E. A. SPERRY.

CONTROLLING MECHANISM FOR SHIPS' GYROSCOPES.

APPLICATION FILED JAN. 25, 1916.

1,342,397.

Patented June 1, 1920.

3 SHEETS—SHEET 1.

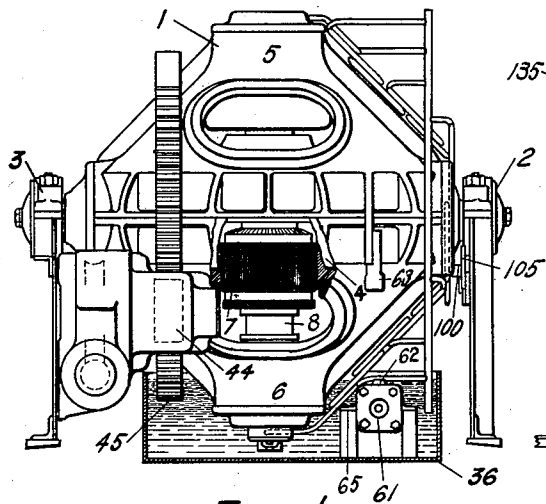

Fig. 1.

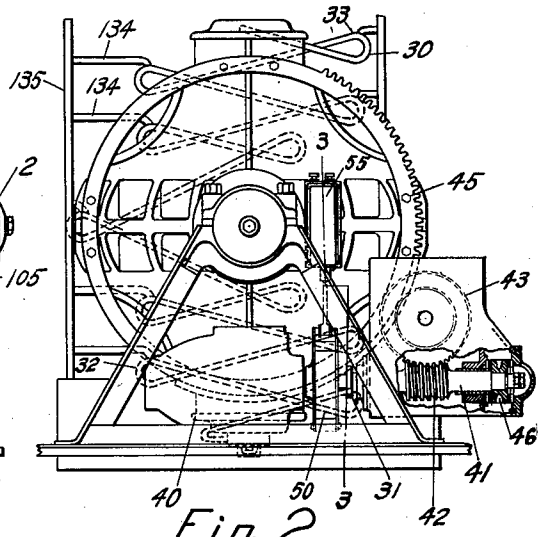

Fig. 2.

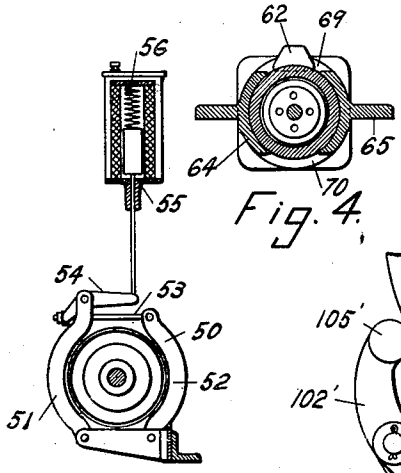

Fig. 4.

Fig. 3.

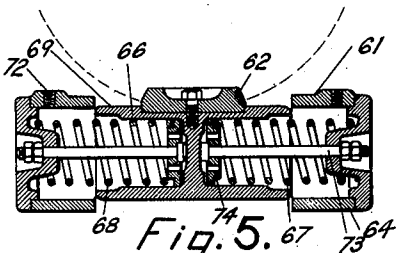

Fig. 5.

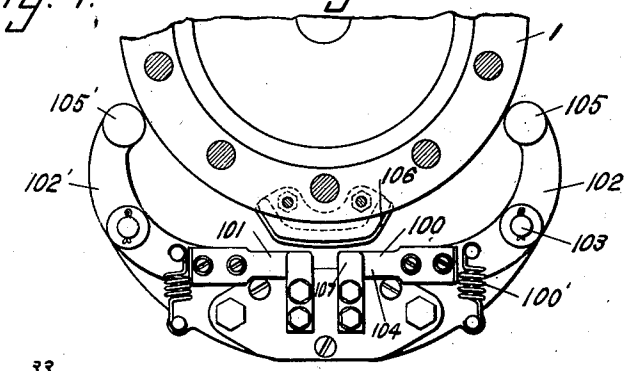

Fig. 6.

