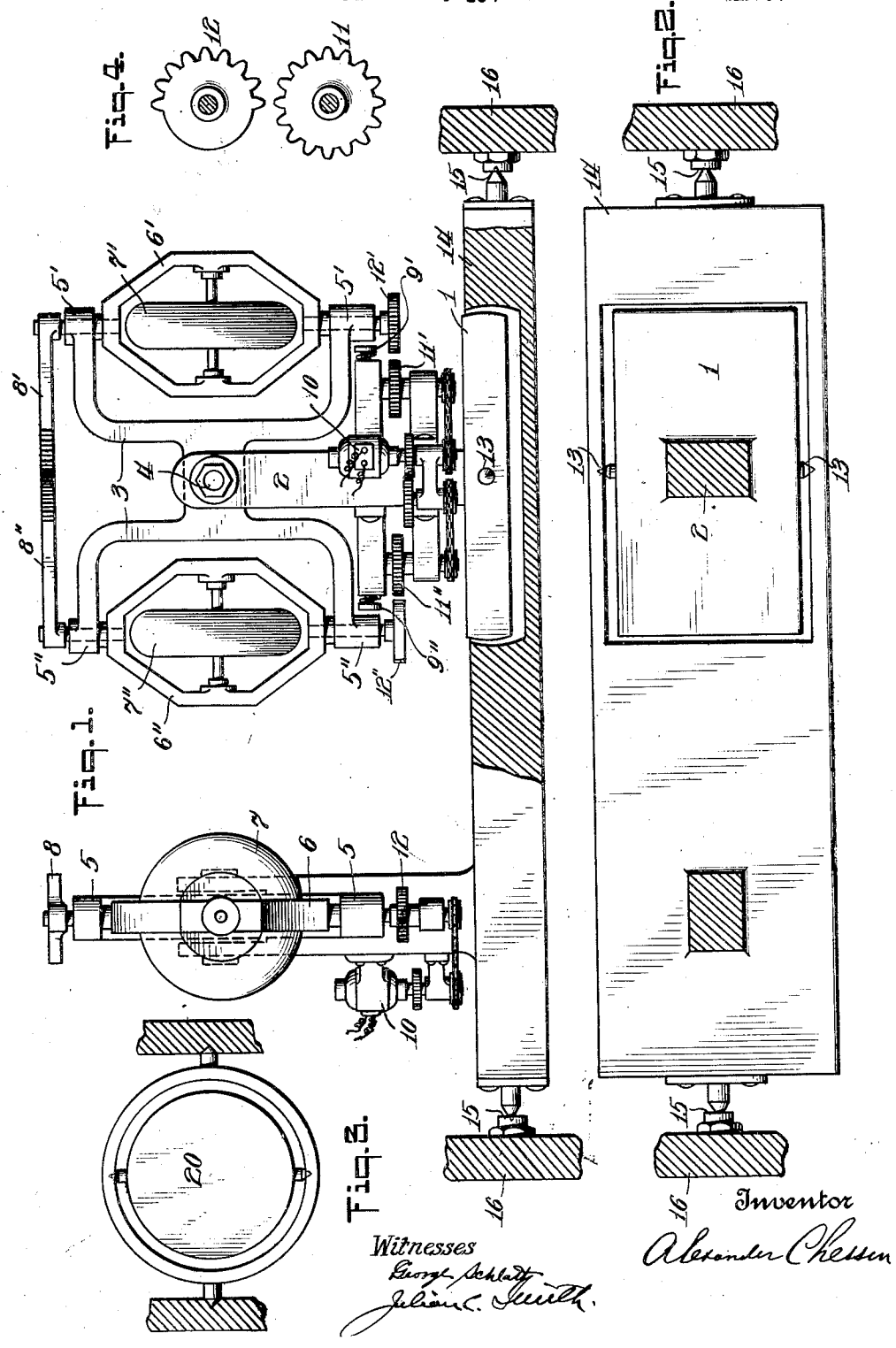
Aug. 4, 1925. 1,548,442

A. CHESSIN

GYROSCOPIC STABILIZER

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A. CHESSIN

GYROSCOPIC STABILIZER

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Fig. 5.

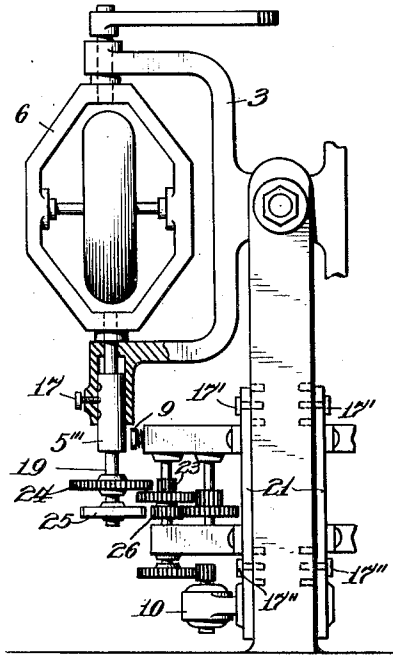


Fig. 9.

