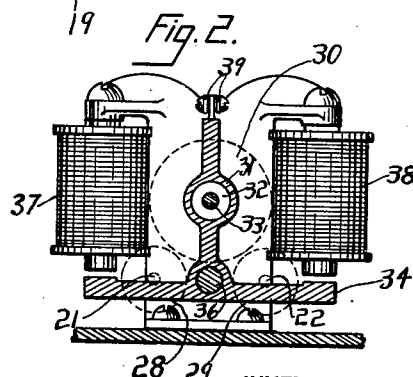
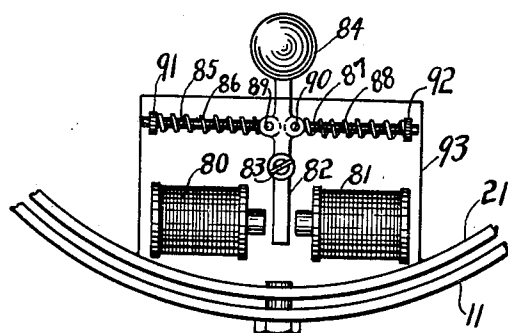
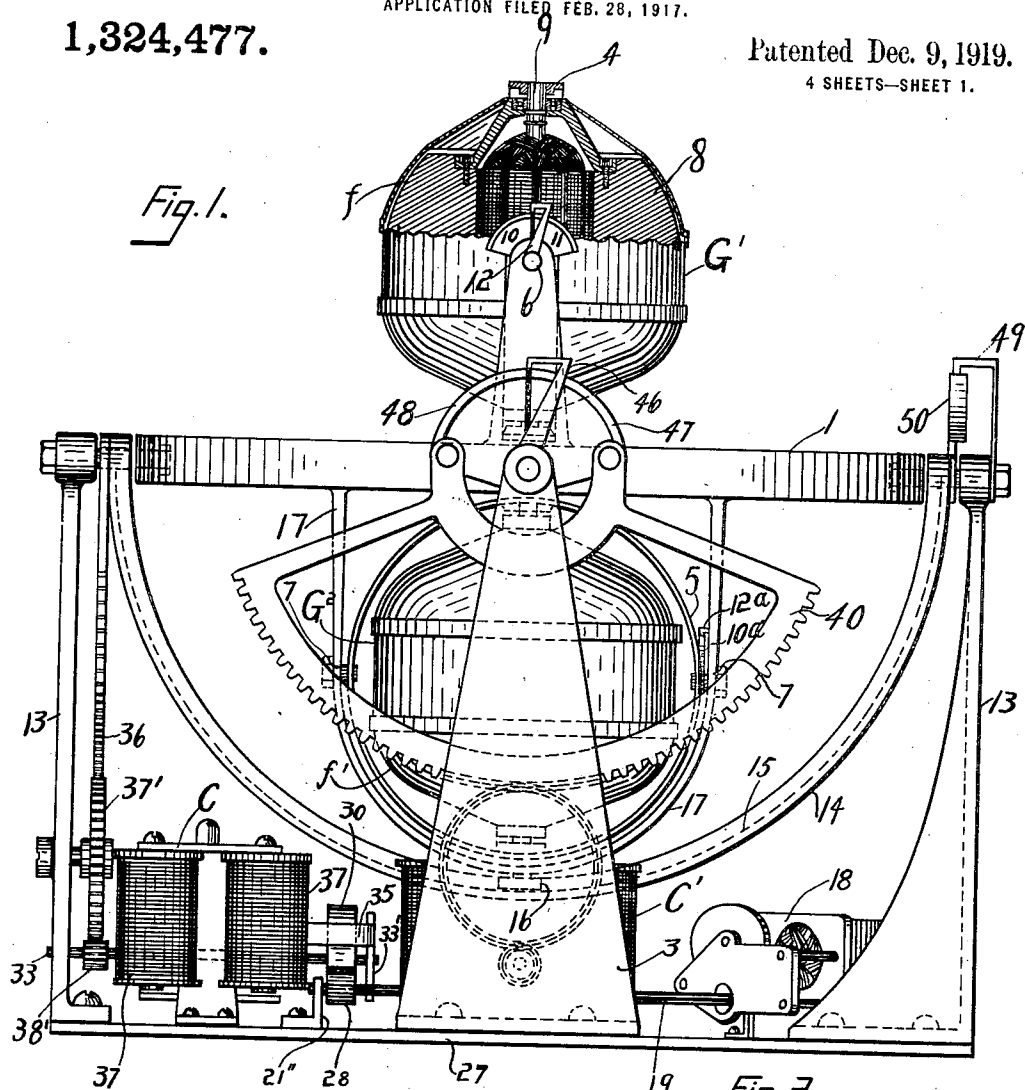


H. L. TANNER.
 STABILIZED GYROSCOPIC PENDULUM,
 APPLICATION FILED FEB. 28, 1917.

1,324,477.