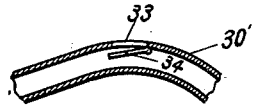

Fig. 13.

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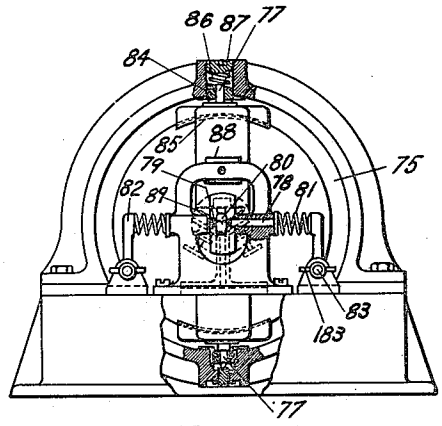

Fig. 7.

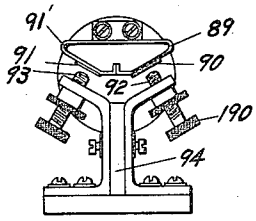

Fig. 8.

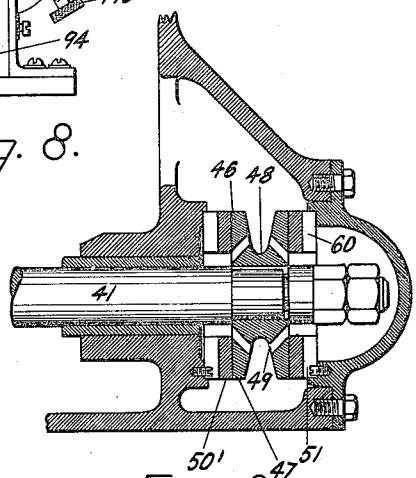

Fig. 9.

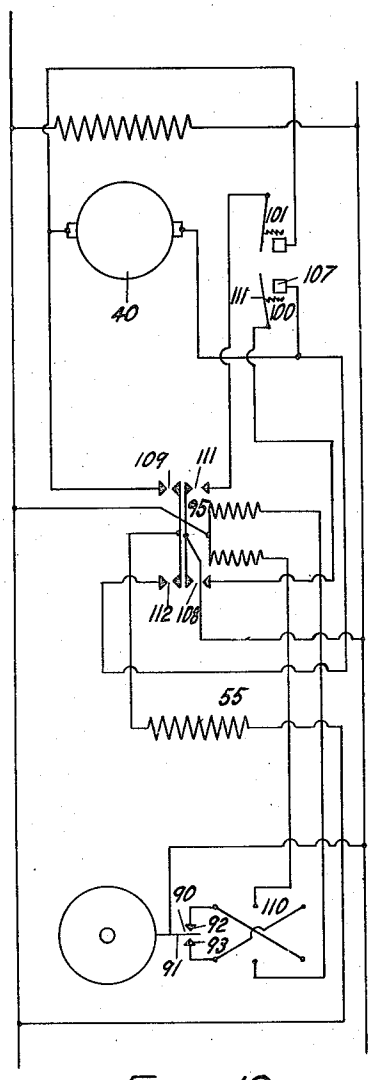

Fig. 10.