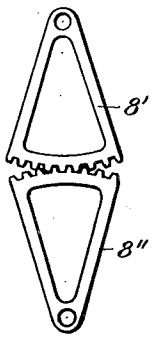
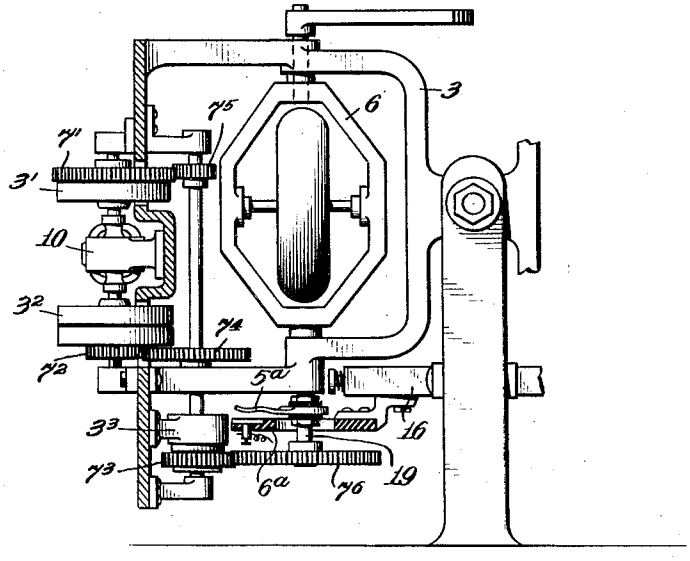


Fig. 6.



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Fig. 8.

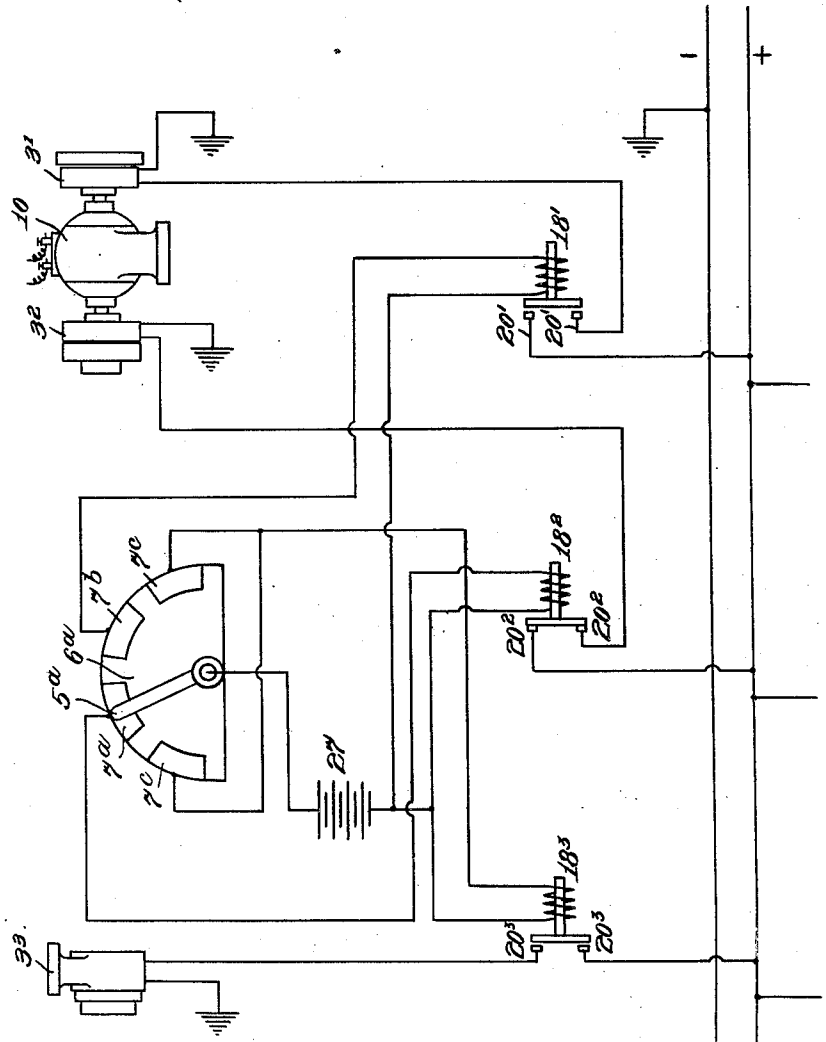
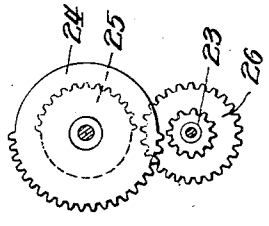


Fig. 7.



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UNITED STATES PATENT OFFICE.

ALEXANDER CHESSIN, OF NEW YORK, N. Y.

GYROSCOPIC STABILIZER.

Application filed July 13, 1920. Serial No. 395,865.

To all whom it may concern:

Be it known that I, ALEXANDER CHESSIN, a citizen of Russia, and resident of New York, in the county and State of New York, have invented certain new and useful Improvements in Gyroscopic Stabilizers, of which the following is a specification.

My invention relates to gyroscopic devices for stabilizing bodies which are by nature subject to angular deviations from a normal position.

The invention, although generally and broadly applicable to various apparatus, is designed especially to stabilize bodies carried by ships navigating in air or water, and for the stabilization of sea and air craft, monorail cars and vehicles which are either unstable or subject to oscillations.

In particular, the invention is an improvement on the devices described in my U. S. Patent #1,134,439, and in my application for Patent, Serial #146,321, one of the novel and important features being means for establishing a definite and controllable relation between what I call the "primary" and the "secondary" effects of the gyroscopic stabilizer. As these terms are used in the following specifications and claims, they will here be first defined and explained.