Patented Dec. 9, 1919.
 4 SHEETS—SHEET 1.



INVENTOR
 HARRY L. TANNER.
 BY
 Herbert H. Thompson
 ATTORNEY

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4 SHEETS—SHEET 2.

Fig. 3.

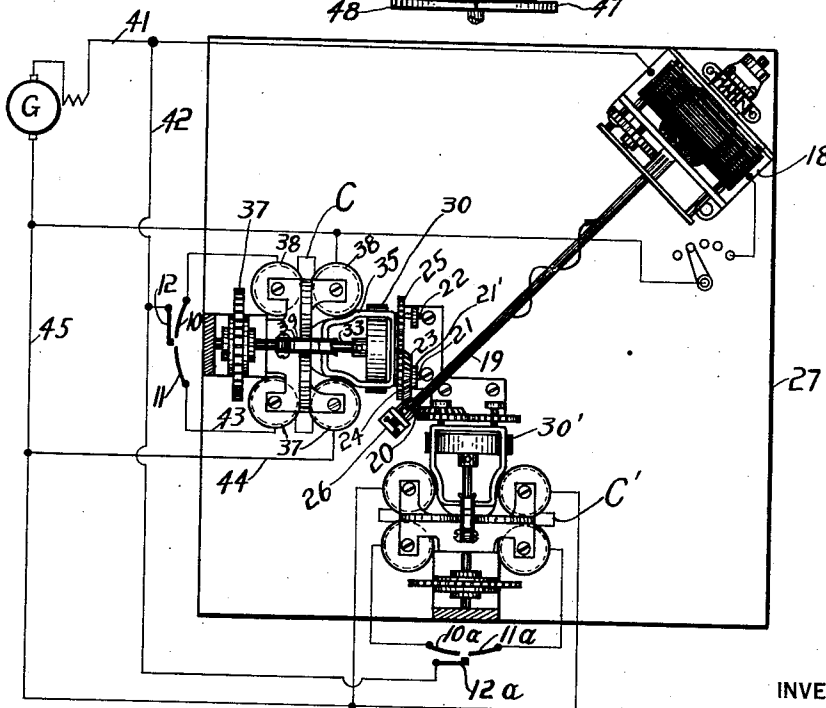
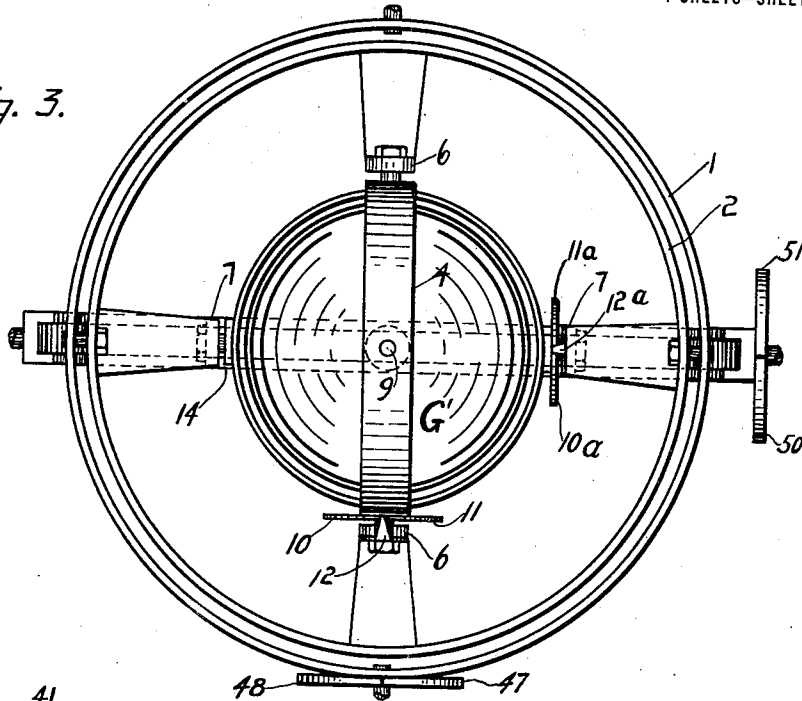