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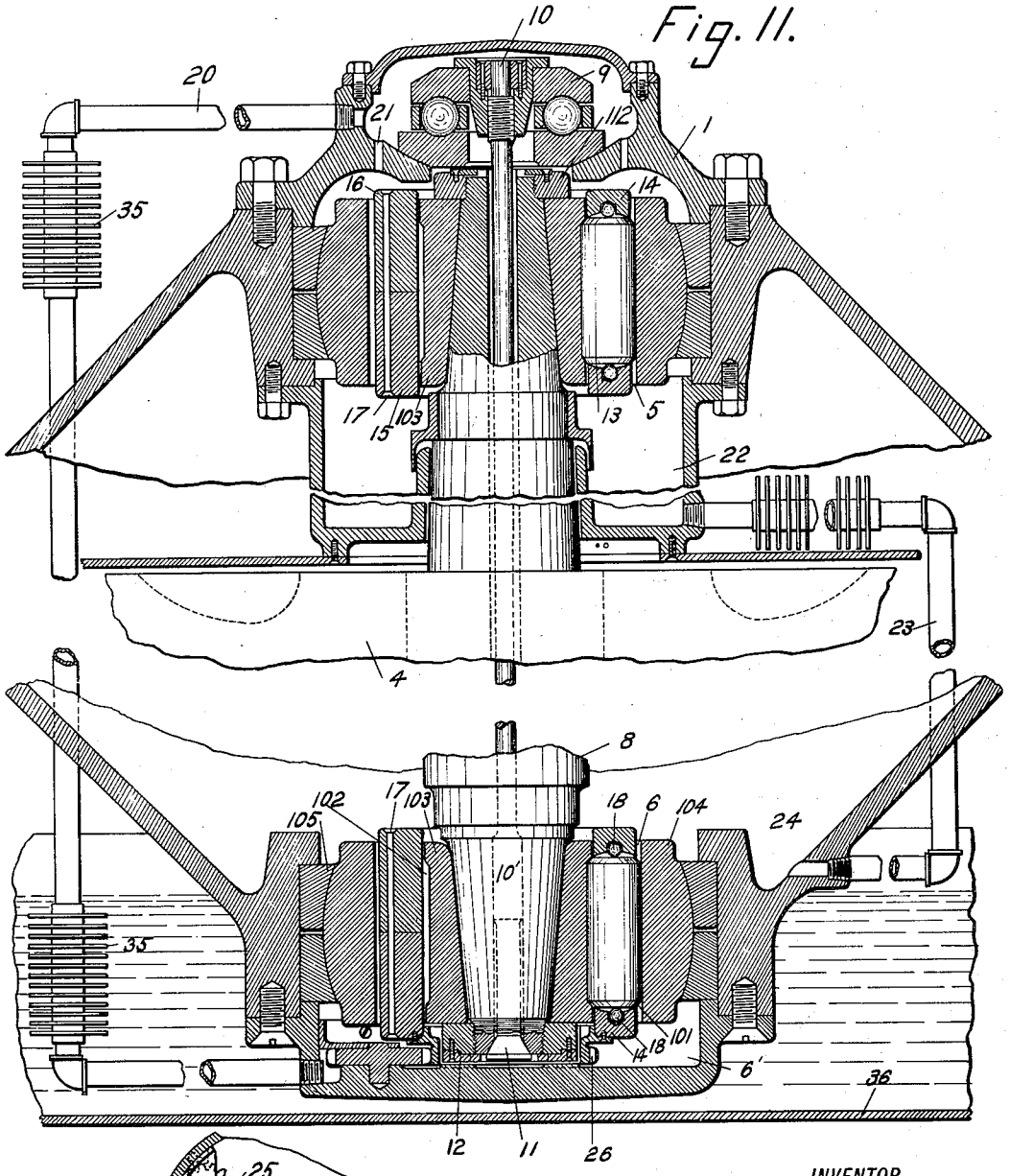
3 SHEETS—SHEET 3.

Fig. 11.



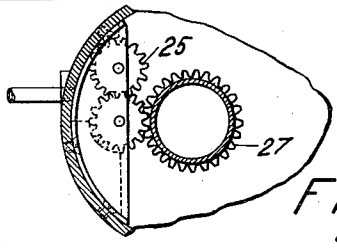


Fig. 12.

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UNITED STATES PATENT OFFICE.

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

CONTROLLING MECHANISM FOR SHIPS' GYROSCOPES.

1,342,397. Specification of Letters Patent. Patented June 1, 1920.

Application filed January 25, 1916. Serial No. 74,075.

To all whom it may concern:

Be it known that I, ELMER A. SPERRY, a citizen of the United States, residing at 100 Marlborough road, Brooklyn, in the county of Kings and State of New York, have invented certain new and useful Improvements in Controlling Mechanism for Ships' Gyroscopes, of which the following is a specification.