When the body which is to be stabilized swerves to one side from its normal position, the gyroscope functions in such a way as to throw the body back towards the normal position. This stabilizing primary effort generally causes the body to swing beyond the normal position, in an opposite direction, and it becomes necessary to give the body a secondary impulse, in direction opposite to the primary, to bring the body back towards the normal position. This secondary impulse must be less than the primary in magnitude, i. e., the consecutive stabilizing impulses must be damped, otherwise the body would be made to oscillate continually back and forth, with possibly increasing amplitudes, instead of righting itself to its normal position.

In defining the primary precession, or the primary stabilizing force, therefore, it is to be understood that they refer to the direct action of the gyroscope in response to an initial tendency of the body to deviate from its normal position, while the secondary precession, or the secondary stabilizing force, refer to the return of the swinging body towards its normal position from one beyond it, in response to the primary action of the gyroscope. Of course, it is conceivable that during the period of a secondary precession the body may receive a new impulse of a primary nature, but this would in no way affect the correlation of precessions or forces, as herein described, each primary impulse being followed by a corresponding secondary effect, the combined result still being to damp the successive stabilizing impulses.

Looking at it from another angle, it may be said that the primary precession and the primary stabilizing force are in direct response to an external cause, whereas the secondary precession and the secondary stabilizing force are in response to these primary gyroscopic effects and not directly to the external cause.

In my Patent #1,134,439, and application Ser. #146,321, above referred to, the secondary effect is produced by what I there called "normal" precession, as against a predetermined precession which may be made greater or less than the normal. In my present invention, both the primary and the secondary precessions are subject to control and can be made to meet the requirements of each case so as to get the best and quickest results, which it is not always possible to do when the secondary precession is limited to the normal.

Another novel feature of my present invention is the means for regulating the limits within which the body is allowed to oscillate. By making these limits as close as desired the slightest tendency of the body to deviate from its normal position is automatically and instantaneously checked.

Other novel features will appear from the detailed description of my invention.

Referring to the accompanying drawings,

Figure 1 is a front elevation of my invention applied to the stabilization of a body about two mutually perpendicular, normally horizontal, axes. It comprises two sets of double gyroscopes, each set stabilizing the body about the corresponding normally

horizontal axis. The constructional details of each set are those embodying the principle of operation as disclosed in my U. S. Patent #1,134,439, but the same disposition of the apparatus is used for the improved stabilizing sets shown separately in Figures 5 and 6, and the arrangement of Figure 1 is intended to cover similar arrangements no matter which one of the operating gyroscopic sets is used in the stabilization of the body about two normally horizontal axes.

Figure 2 is a horizontal section of the arrangement shown in Figure 1, taken at the base of the two gyroscopic sets, being also a top view of what might be called the table carrying the gyroscopic sets.

Figure 3 shows another arrangement of this table which in this case is suspended in gimbals in the standard manner, the two gyroscopic sets being attached to the table at 20, on the same, or on opposite, sides of it.

Figure 4 is a detail of the mutilated gears used in the construction of the gyroscopic sets of Figure 1.

Figure 5 is one form of my improved stabilizer, only one half of the set being shown because of the symmetrical construction.

Figure 6 is another form of this improved stabilizer, wherein electro-magnetic clutches are used for producing the various precessional movements, as against the mutilated gears of Figure 5.

Figure 7 is a detail of the mutilated gears used in the apparatus shown in Figure 5.

Figure 8 is a diagram of the electrical connections governing the operations of the apparatus shown in Figure 6.

Figure 9 is a detail showing the toothed sectors connecting the two gyroscopes of each set.

In the following description and claims, specific means are used for identification of parts, but they are intended to be as generic in their application to similar parts as the art will permit.

Referring particularly to Figures 1 and 2, 1 indicates the body or table to be stabilized; 2 is a support carried by the body 1; 3 is a frame mounted on the support 2 for small oscillations about a normally horizontal axis 4; in the frame 3 are mounted two gyroscope frames 6′ and 6″, whose axles are rotatable in the respective bearings 5′ and 5″ of the frame 3; these gyroscope frames are connected by means of the toothed sectors 8′ and 8″ in such a manner that the frames 6′ and 6″ can only rotate simultaneously and in opposite directions; in the frames 6′ and 6″ are pivoted the two gyroscopes 7′ and 7″ which spin in opposite direction. The lower bearings 5′ and 5″ are adapted to engage contact members 9′ and 9″, which are arranged to yield to a limited extent against the tension of springs, as in my device previously referred to and described in the U. S. Patent #1,134,439, where is further shown how these contact members can be adjusted and regulated to control the play between them and the bearings 5′ and 5″; on the support 2 is mounted a motor 10 driving a set of transmission gears and chains in such a way that the two gears 11′ and 11″ rotate with the same speed but in opposite direction; these gears 11′ and 11″ are adapted to engage the mutilated gears 12′ and 12″ which revolve with the axles of the frames 6′ and 6″, Figure 1 showing the toothless portion of the gear 12 and the toothed portion of the gear 12′, the disposition of these gears in relation to the gears 11 being shown in detail in Figure 4.