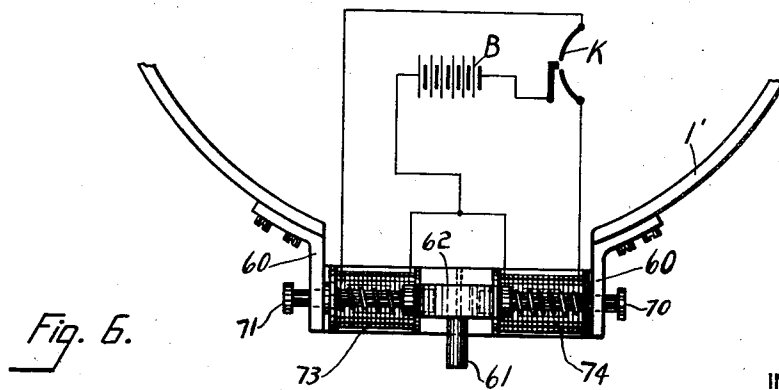
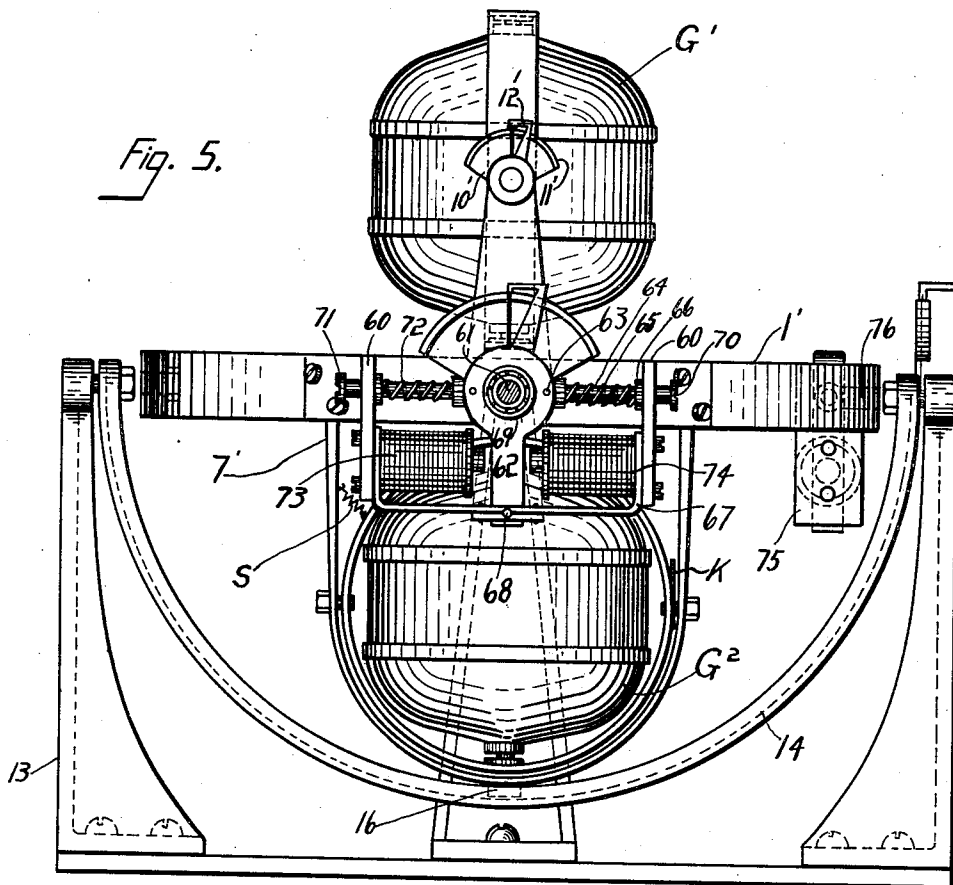
Fig. 4.

INVENTOR
HARRY L. TANNER.
BY
Herbert H. Thompson
ATTORNEY

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HARRY L. TANNER.
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ATTORNEY

1,324,477.

4 SHEETS—SHEET 4.

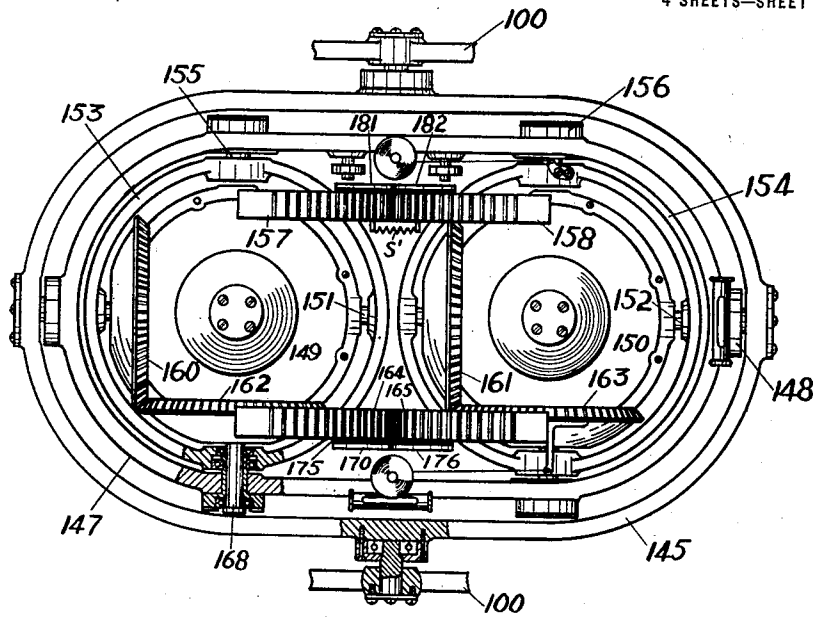


Fig. 8.