This invention relates to gyroscopes for ships of the type shown in my Patent No. 1,150,311, dated August 17th, 1915, and also in my co-pending application Serial No. 716 for ship stabilizing and rolling apparatus, filed January 6th, 1915. As explained in said specifications, gyroscopes of this type may be used either for stabilizing a ship or for rolling it, or both rolling and stabilizing at the option of the commander. The main objects of this invention are to improve upon the system of control and lubrication of these gyroscopes.

Referring to drawings in which what I now consider to be the preferred forms of my invention are shown: Figure 1 is a side elevation of a gyroscope as installed upon a ship. Fig. 2 is an end elevation thereof. Fig. 3 is a detail of the brake which operates to limit the oscillations of the gyroscope—this view being a section on line 3—3 of Fig. 2. Figs. 4 and 5 are transverse and longitudinal sections respectively of the limit stop. Fig. 6 is an enlarged view of the circuit breaking switches on the gyroscope. Fig. 7 is an elevation partly in section of the auxiliary or control gyroscope which governs or times the movement of the main gyroscope. Fig. 8 is an enlarged detail of a control switch on the auxiliary gyroscope. Fig. 9 is an enlarged section of the thrust bearing used on the worm shaft of the transmission gearing between the precession motor and the gyroscope. Fig. 10 is an elementary wiring diagram on the control connections and contacts. Fig. 11 is an enlarged section of the upper and lower bearings of the main gyroscope, showing, however, a slight modification in the oiling system. Fig. 12 is a detail of the oil gear pump used in connection therewith. Fig. 13 is a detail of the modified form of oil elevating pipe.

The main gyroscope as shown, comprises a rotor bearing frame 1, which is supported in the horizontal precession gudgeons 2 and 3, placed crosswise on the ship as indicated by the arrow in Fig. 2 representing the fore and aft line of the ship. The rotor 4 is supported in vertical bearings 5 and 6 within the frame and may be driven by any suitable means such as the armature 7 of an electric motor which may be built directly on the shaft of the rotor as indicated in Fig. 1. I prefer to construct the rotor bearings as indicated in Fig. 11. The main rotor shaft 8 is made hollow and is suspended from the thrust bearing 9 from the top of casing 1 by means of a long, comparatively slender, resilient rod 10. Throughout the greater portion of its length it is spaced from the inner walls of shaft 8 so that vibration of the shaft will not be transmitted thereto. It is enlarged within one of the bearings at 10' to center it in the shaft, but is only secured to the shaft at its lower end 11 where the rod is enlarged and serves to support the entire weight of the rotor 4 and shaft 8. Nuts 12 and 112 are secured to each end of the rotor shaft to hold the inner races 103 of bearings 5 and 6 in place upon the tapered ends of shaft 8, and also in the case of nut 12 to prevent the spreading of the shaft, where the wedging action of the cone is exerted upon the end of the rod 10. The thrust bearing 9 is preferably of the antifriction type being shown as a ball-bearing universally supported at the top of the casing 1. The large radial bearings 5 and 6 are preferably also of the antifriction type, being shown as a special type of roller bearing. The rollers 13 are supported in a cage or retainer 14 which comprises a plurality of sections 15 and 16 riveted or otherwise secured together between the rollers as indicated at 17. Preferably small balls 18 are interposed between the ends of the rollers and the cage to reduce friction at these points.

The ends 101 of the rollers are preferably beveled and the inner race 103 is provided with an annular depression 102 in which the rollers rest. The outer race 104, however, has no depressed portion, so that the rollers are free longitudinally therein. This construction not only facilitates the assembling of the bearing parts but allows free expansion and contraction of shaft 8, which feature becomes quite an important advantage in the art of stabilizing gyroscopes. Another advantage is that it does not permit the bearings 5 and 6 to support any of the

weight of the rotor, but allows the entire weight to be supported by rod 9 and thrust bearing 10, as explained above. The race 104 is universally mounted on blocks 105 in frame 1.