The body or table 1 is pivoted at 13 in the frame 14, which frame is pivoted at 15 in the body carrying the apparatus, which allows the body 1 freedom of rotation about two normally horizontal axes 13—13 and 15—15 with regard to the body 16. On the frame 14 is mounted a duplicate of the structure carried by the table 1, but disposed at right angles to the first, so that in Figure 1 the left hand structure, as shown, may be considered as a side elevation of the structure shown on the right hand, and vice versa.

The details of Figure 5 differ from those of Figure 1 in the following respects:

Instead of the plain bearing 5 of Figure 1, the frame 3 carries a sleeve or bearing member 5‴ with a guiding movement parallel to the axle of the frame 6 and adjustable in various positions as, for instance, by means of the pin 17 which may be dropped in one of the several holes arranged for the purpose. The axle 19 of the frame 6 in this case is made so as to allow extension or contraction in length, any one of the known methods being used for this purpose. The yielding contact member 9, together with the motor and transmission gears, is movable on the support 2, parallel to the movement of the sleeve 5‴, and adjustable to correspond to that movement by means of the pins 17′ and 17″, which may be dropped in corresponding holes.

Another difference between Figures 1 and 5 is in the gearing arrangement. The axle 19 now carries two mutilated gears 24 and 25, the toothed portions and the toothless portions being on opposite sides of the two gears, as is clearly shown in detail in Figure 7. These mutilated gears are adapted to engage the gears 23 and 26, which form a part of the transmission system driven by the motor 10.

Figure 6 shows another construction embodying the invention shown in Figure 5, this other construction utilizing electro-

magnetic clutches in lieu of mutilated gears, and bearing the same relation to the apparatus shown in Figure 5 as my pending application Ser. #146,321 bears to my Patent #1,134,439. In this type of apparatus the frame 3 carries three electro-magnetic clutches 3^1, 3^2, and 3^3. When energized, these clutches act respectively to drive the gears 7^1, 7^2, or to lock the gear 7^3. According as the clutch 3^1 or 3^2 is energized, the gear train 7^1—7^5—7^3—7^6 or the gear train 7^2—7^4—7^3—7^6 become operative, the gear 7^6 being mounted on the axle 19 of the gyroscope bearing frame 6 which turns with the gear 7^6. On the same axle 19 is mounted a member 5^a electrically insulated from it and adapted to form an electrical contact with a member 6^a carried by the support 16 and bearing four conductive plates 7^c, 7^a, 7^b, 7^c, insulated from the member 6^a and from one another.

Figure 8 is a diagram of electrical connections in the operation of the device shown in Figure 6, namely: when the member 5^a makes contact with the plate 7^a, as illustrated in Figure 8, the circuit 5^a—7^a, including the battery 27, is closed, energizing the electro-magnet 18^2, whereby contact is made at 20^2, the latter contact closing the circuit of the main line (+, −) with the clutch 3^2, energizing this clutch. Likewise, when the member 5^a is in contact with the plate 7^b, the circuit 5^a—7^b, through the battery 27, will energize the electro-magnet 18^1 and close the circuit of the main line with the clutch 3^1; finally, when the member 5^a is in contact with the plate 7^c, the closing of the circuit through the battery 27 will energize the electro-magnet 18^3 and close the circuit of the main line with the stop-clutch or brake 3^3.

It should be observed that the motor 10, in any one of the types of apparatus here shown, may be a variable speed motor, so that a variety of precessional speeds may be obtained without necessarily changing the relative dimensions of the gears used in the transmission systems.

In order not to complicate the drawings, no means are shown on my preferred type, namely the type illustrated in Figure 6, for adjusting the distance from the center of each gyroscope to the corresponding points of contact between members carried by the support and the co-operating members carried by the oscillating structure, since it is clear that the means shown on Figure 5 are equally applicable to the type shown in Figure 6, and it is to be understood that such means are not restricted to any particular type of my invention.

The operation of the apparatus will now be briefly explained.

First of all, let it be understood that if the structure which is to be stabilized is attached to a stationary body, or a vehicle moving in a straight line, the "normal" position of the structure is its position of stable, or unstable, equilibrium, as the case may be, under the action of the force of gravity. If the structure is attached to a vehicle moving along a curve, then the "normal" position of the structure is its position of equilibrium under the combined action of gravity and centrifugal forces.

Considering the operation of the type of my invention as illustrated in Figure 5, stabilization being desired about a normally horizontal axis, let the body start to swing transversely to this axis. Immediately the mutilated gear 25 on one side of the support will mesh into the driving gear 26, the impact being taken up by the simultaneous engagement of the members $5'''$ and 9. The gear 26, which is being driven at a predetermined speed by the motor 10, now transmits this rotation to the frame 6 and its companion frame with which it is coupled. Thus, a predetermined precession of the pair of gyroscopes is produced, and the combined action of the pair is to exert a force which acts contrary to the swinging tendency of the body. Generally, the body will not be immediately righted thereby, but will be thrown beyond its normal position unto the other side. When this occurs, immediately the mutilated gear 24 and the driving gear 23, on the other side of the support, mesh, the effect being to again produce precession of the pair of gyroscopes, but in reverse direction and, moreover, in a reduced ratio, so that the force now exerted by the gyroscopes on the body merely counteracts the excessive effect of the first force, thereby righting the body.

The precessional speed being under perfect control, both for the original and the return swings, the device permits of such regulation as to secure, automatically, the return of the gyroscopes to their original position when the body assumes its normal position, since this condition is fulfilled by equalizing the precessional swings of the gyroscopes corresponding to the direct and the return swings of the body.