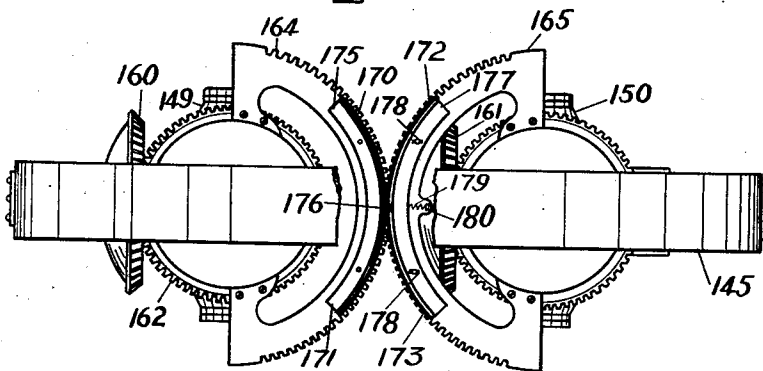


Fig. 9.

INVENTOR
HARRY L. TANNER.
BY
Herbert H. Thompson
ATTORNEY

UNITED STATES PATENT OFFICE.

HARRY L. TANNER, OF BROOKLYN, NEW YORK, ASSIGNOR TO SPERRY GYROSCOPE COMPANY, OF BROOKLYN, NEW YORK, A CORPORATION OF NEW YORK.

STABILIZED GYROSCOPIC PENDULUM.

1,324,477.

Specification of Letters Patent.

Patented Dec. 9, 1919.

Application filed February 28, 1917. Serial No. 151,487.

To all whom it may concern:

Be it known that I, HARRY L. TANNER, a citizen of the United States of America, residing at 1144 East 19th street, Brooklyn, in the county of Kings and State of New York, have invented certain new and useful Improvements in Stabilized Gyroscopic Pendulums, of which the following is a specification.

10 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. My invention is, however, independent of the means to control the stability of the vehicle from the stabilized plane and furthermore it is not limited to such use but is adapted for use as an inclinometer and other purposes.

25 The basis of the system is a pendulum, the stability of which is increased by two 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. My invention overcomes these defects by the means which will now be described in detail:

Figure 1 is an elevation of one form of my invention.

40 Fig. 2 is a sectional elevation of an electro-magnetic clutch used in my system.

Fig. 3 is a plan view of the mechanism shown in Fig. 1, the support and certain other parts being omitted.

45 Fig. 4 is a partly diagrammatic view of the force applying means.

Fig. 5 is a sectional elevation of a modified form of my invention.

50 Fig. 6 is a fragmentary plan view of a part of the mechanism illustrated in Fig. 5.

Fig. 7 is a fragmentary plan view illustrating a further modification.

Fig. 8 is a fragmentary plan view of a

further modification, and Fig. 9 is an elevation of the mechanism illustrated in Fig. 8 with certain parts broken away.

The form of my invention shown in Figs. 1 to 4, comprises two rotors or gyroscopic wheels, each stabilizing about a different horizontal axis but both mounted on a common support shown as a pair of Cardan rings 1, 2 pivoted within a pair of brackets one of which is shown as 3 in Fig. 1. Two rotor bearing frames are mounted on ring 2 respectively above and below the same so as to be rotatable on horizontal axes at right angles to each other. While I am aware that the gyro casings f and f' could be directly pivoted to the bearings to serve as the rotor bearing frames, I have illustrated intermediate rings 4 and 5 which are shown pivoted in bearings 6, 6 and 7, 7 respectively. The gyros G' and G^2 illustrated in Fig. 1 are pendulous, *i. e.*, the center of gravity of each gyro is placed below its pivot although as will appear later this feature is not indispensable.

The frame 4 supports a rotor or gyroscopic wheel 8 rotatable about a normally vertical shaft 9 fixedly mounted in said frame. The shaft 9 carries also an A. C. winding for causing rotation of the rotor 8. While the specific type of gyroscope forms no part of this invention I have illustrated the one above described, as this form is perhaps preferable. The gyroscope above described is adapted to control a suitable two-way contact shown as 10, 11, 12, contacts 10 and 11 being insulated from each other and from contact 12 and being movable with casing f as by being mounted on ring 4. Contact 12 is fixedly supported on one of the bearings 6 and the function of these contacts will appear later. Ring 5 carries a gyroscope G^2 similar in all respects and comprising all of the parts described in connection with the gyroscope G' . The gyro G^2 is equipped with and controls contacts 10^a, 11^a and 12^a similar in all respects to contacts 10, 11 and 12 and controlled in a similar manner. In order to utilize and control the position of the gimbal ring 2, a swinging loop or bail 14 is pivoted to brackets 13, 13. The bail 14 is provided with a groove 15 which receives a roller 16 mounted on a U-shaped member 17 connecting bearings 7, 7.