In order to lubricate and cool these bearings, oil is introduced through a pipe 20 into the top of casing 1 where it lubricates bearing 9. From thence it flows down through small openings 21 into and through bearing 5 and into receptacle 22. From thence it is led by pipe 23 into a lower receptacle 24 where it flows into and through the lower radial bearing 6. In Fig. 11 the oil is shown as elevated from the oil well 6′ at the bottom of bearing 6 up to the top of the casing so that it may be used again by means of a small gear pump 25, which is operated by means of a gear 26 secured to the retainer 14 of the bearing 6 with which the idler 27 which drives the gear pump meshes.

By using the retainer 14 to drive the pump, a much slower speed is attained than if the shaft 8 were used. In gyroscopes, which are operated normally at high speed, this becomes quite an advantage. In Figs. 1 and 2 a different system is employed for elevating the oil, which renders unnecessary the employment of a pump for this purpose. As is well known, a gyroscope, especially of the active type, mounted on a ship in a fairly rough sea will oscillate continuously on its precession bearings to the full extent permitted by the construction. This phenomenon is made use of to elevate the oil by employing an inclined coil or duct 30, which rises from the base of bearing 6 to the top of bearing 9 in a series of reverse bends. The coil is so designed that when the gyroscope swings to the left in Fig. 2, for instance, the oil will run down into the reverse bend 31, so that when the gyroscope swings over an equivalent amount to the right the oil there entrapped will flow down into the next reverse bend 32, and so on until the oil has risen to the top of the casing. In order to prevent the oil from running back through the tube from the reverse bends when the gyroscope swings in the opposite direction it may be found desirable to provide vents 33 which will allow the oil beyond the bend to run down into the next reverse bend and prevent it from being drawn back into the pipe into the convolution below. These vents may be closed by the flap valve 34 as indicated in Fig. 13, or a tube 134, or tubes, may be connected thereto which rise above the normal level of the oil by being connected to a normally vertical pipe 135 so that the oil cannot escape therefrom during the oscillations of the gyroscope.

In order to cool the rotor bearings, cooling ribs or vanes 35 may be provided on the oil pipes as shown in Fig. 11. I find, however, a most effective means to effect this result is to provide a large oil tank 36 adjacent the base of the gyroscope in which the lower bearing of the gyroscope normally is immersed and through which it swings when the gyroscope is operating. This oil bath is found to effectively cool the gyroscope, as, in operation, the gyroscope will continuously splash through it and thereby cause a constant circulation of the oil.

The precession engine or motor is shown at 40. As explained in my prior patents above referred to, this motor performs a very important function in accelerating the precession at proper times and thus suppressing the incipient tendency of the ship to roll before it has become noticeable. I have found, however, that by proper design of the motor and its connections with the gyroscope that it may be made to perform several additional functions. Mounted on the motor shaft 41 is a worm 42 which drives the worm wheel 43. A pinion 44 mounted on the worm wheel shaft meshes with the large gear sector 45 on the casing of the gyroscope, so that the rotation of the motor in either direction will cause forced oscillation of the gyroscope, while any tendency for the gyroscope to oscillate independently of the motor will be resisted by the worm and worm wheel connection. Since these forces exerted by the gyroscope become exceedingly powerful when the sea is rough, and since I have found it very desirable that these forces should be absorbed to a great extent, I mount on the worm shaft one or more power absorbing thrust bearings 46 (see Fig. 9). Preferably I secure to the worm shaft a collar 47 which is circumferentially grooved as at 48 and provided with oil ducts 49 so that it may be properly cooled and lubricated. The collar is mounted between fixed thrust bearing blocks 50′ and 51 so as to absorb the thrust in either direction. Said blocks are provided with radial ducts 60, which communicate with ducts 49 through the center of the blocks. Also mounted on the motor shaft or other part of the precession engine is an automatic brake mechanism 50, which is designed to be applied when the motor is rendered inoperative, or when it exceeds a predetermined speed. This mechanism preferably comprises one or more pivoted brake shoes 51 and 52 which are connected by a link 53 and bell crank lever 54, so that when the lever is thrust downwardly the brake is applied. Connected adjacent one end of lever 54 is a solenoid 55 or other electro-mechanical device which normally holds the bell crank lever 54 elevated, but if the current through the solenoid 51 should be interrupted or lessened a spring 56 therein pushes lever 54 down and applies the brake.