The sensitiveness of the apparatus is regulated by adjusting the distance from the center of each gyroscope to the corresponding contact points between the mutilated and the driving gears, thus making the permissible angle of deviation of the body as small as desired. Furthermore, the combined regulation of this angle and of the precessional speed furnishes means for complete control of the time element in the stabilization of the body, both in regard to the precessional period and in regard to the starting moment and duration of engagement of the various co-operating members.

Considering now my preferred form illus-

trated on Figure 6, as the body starts to swing transversely to the axis of stabilization, the brush 5^a makes contact with the plate 7^b, the clutch 3^1 is energized and the driving force of the motor 10 is transmitted through the gear-train 7^1—7^5—7^3—7^6 to the pair of coupled frames 6. Thus, a predetermined precession of the pair of gyroscopes is produced and the effect is similar to that of the preceding type. As soon as the body is thrown to the opposite side of the support, the brush 5^a and the plate 7^a, on this other side of the support, make contact and now, through the energized clutch 3^2 and gear-train 7^2—7^4—7^3—7^6, another precession of predetermined speed is produced, smaller than the first precession, the effect of which is to correct the tendency of the body to swing beyond its normal position, as in the case of the type illustrated in Figure 5, explained above. The preferred form shows the additional provision for stopping the precessional frames and locking them when they turn beyond a certain angle from their normal position. When the precession exceeds this predetermined angle, the brush 5^a makes contact with the plate 7^c, and this, as already explained, brings into operation the brake or lock mechanism comprising the magnetic brake 3^3, acting through the gear 7^6 to lock the gyroscope bearing frames. The object of this provision is to meet emergency cases when the deviations of the body exceed ordinary limits. In such cases, sometimes, it is desirable to lock the mechanism rather than attempt to right the body. While no such mechanism is shown here in connection with the other forms of my invention, it is to be understood that the device shown in Figure 6, or any other form of it as may be appropriate to the type in view, may be used in connection with it.

From the explanation just given of the operation of the invention when stabilization is to be effected about one axis, it is clear how the invention works when stabilization about two axes is desired. The modus operandi is exactly the same with regard to each axis of stabilization. For instance, as illustrated in Figures 1 and 2, the frame 14 is stabilized by the gyroscopic unit on the left hand side, about the axis 15—15. The other gyroscopic unit, on the right hand side, serves to stabilize the table 1 about the axis 13—13, the two units combined acting to stabilize this table about both axes, or in the horizontal plane. As already stated, both units can be attached to the table, as in Figure 3, the table 20 itself being on gimbals, which also accomplishes stabilization in a plane, or about two perpendicular axes. Furthermore, the two units may be placed above, or below the table, or one may be above and the other below. According as this disposition of the apparatus brings the center of gravity of the body to be stabilized above or below the axes of stabilization, the body will be in a position of unstable or of stable equilibrium when it is in its "normal" position.

For a sensitive stabilizer a modified type of the form shown in Figure 5 may be preferable, using friction rollers in lieu of the gears, especially for the mutilated gears and the driving gears which are shown here to engage these mutilated gears when the body deviates from its normal position. It did not seem necessary to show such a modification in a separate drawing, the above statement being deemed sufficient for the purpose.

In general, while I have shown and described, and have pointed out in the annexed claims, certain novel features of my invention, it will be understood that various omissions, substitutions and changes in the form and details of the device as illustrated and in its operation may be made by those skilled in the art without departing from the spirit of the invention.

Having fully described my invention, I claim:

1. In a stabilizing apparatus, a gyroscope, and means for producing precession of different speed, according as said precession is from, or toward, the normal position of said gyroscope, both said speeds being capable of predetermined changes.

2. In a stabilizing apparatus, a gyroscope, and means for producing precession of predetermined speed, said predetermined speed being greater, or less, according as said precession is from, or toward, the normal position of said gyroscope.

3. In a stabilizing apparatus, a gyroscope, means for producing precession of predetermined speed, said predetermined speed being subject to change, according as said precession is from, or toward, the normal position of said gyroscope, and means for automatically controlling said change.

4. In a body subject to oscillation, a stabilizing gyroscope therefor, power means for producing precession of said gyroscope, and means, responsive to said precession, for exerting damped torques on said body, the damping coefficient of said damped torques being capable of regulation.

5. The combination with a gyroscope, of means for rotating said gyroscope about its precession axis at a uniform but different speed, according as the gyroscope is rotated away from, or toward, its neutral position.

6. The combination with a pair of gyroscopes spinning in opposite direction and coupled for opposite precession, of means for rotating said gyroscopes about their precession axes at a uniform but different speed, according as the gyroscopes are rotated away from, or toward their neutral positions.

7. The combination with a gyroscope, of means for imparting rotation to said gyroscope about an axis other than its axis of spin at a uniform speed, said speed being greater, or less, according as said rotation is from, or toward, the neutral position of said gyroscope.

8. In a stabilizing apparatus, the combination with a gyroscope, of means, brought into action by precession of said gyroscope, for exerting different stabilizing forces, according as said precession is from, or toward, the normal position of said gyroscope, said different stabilizing forces having a predetermined relation.