The system as a whole is made pendulous by placing the pivots of the ring 1 above the center of gravity of the system and the gyroscope G' is preferably rotated in a direction the reverse of that of G^2 .

Assuming that the apparatus is placed on a vehicle with the axis of ring 1 parallel to the longitudinal axis of the vehicle it will be seen that any force tending to tilt the system about a lateral axis, as by pitching of the vehicles, will be resisted by the gyro G' while any force tending to tilt the system about a longitudinal axis, as by rolling of the vehicle, will be resisted by the gyro G^2 . If, however, either or both of these forces is applied continuously, a continued precession of a corresponding gyro or gyros will take place until a position is reached where the reactance resulting from the precession will no longer be effective to resist the movement of the pendulous system in the direction of the applied force. To overcome this and eliminate entirely the effect of acceleration pressures I utilize the contacts, 10, 11, 12 and 10^a , 11^a , 12^a to cause a force or forces to be applied or exerted on the system opposed to and preferably overbalancing the external force or forces.

One form of force applying means is illustrated in Figs. 1 and 4, and comprises an electric motor 18 and two double clutches designated generally as C and C' and while I am aware that the motor could be connected so as to operate only when one or more of the clutch magnets is energized I prefer to operate the motor continuously by means of a generator or other source of E. M. F. As the clutches C and C' are exactly similar a description of one will suffice for both. Referring to Figs. 2 and 4 it will be seen that the clutch C comprises two shafts 21, 22 rotatably mounted in suitable bearings on the base 27, shaft 21, for example being shown as journaled in bearings 21' and 21''. The last mentioned shaft fixedly carries two gears, one a spur gear 24 and the other a beveled gear 23, the latter at all times meshing with a beveled gear 20 fixedly mounted on shaft 19. The gear 24 meshes with a corresponding gear 25 fixed on shaft 22. The shafts 21 and 22 fixedly carry, respectively, friction wheels 28 and 29 normally out of engagement with but each adapted to be engaged by a large friction wheel 30 fixedly mounted on a shaft 33 (see Fig. 2). The last mentioned shaft is shown as journaled at one end in bracket 13, and at the other end in a bearing 33' on a frame 35 to be hereinafter more specifically described. The shaft 33 is operatively connected to the sector 36, secured to the bail 14, through suitable gearing shown as a pinion 38 and a gear 37 in order that a torque may be transmitted to said bail (see Fig. 1). As has been previously stated the

shaft 33 is journaled at one end in a frame 35 which frame is secured to the armature 34 shown in the shape of an inverted T (see Fig. 2) and pivoted at 36. By shifting the armature to one side or the other the frame 35 is correspondingly shifted and the wheel 30 will be thrown into engagement with one or the other of wheels 28 or 29. The armature is biased to neutral position by means such as stationary leaf springs 39 engaging the upper end thereof and the armature is adapted to be moved to either side of neutral or central position by means of electro-magnets 37 and 38. The armature 34 is provided with an enlarged portion 31 centrally apertured at 32 to clear the shaft 33. The clutch member C' is constructed, as has been mentioned, in a manner similar to clutch C but is adapted to transmit power to the sector 40 secured to ring 1.

The operation and electrical connections of my invention may best be understood by reference to Figs. 1 and 4. Let it be assumed that the gyro wheel 8 is rotating in a counter clockwise direction, looking downward on shaft 9; that shaft 19 is rotating in the direction of the arrow shown in Fig. 4 and that a force is applied which tends to rotate the top of gyro 9 down into the page as viewed in Fig. 1. This force will cause the gyro G' to precess toward the left (Fig. 1) and electrical contact will be established between contacts 11 and 12 thus energizing magnets 37, 37 through the following circuit (see Fig. 4). From source G through conductor 41, conductor 42, contacts 12 and 11, conductor 43, magnets 37, conductors 44 and 45, back to the source. The magnets 37, 37 thus energized attract armature 34 thereby throwing wheel 30 into operative engagement with wheel 29, thus causing the latter to be rotated by the shaft 19 and to transmit power through the gears 38', 37' to apply a torque on the bail 14 tending to rotate the bottom of the bail down into the page as viewed in Fig. 1. This torque it will be noticed is in opposition to the force first mentioned and will cause the gyro G' to precess back. Similarly a force applied in such a manner as to cause precession of the gyro G' to the right (Fig. 1) would cause the magnets 38 to be energized to operate the clutch so as to cause a torque to be applied to the bail the reverse of that described in the first case assumed. Similarly if a force tending to produce a torque about the longitudinal axis is applied, precession of the gyro G^2 results which closes contacts 10^a , 12^a or 11^a , 12^a to energize one or the other of the sets of electro-magnets of the clutch C' to cause a torque to be applied through the sector 40 to the ring 1 to oppose the externally applied force. It should be noted that each gyro is in effect stabilized by the other

about the axis it does not stabilize about, *i. e.*, about the axis on which its contacts are mounted.

