatus, a universally mounted support, which together with its contained parts is pendulous about both principal horizontal axes, a gyroscope mounted on said support so as to stabilize it about one of said axes, a second gyroscope mounted on said support so as to stabilize it about said other axis, and means responsive to precession of each gyroscope

within the support for causing a torque to be applied about the corresponding axis of stabilization.

37. In apparatus for the automatic control of the stability of vehicles, a pendulous support, a Cardan mounting therefor, gyros mounted thereon adapted to stabilize it about a plurality of axes, the pendulous ballistic about the two Cardan axes being different, and mechanism adapted to cause said support to be practically unaffected by translated forces of the pendulum.

38. In apparatus for the automatic control of the stability of vehicles, a pendulous support, a pair of automatically centralized gyros mounted on said support in static equilibrium, and mechanism adapted to cause said support to be practically unaffected by translated forces of the pendulum.

39. In mechanism for establishing a base line on moving objects, a pendulum and mechanism cooperating therewith in two directions for preventing lateral pressures acting upon the ballistic mass of said pendulum from altering its angular position with reference to the earth, and means for adjusting the effect upon the pendulum of the action of said mechanism in one direction with reference to that in another.

40. A device for preventing excessive precession of a gyroscope in a freely supported gyroscopic stabilized system, comprising a force-impressing means adapted to exert a torque about an axis of the system, a primary controlling means for said force-impressor adapted to be actuated by the precession of the gyroscope, and a secondary adjustable controlling means adapted to vary the torque exerted by said force-impressor.

41. In a gyroscopic system, the combination with a rotor frame supported for both oscillation and precession, of a force-impressor adapted to exert a torque about an axis of the system at right angles to the precession axis, a contact switch on the rotor frame adapted to be actuated by a precession of the frame beyond a predetermined amount and arranged to control said force-impressor, a variable resistance in circuit with said force-impressor, whereby the time during which said impressor acts is varied, and a decentralizing means arranged to be actuated at approximately the same time as the force-impressor and adapted to overcome the effect of the normal centralizing means.

42. In gyroscopic apparatus, a support mounted for oscillation about an axis which together with its contained parts is pendulous, a gyroscope supported on said support for precession relative thereto, and means responsive to precession of said gyroscope for causing a torque to be applied about said axis of the support.

43. In gyroscopic apparatus the combination with a pair of Cardan rings mounted one within another and a gyroscope mounted on the inner ring, of means for applying a torque about the axis of support of the inner ring comprising a loop pivoted in line with said axis, a slidable connection between said loop and said inner ring, and power means connected to said loop adapted to exert a torque thereon.

44. In gyroscopic apparatus, a universally mounted pendulous support, a plurality of gyroscopes mounted thereon so as to stabilize it about both horizontal axes, means responsive to relative precession of the gyroscopes due to a torque on the support about one axis for opposing said torque and means responsive to relative precession of the gyroscopes due to a torque about the other axis for opposing said second mentioned torque.

45. In gyroscopic apparatus, a universally mounted pendulous support, a gyroscope mounted on said support so as to stabilize it about one horizontal axis, a second gyroscope mounted on said support so as to stabilize it about a second horizontal axis, and means responsive to precession of one of said gyroscopes for exerting a torque about its axis of stabilization.

46. In a device for stabilizing a plane, a Cardan ring support including a pivoted ring, a pair of oppositely facing frames with vertical bearings secured above said ring, and a pair of oppositely facing frames with vertical bearings secured below said ring, a coupling means connecting the frames of each pair permitting opposite turning only, and a rotor revolvably mounted in each frame on horizontal axes, the axis of one pair being at right angles to the axis of the other pair, the two rotors of each pair being adapted to be oppositely rotated.

47. In gyroscopic apparatus, a support, a member pivoted thereon about both horizontal axes, and means for applying torques thereon about said axes including a continuously driven motor, a plurality of clutch members, gearing connecting said motor and the driving portion of each of said clutches, means for closing the clutches and gearing connecting the driven portion of each clutch to said member.

48. In apparatus of the character described, a support, a gimbal ring pivoted thereon about an axis, a member pivoted within said ring about a second axis, a loop pivoted on said support about said second mentioned axis, a slidable connection between said loop and said member and power means connected to said loop and to said ring for exerting torques on said member about either or both of said axes.

49. In gyroscopic apparatus, the combination with a support, a gimbal ring pivoted thereon about an axis, of a gyroscopic de-

vice including a gyroscope pivoted within
the said ring about a second axis, a loop
pivoted on said support about said second
axis, a slidable connection between said loop
5 and said member and means responsive to
the precession of said gyroscope and con-
nected to the loop for exerting a torque on
said device about said second axis.

In testimony whereof, we ELMER AMBROSE

SPERRY and HARRY LAURENCE TANNER have 10
signed our names to this specification, in
the presence of two subscribing witnesses,
this 13th day of July, 1914.

ELMER AMBROSE SPERRY.

HARRY LAURENCE TANNER.

Witnesses:

A. W. STRINGHAM,

L. J. DIBBLE.