9. In a body subject to oscillation, a stabilizing gyroscope therefor, means for producing precession of different speed according as said precession is from, or toward, the normal position of the gyroscope, both said speeds being capable of regulation, and means, responsive to said precession, for exerting damped torques on said body, the coefficient of damping of said damped torques being capable of variation responsive to said regulation of said precessional speeds.

10. In an apparatus for stabilizing a body, the combination with a structure comprising a pair of gyroscopes possessing three degrees of rotational freedom relatively to the said body said gyroscopes spinning in opposite direction and being coupled for opposite precession, of driven members carried by said structure, driving members normally out of engagement with the said driven members, and means for establishing a driving connection between said driving and said driven members.

11. In a body capable of angular deviations, a pair of gyroscopes spinning in opposite direction and coupled for opposite precession, means for automatically producing precession of different speed, according as the gyroscopes precess away from, or toward, their normal position, and means for controlling said speed.

12. The combination with a gyroscope, of means for imparting rotation to said gyroscope about an axis other than its axis of spin at uniform but different speed, according as said rotation is away from, or toward, the neutral position of said gyroscope, said different speeds having a predetermined relation.

13. In a body subject to angular deviations, the combination with a gyroscope, of means, controlled by said angular deviations, for causing said gyroscope to precess, means for locking the gyroscope against precession when the gyroscope precesses away from its normal position, and means for automatically unlocking the gyroscope as the direction of said angular deviations of the body is reversed and causing the gyroscope to precess back to its normal position at reduced speed.

14. In a body subject to angular deviations, the combination with one or more gyroscopes possessing three degrees of rotational freedom relatively to the said body, of means, brought into action by precession of said gyroscopes, for exerting a stabilizing effect on the body as it tends to deviate from its normal position and as the tendency of the body to deviate from its normal position is reversed, and means for automatically controlling said stabilizing effect.

15. In a body subject to angular deviations, the combination with one or more gyroscopes, of means brought into action by precession of said gyroscopes for exerting a force opposing the tendency of the body to deviate from its normal position and a force opposing the tendency of the body to pass its normal position in response to the first force, said forces having a predetermined relation.

16. In a body subject to angular deviations, the combination with a gyroscope, of means, controlled by said angular deviations, for causing said gyroscope to precess, means for automatically locking the gyroscope when the gyroscope precesses away from its normal position beyond a pretermined limit, and means, automatically responsive to said angular deviations of the body, for unlocking the gyroscope.

17. In a body subject to angular deviations, one or more gyroscopes, means responsive to external causes for producing precession of said gyroscopes, and means responsive to the effect of said precession for producing another precession, the two said precessions having a predetermined relation.

18. In a body subject to angular deviations, a pair of gyroscopes spinning in opposite direction and coupled for opposite precession, means for locking said gyroscopes against precession in response to an excessive angular deviation of the body, and means for automatically unlocking the gyroscopes as the direction of said excessive angular deviation is reversed.

19. In a body subject to angular deviations, the combination with a stabilizing gyroscope having a limited rotational freedom, relatively thereto, other than freedom to precess of means for regulating the limit of said limited rotational freedom.

20. In a body subject to angular deviations, a gyroscope, means for producing precession of said gyroscope as the body tends to deviate from its normal position, and means for changing the precessional speed of said gyroscope as the tendency of the body to deviate from its normal position is reversed, said changed precessional speed having a predetermined value.

21. In a body subject to angular deviations, one or more gyroscopes possessing three degrees of rotational freedom relatively to the said body, means for producing precession of predetermined speed as the body tends to deviate from its normal position, and means for producing precession of a different predetermined speed as the body's tendency to deviate from its normal position is reversed.

22. In a body subject to angular deviations, a pair of gyroscopes spinning in opposite direction and coupled for opposite precession, means for imparting precession of predetermined speed to said gyroscopes as the body tends to deviate from its normal position, and means for counteracting the excessive effect the said precession.

23. In a body subject to angular deviations, one or more gyroscopes possessing three degrees of rotational freedom relatively to said body, means for producing precession of said gyroscopes as the body tends to deviate from its normal position, and precession of different speed as the tendency of the body to deviate from its normal position is reversed, and means for controlling the precession in either case.

24. In a body to be stabilized, the combination with a structure comprising one or more gyroscopes possessing three degrees of rotational freedom relatively to said body, of driven members carried by said structure, driving members normally out of engagement with said driven members, and electrically controlled means for establishing a driving connection between said driving and said driven members.

25. The combination with a body, of a structure rotatably connected thereto and comprising one or more gyroscopes, means, brought into action by precession of said gyroscopes, for exerting primary and secondary stabilizing forces on said structure the secondary stabilizing force being opposite in effect to, and less than, the corresponding primary stabilizing force, and means for controlling said stabilizing forces.

26. The combination with a body, of a support rotatably connected thereto, a structure mounted on said support for limited oscillation, yielding contact members carried by said support and adapted to engage portions of said structure, a pair of frames journaled in said structure and coupled for opposite rotation, a gyroscope mounted in each frame, driven members rotatable with said frames, driving members adapted to engage said driven members, and means for actuating said driving members.

27. A stabilizing unit comprising a support, a structure mounted on said support for limited oscillation about the axis of stabilization, contact members carried by said support and adapted to engage portions of said structure, a pair of frames journaled in said structure and coupled for opposite rotation, a gyroscope mounted in each frame, the two gyroscopes spinning in opposite directions, driven members rotatable with said frames, driving members adapted to engage said driven members, and means for actuating said driving members.