As has been pointed out the gyros G' and G^2 may be made pendulous about their precessional axes to constitute a centralizing means but no decentralizer is necessary as the decentralizing function may be performed by delivering sharp blows by the force applying means which are properly adjusted with respect to the inertia of the gyros. Thus, assume that an external force is applied which tends to rotate the top of gyro G' (in Fig. 1) down into the page, as previously described. This causes gyro G' to precess to the left and as this would throw the center of gravity of G' to the right of the axis of precession there would be a torque due to the force of gravity tending to rotate the top of the gyro G' to the right which would cause a precession in the same direction as the external force. To overcome this last mentioned effect the force delivered by the force applying means is exerted as a sharp blow or series of blows which act quickly and before the reaction due to precession can become effective.

The contacts 47 and 48 mounted on ring 1 and cooperating with fixed contact 46, mounted on one of the brackets 3, together with contacts 50 and 51 mounted on bail 15 and cooperating with fixed contact 49, mounted on one of the brackets 13, may be used to control vehicle stabilizing or other apparatus.

Referring to Figs. 5 and 6 it will be seen that the structure is similar to that shown in Figs. 1 to 4 with the exception that the type of force applying means shown in Figs. 1 to 4 is modified and certain other mechanism added. Instead of applying directly to the system a positive torque by mechanical means, I make use of the force of gravity to apply such a torque by shifting the relative positions of the center of gravity of the system and the points of support. To accomplish this end the ring 1' is shiftably connected to its pivot as by means of the following structure. A part of the ring 1' is broken away (see Fig. 6) and brackets 60, 60 suitably secured to the ends of said ring. The yoke 67 connects brackets 60, 60 and is pivotally secured to a hanger 62 at 68, said hanger 62 being freely oscillatable about pivot 61 by virtue of a suitable bearing such as a ball bearing 69. A rod 70 is slidably mounted at one end in one of the brackets 60 and is pivotally secured at its other end at 63 to the hanger 62. The rod 70 has a reduced portion 64 on which a spring 65 is loosely mounted, said spring abutting at one end against the enlarged portion of the rod and at the other end against a washer 66 loosely surrounding the rod. The rod 71 is mounted similarly in all respects to the

rod 70 and is provided with a spring 72 similar to spring 65. The springs 65 and 72 acting through the mechanism just described serve normally to centralize the ring 1' with reference to pivot 61. Electromagnets 73, 74 are mounted on brackets 60, 60, each of which electromagnets is adapted to exert a pull on the hanger 62 which is of magnetizable material. The function of the above described mechanism connecting the ring 1' and pivot 61 is to shift the center of gravity of the system with reference to the pivot 61. Thus if magnet 74 is energized a pull is exerted between hanger 62 and this magnet which will shift the ring 1' and the center of gravity of the system to the left of pivot 61 as viewed in Figs. 5 and 6. The inner ring (not shown) is pivoted to the outer ring 1' by means of a pivot 76 and mechanism 75 similar in all respects to that between pivot 61 and ring 1'. The gyro G' is provided with contacts 10', 11' and 12' similar in all respects to the contacts 10, 11 and 12 of the gyro G' in Fig. 1, and the gyro G^2 is provided with a similar set of contacts K. The contact mechanism K of gyro G^2 controls circuits such as those shown in Fig. 6, to energize one or the other of magnets 73 or 74 by means of battery B, depending on the direction in which gyro G^2 precesses. Similarly the magnets of the apparatus 75 are controlled by contacts 10', 11' and 12' of gyro G' .

While the gyros may be made pendulous as set forth in connection with Fig. 1, in order to constitute centralizing means, it is obvious that springs similar to the spring S in Fig. 5 may be used instead or as a supplemental centralizing means. Spring S is shown as secured to the bracket 7' at one end and at the other to the rotor bearing frame. This spring is normally under tension so that it centralizes or aids in centralizing the gyro. By using springs as described the effect of accelerating pressures within the gyro frames may be reduced either in whole or in part.

The operation of the form of my invention illustrated in Figs. 5 and 6 is as follows: Assuming that a force is applied to the system which produces a torque tending to rotate the top of the gyro G' down into the page as viewed in Fig. 5, the said gyro G' will precess toward the left causing contact 11' to engage contact 12' to energize the rear magnet of apparatus 75 (as viewed in Fig. 5). Energization of the last mentioned magnet will cause the center of gravity of the system to be shifted to a point in front of the axis 76 thus causing the force of gravity to set up a torque opposing that produced by the first mentioned force which will cause the gyro G' to precess back toward the right. The action for a force applied in the other direction or forces applied in a vertical

plane at right angles to that of the first assumed force is similar to that above described and need not be described in detail.

A slightly modified means for shifting the center of gravity of the system is illustrated in Fig. 7. The inner ring 21 carries a suitable support shown as a base plate 93 on which two electromagnets are mounted and on which a lever 82 is pivoted as at 83. The lever 82 is provided with a suitable centralizing means shown as a pair of rods 85, 87, pivoted at 89 and 90 respectively to the lever 82, slidably mounted in lugs 91 and 92 on the base plate 93 and each bearing a spring 86, 88 loosely mounted thereon. Each spring abuts at one end of the lever 82 and at the other a corresponding lug 91 or 92. The end of the lever 82 adjacent the magnets 80, 81 is of magnetizable material while the other end thereof is weighted as at 84. Obviously by energizing the magnet 81 the weight 84 and consequently the center of gravity of the system is shifted to the left and by energizing magnet 80 the center of gravity of the system is shifted to the right. It is to be understood, of course, that the ring 1 could be provided with similar means.

Figs. 8 and 9 illustrate another arrangement, differing somewhat from those above described, for controlling contacts of the force impressing or applying system by means of the relative precession of two interconnected gyros with respect to each other. No force impressing system is illustrated in these figures but it is obvious that any one of those illustrated in the preceding figures may be used.

In the form shown in Fig. 1, the gyroscopes may be entirely independent, except for the fact that they are mounted on a common support (ring 2) with only two degrees of freedom and with their axes of precession at right angles to each other. According to Figs. 8 and 9, however, the two gyroscopes are mounted in ring 155 with three degrees of freedom, but are interconnected about both axes of oscillation so as to oscillate or precess only in opposite directions. The force applying means is brought into operation by this relative precession of the gyroscopes about one or the other precession axis. In the main form of the invention, this action also occurs, since each gyroscope is rigidly connected to ring 2 about the axis of precession of the other gyroscope, so that each precessional movement is not only a movement with respect to the support but also with respect to the other gyroscope.

The form shown in Figs. 8 and 9 may be constructed as follows: The frames 145 and 147 corresponding to the outer and inner Cardan rings of the preceding forms, are shown mounted in supporting brackets 100, 100 and the gyros 149 and 150, correspond-

ing to gyros G' and G'' are coupled together so as to have equal and opposite precession upon two axes at right angles to each other. The gyros 149 and 150 comprise rotors spinning about normally vertical axes and in opposite directions and are mounted for precession about horizontal axes by means of bearings 151 and 152 in rings 153 and 154 respectively. The last mentioned rings are mounted for pivotal movement with respect to frame 147 by means of suitable bearings shown at 155 and 156. The means for coupling the gyros for equal and opposite precession may take the form of gearing 157, 158, 160, 161, 162, 163, 164 and 165. The intermeshing segmental racks 157 and 158 are fixed to rings 153 and 154 respectively. The beveled gears 160 and 161 are secured respectively to the gyros 149 and 150 to rotate therewith and mesh respectively with beveled gears 162 and 163 carrying intermeshing segmental racks 164 and 165. One way of utilizing the relative precession of the gyros about their axes which are in alinement to control the force impressor is by means of contacts 170, 171, 172 and 173. Contacts 170 and 171 are mounted on a strip 175 of insulating material and are insulated from each other at 176. The strip 175 is fixedly mounted on the rack 164. Contacts 172 and 173 are similarly mounted on a strip of insulation 177 slidably connected to rack 165 as by means of pin and slot connections 178. Suitable means, such as a spring 179 abutting at one end the strip 177 and at the other a lug 180 on the rack 165, are provided to insure a firm engagement between contacts 170 and 172 or 171 and 173. Similar contacts 181 and 182 etc. are provided on gears 157 and 158 for utilizing the relative precession of the gyros with respect to each other about the parallel precessional axes. If the precession of the gyros is such as to cause the rack 164 to rotate in a clockwise direction contacts 170 and 172 will be brought into engagement and if rack 164 rotates counterclockwise contacts 171 and 173 are brought into engagement. Contacts 181, 182, etc., operate in a similar manner.

In addition to the advantages possessed by the other forms the form of invention illustrated in Figs. 8 and 9 possesses the following advantages. Any external force applied to the system is resisted at all times by the reaction of both gyros. Furthermore any acceleration pressure acting directly on the pendulous mass of each gyro is neutralized by virtue of the coupling of the gyros.