28. The combination with a body subject to angular deviations about a plurality of axes, of a corresponding number of stabilizing units, each unit as described in the preceding claim, said units being so disposed that each axis of stabilization coincides with, or is parallel to, one of said axes of angular deviations of said body.

29. In a body, a second body universally connected thereto and to be stabilized independently of said first body, a pair of stabilizing units, each pair substantially as described in claim 27, the axes of stabilization of said stabilizing units coinciding with, or being parallel to, the axes of said universal connection.

30. In an apparatus for stabilizing a body and comprising one or more pairs of gyroscopes coupled for opposite precession, a precession producing device comprising normally disengaged members adapted to engage one another as the body deviates from its normal position, and yielding devices for checking the impact at the time of such engagement.

31. In a body subject to angular deviations, one or more pairs of gyroscopes coupled for opposite precession, means for producing precession of predetermined speed as the body tends to deviate from its balanced position, and means independent of said first mentioned means for producing precession as the deviating tendency of the body is reversed.

32. In a body subject to angular deviations, a stabilizing apparatus comprising one or more pairs of gyroscopes, each pair coupled for opposite precession and the gyroscopes of each pair spinning in opposite direction, precession producing means comprising elements carried by the body and elements carried by the said apparatus, and yielding devices for checking the impact between said elements carried by the body and said elements carried by the stabilizing apparatus.

33. In an apparatus for stabilizing a body about an axis, a structure capable of limited oscillation relatively thereto, a pair of frames journaled in said structure at right angles to said axis and coupled for opposite rotation, a gyroscope mounted in each frame, driven members carried by the axles of said frames, driving members adapted to engage said driven members, yielding devices for checking the impact at the time of such engagement, means for regulating the

angle of deviation of the body at which said engagement takes place, and means for adjusting said driving and said driven members and said yielding devices, to conform with said regulation.

34. In a body to be stabilized, an apparatus movably connected thereto and comprising one or more pairs of gyroscopes coupled for opposite precession, moving means, comprising elements carried by the body and elements carried by the apparatus, normally not operatively connected, and means for establishing an operative connection between said elements, to produce precession of said gyroscopes.

35. In a body to be stabilized, the combination with a structure movably connected thereto and comprising a plurality of gyroscopes coupled in pairs for opposite precession, of a precession generating device comprising elements carried by the body and elements carried by said structure, which elements are not operatively connected when the body is in its normal position, means for establishing an operative connection between the said elements as the body tends to deviate from its normal position, and means, controlled by the said precession generating device, for exerting a predetermined stabilizing force on the body.

36. In a body subject to angular deviations, a plurality of gyroscopes adapted to exert stabilizing forces on said body and having one of their degrees of rotational freedom limited, the angle of deviation of said body at which said stabilizing forces are generated being controlled by said limited degree of rotational freedom of said gyroscopes.

37. In a stabilizing apparatus, the combination with one or more pairs of gyroscopes having three degrees of rotational freedom and coupled for opposite precession, of means for producing precession of said gyroscopes, and means for locking the gyroscopes when the precession tends to exceed certain predetermined limits.

38. In a stabilizing apparatus comprising a gyroscope, means for producing primary and secondary precessions, the secondary precession being opposite in direction to, and of less speed than, the primary precession, means for controlling said primary and secondary precessions, and means for locking the gyroscope when said primary precession tends to exceed a predetermined limit.

39. In a body subject to angular deviations, the combination with one or more gyroscopes, of means, subject to relatively small angular deviations of the body, for producing primary and secondary precessions, the secondary precession being opposite in direction to, and of less speed than, the primary precession, and means for locking the gyroscopes against precession when the limit of said angular deviations of the body is exceeded.

40. The combination with a body, of a support rotatably connected thereto, a structure mounted on said support for limited oscillations, a pair of frames journaled in said structure, one on each side of the support, and coupled for opposite rotation, a gyroscope journaled in each frame to spin about an axis perpendicular to the axis of rotation of the frame, precession producing means, comprising a transmission system which is inoperative as long as the body preserves its normal position, elements rotatable with said frames and forming part of said transmission system, and means, automatically controlled by the swinging tendencies of the body, for making said transmission system operative.

41. The combination with a body, of a support movably connected thereto, a structure capable of limited oscillations relatively to said support, a pair of frames journaled in said structure, one on each side of said support, and coupled for opposite rotation, a gyroscope journaled in each frame to spin about an axis perpendicular to the axis of rotation of the frame, multiple circuit closers, one set of elements of which is carried by the support, while the set of co-operating elements is carried by the said structure, precession producing means, comprising a transmission system whose driving members are normally out of engagement with the driven members of the system, driven members rotatable with said frames and forming part of said transmission system, means for actuating said driving members, and means, controlled by the said multiple circuit closers, for effecting engagement between the driving and the driven members of the said transmission system.

42. The combination with a body, of a support universally connected thereto, a structure mounted on said support for limited oscillations, a pair of frames journaled in said structure and coupled for opposite rotation, a gyroscope journaled in each frame to spin about an axis perpendicular to the axis of rotation of the frame, multiple circuit closers, one set of elements of which is carried by the said structure and the other, or co-operating, set carried by the said support, means, controlled by said multiple circuit closers, for producing precession of predetermined speed, and contact members carried by said support and adapted to engage portions of said structure, to produce normal precession of said gyroscopes.