Each of the gyros 149 and 150 may be made slightly pendulous to constitute a centralizing means or instead of this arrangement or supplemental thereto cen-

tralizing springs may be used. Such springs may take the form of the spring illustrated as S' in Fig. 8. The spring S' is connected at opposite ends to racks 157 and 158 and is normally in tension. Obviously a similar spring could be provided for racks 164, 165.

Attention is called to the fact that in all forms of my invention the spinning axes of the gyros are normally vertical and this arrangement will be found particularly advantageous in that the gyros can be made pendulous about the precessional axis for a purpose already pointed out and further there will be no precession of the gyros due to torques about the vertical axis.

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 be 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 combinations and relations described, some of these may be altered, others omitted and the features of certain of the modifications utilized in others without interfering with the more general results outlined, and the invention extends to such use.

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

1. Means for stabilizing a plane on a freely movable body, comprising a support fixed on said body, two gyroscopes mounted on said support for free and concerted oscillation about one or more axes, and precessional movement about axes parallel to said first mentioned axes, means to limit said precessional movement comprising a force applying means adapted to cause a torque to be exerted about one of the first mentioned axes and controlling means for said means adapted to be actuated by precessional movement of a gyroscope.

2. 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 free and concerted oscillation about one or more axes, said system comprising two wheels oppositely rotating about axes at right angles to the plane of said first mentioned axes, means to limit the precessional movement of said gyroscopes comprising a force applying means adapted to cause a torque to be exerted about one of said first mentioned axes and controlling means for said force applying means adapted to be actuated by precessional movement of a gyroscope.

3. In a gyroscopic apparatus, a pivoted support, which, together with the mecha-

nism it supports, is pendulous, a rotor normally spinning about a vertical axis, a rotor bearing frame pivotally mounted on said support and means responsive to the exertion of a pressure on the main support for eliminating the effect of such pressure.

4. In a gyroscopic apparatus, a universally mounted pendulous support, a gyroscope mounted on said support so as to stabilize it about at least one horizontal axis, a second gyroscope mounted on said support so as to stabilize it about a second horizontal axis, the spinning axes of said gyroscopes being normally vertical and means responsive to precession of one of said gyroscopes for causing a torque to be exerted about its above mentioned axis of stabilization.

5. Means for stabilizing a plane on a freely movable body, comprising a support fixed on said body, two gyroscopes mounted on said support for free and concerted oscillation about one or more axes, and precessional movement about horizontal axes, means to limit said precessional movement comprising a force applying means adapted to cause a torque to be exerted about one of the first mentioned axes and controlling means for said means adapted to be actuated by precessional movement of a gyroscope.

6. In a gyroscopic apparatus, a universally mounted pendulous support, a gyroscope mounted on said support for precession about a horizontal axis so as to stabilize it about the other horizontal axis, means responsive to precession of said gyroscope for causing a torque to be exerted about said other axis and means for stabilizing said support about the first named axis.

7. In a gyroscopic apparatus, a universally mounted pendulous support, a gyroscope mounted on said support for precession about a horizontal axis so as to stabilize it about the other horizontal axis, means responsive to precession of said gyroscope for causing a torque to be exerted about said other axis and means for stabilizing said gyroscope about an axis at an angle to said axis of stabilization.

8. Means for stabilizing a pendulum, including a pair of gyroscopes, a contact carried by one of said gyroscopes, a cooperating contact carried by the other of said gyroscopes and torque applying means controlled by said contacts.

9. In combination, a pendulum comprising a plurality of gyroscopes having normally vertical spinning axes and means controlled by relative precession of said gyroscopes for applying a torque on said pendulum.

10. In combination, a pendulum comprising a plurality of gyroscopes at least one of which has its spinning axis normally ver-

tical and means controlled by relative precession of said gyroscopes for applying a torque on said pendulum.

11. In combination, a pendulum comprising a plurality of gyroscopes at least one of which has its spinning axis normally vertical and means called into action on relative precession of said gyroscopes for causing precession of said gyroscopes.

12. In combination, a pendulum comprising a plurality of gyroscopes at least one of which has its spinning axis normally vertical and means called into action on precession of one of said gyroscopes for causing precession of another of said gyroscopes.

13. In a gyroscopic apparatus, a universally mounted pendulous support, a gyroscope mounted on said support so as to sta-

bilize it about at least one horizontal axis, a second gyroscope mounted on said support so as to stabilize it about a second horizontal axis, the spinning axes of said gyroscopes being normally vertical and means including a motor and responsive to precession of one of said gyroscopes for causing a torque to be exerted about its above mentioned axis of stabilization.

14. In combination, a pendulum comprising a gyroscope and means controlled by movement of said gyroscope for applying a torque on said pendulum about either of two axes.

In testimony whereof I have affixed my signature.

HARRY L. TANNER.