43. In a body subject to angular deviations, the combination with one or more pairs of gyroscopes having three degrees of

rotational freedom and coupled for opposite precession, of means, subject to relatively small angular deviations of the body, for producing precession of said gyroscopes, and means for automatically locking said gyroscopes against further precession when the limit of said angular deviations of the body is exceeded.

44. In a stabilizing apparatus, the combination with a plurality of gyroscopes having three degrees of rotational freedom and coupled in pairs for opposite precession, of means, responsive to external causes, for producing precession of the said gyroscopes, and means for locking the gyroscopes when said external causes exceed a predetermined limit.

45. In a body to be stabilized, the combination with a structure movably connected thereto, of a pair of gyroscopes spinning in opposite directions and mounted in frames which are journaled in the said structure and are coupled for opposite rotation, and means for automatically locking said frames when the precession of said gyroscopes exceeds a predetermined limit.

46. In a stabilizing apparatus, the combination with one or more gyroscopes, of a precession producing device comprising a multiple speed transmission system adapted to give different speeds to the primary and to the secondary precessions.

47. In a body to be stabilized, the combination with a structure movably connected thereto and comprising a pair of gyroscopes coupled for opposite precession, of driven members carried by said structure, means, brought into action by relatively small angular deviation of the body, for applying a driving force to said driven members, to produce precession of said gyroscopes, and means for locking said driven members when the limit of said angular deviations of the body is exceeded.

48. In a stabilizing apparatus comprising one or more pairs of gyroscopes having three degrees of rotational freedom and coupled for opposite precession, means for producing precession of said gyroscopes, and means for neutralizing the gyroscopic effect when the said precession tends to exceed certain limits.

49. In a stabilizing apparatus comprising one or more gyroscopes, means for producing primary and secondary precessions of predetermined speed said predetermined speed being greater in the primary than in the secondary precession, and means for neutralizing the gyroscopic effect when the said primary precession exceeds a predetermined limit.

50. In a stabilizing apparatus, the combination with one or more pairs of gyroscopes coupled for opposite precession, of means, comprising a multiple speed transmission system, for producing precession of said gyroscopes, and means for automatically neutralizing the gyroscopic effect when the said precession tends to exceed certain limits.

51. In a stabilizing apparatus, the combination with a pair of self controlling, force-impressing gyroscopes, spinning in opposite direction and coupled for opposite precession, of means for automatically locking said gyroscopes against precession.

52. In an apparatus for stabilizing a body and comprising one or more pairs of gyroscopes coupled for opposite precession, a multiple speed precession producing device, a system of electro-magnetic clutches for controlling said precession producing device, a precession locking device, magnetic brakes for controlling said precession locking device, a system of circuit closers made operative by the deviations of the body from its normal position, and means, controlled by said circuit closers, for energizing said electro-magnetic clutches and magnetic brakes.

53. In an apparatus for stabilizing a body and comprising one or more gyroscopes, a multiple speed precession producing device, a system of electro-magnetic clutches for controlling said precession producing device, a precession locking device, magnetic brakes for controlling said precession locking device, means, subject to relatively small deviations of the body from its normal position, for energizing said electro-magnetic clutches, and means for energizing said magnetic brakes when the limit of said deviations of the body is exceeded.

54. A stabilizing unit comprising a support rigidly connected to a body which is to be stabilized about an axis, a structure mounted on said support for limited oscillation relatively thereto in a plane perpendicular to said axis of stabilization, said structure being symmetrically disposed relatively to the support in such a manner that the various parts and the direction of motion of the various moving elements are identical for each half of the said structure if observed from opposite sides; each half of said symmetrical structure comprising a frame journaled therein, the axle of said frame bearing a toothed sector meshing into the teeth of the corresponding sector of the other half of the structure, a gyroscope pivoted in the frame to spin about an axis perpendicular to the axis of rotation of the frame, a yielding contact member carried by the support and adapted to engage a portion of the said structure as the body deviates from its normal position, a stationary member carried by the support and adapted to co-operate with a member carried by the structure which co-operating member is rotatable with the gyroscope bearing frame, said stationary member and said co-operat-

ing rotatable member forming elements of a multiple circuit closer, a multiple speed transmission to the axle of the gyroscope bearing frame, driving members carried by said structure and forming part of said multiple speed transmission, a double clutch mechanism, said driving members being controlled by said double clutch mechanism, means for actuating said driving members, a brake mechanism carried by the said structure and adapted to lock the gyroscope bearing frame, and means controlled by the said multiple circuit closer, for energizing one or the other clutch of the said double clutch mechanism, or the said brake mechanism.

55. The combination with a body subject to angular deviations about a plurality of axes, of a corresponding number of stabilizing units, each unit substantially as described in the preceding claim, said units being so disposed that the axis of stabilization of each coincides with, or is parallel to, one of said axes of angular deviations of said body.

56. In a swinging body, a frame mounted thereon for limited movement relatively thereto, a gyroscope mounted on said frame, means, controlled by the relative movement of said body and said frame, for causing said gyroscope to exert torque on said body during periods when the angular deviation of said body from its normal position is within certain limits, and means for rendering said first means inoperative when the angular deviation of said body exceeds said limits.

ALEXANDER CHESSIN.

Witness:
LAMAR LYNDON.