In addition to the above described brak-

ing means a positive stop may be provided for the gyroscope to limit its oscillations. This stop may be positioned at 61 near the base of the gyroscope so that the lug 62 is struck by one or the other of two projections 63 on opposite sides of the casing 1. The stop 61 is entirely immersed in the oil bath within tank 36. It is made up of a hollow cylindrical portion 64, secured to a base by means of side flanges 65, and a double acting spring pressed plunger 66. Said plunger is slidably mounted within the cylinder and is centrally positioned therein by means of springs 67 and 68. Lug 62 is secured to plunger 66 and projects through a cutaway portion 69 in the wall of the cylinder 64. When the projection 63, for instance, strikes lug 62 the plunger is moved against the action of spring 68, thereby quickly closing the slight clearance which exists between the end of the plunger and the closed portion of the cylinder 64 beyond the cutaway portions 69 and 70. The movement of the plunger is then powerfully resisted by the oil within the cylinder, since the oil can only escape through a small opening 72, thereby quickly bringing the gyroscope to rest. To position properly the springs within the cylinder and piston a limit device may be provided in the shape of a rod or bolt 73 provided with a washer 74 against which the inner end of the spring bears.

The electrical control of the gyroscope is effected in the main by means of an auxiliary gyro 75 (Fig. 7) which in practice is made very much smaller than the main gyro. It is shown as mounted upon a horizontal spinning axis which is placed athwartship in Fig. 7 with a vertical precession axis 77, although it is obvious that the same result may be obtained by making the spinning axis vertical as is done with the main gyro. Said auxiliary gyro is designed to control the precession motor 40 by completing contacts through its precessional movement as is disclosed in my co-pending application No. 716 above referred to. Resilient centralizing means may be provided for the gyro which may assume the form of spring pressed pins 78 and 79 which bear against the lug 80 on the gyro casing. A spring 81 is positioned between the end of each pin and an upright arm 82, which is preferably adjustable about a pivot 83 so as to vary the tension of the spring as by means of a thumb nut 183. Means are also provided to vary the sensitiveness of the gyro, since it is found that the gyro may be too sensitive in responding to slight disturbances on the ship, such as the jar of the engines, and thereby throw unnecessary work upon the main gyro. For this purpose the vertical precession pivots 77 may be provided with friction blocks 84. These blocks are pressed upon the vertical ring 85 of the gyro by means of springs 86, the tension of which may be readily adjusted by means of screw plugs 87. In addition or in place of the friction blocks, just described, a brake shoe may be provided at 88 to act directly on the ring 85 at a point where its movement about the vertical axis is relatively much greater than near pivot points 77.

The precession contacts are shown only in dotted lines Fig. 7, at 89 but are shown in detail and on a larger scale in Fig. 8. The contact blocks 90 and 91 are mounted on the end of the gyro casing or ring 85, preferably by being secured to the bent spring 91′ so that a yielding and self-cleaning contact will be made thereby with the complementary contacts 92 and 93. Said contacts are mounted on brackets 94 fixed to the ship so that a circuit will be completed on precession of the gyroscope in either direction. Contacts 92 and 93 are shown as adjustable.

The precession motor 40 is controlled from said contacts through the intermediary of the reversing relay 95, shown in Fig. 10, which reverses, in the embodiment shown, the armature connections of said motor when the precession contacts are changed. As soon, therefore, as the ship starts to roll, the motor 40 is actuated to accelerate the precession and thereby damp the oscillations at their inception. If the overturning influence is continued and exceptionally strong, however, a different condition is presented, which must be met in a different way. In other words, under such conditions it is found more desirable to brake the precession than to accelerate it. I automatically accomplish this result by designing the motor to run at a comparatively constant speed, when energized, so that when a force exerted by a wave on the gyro gudgeons exceeds a predetermined amount, it will tend to cause precession of the gyro at a rate greater than the speed of the motor 40, and a powerful braking effect will be exerted through the worm wheel 43, worm 42 and power absorbing thrust bearings 46, as explained above. The brake 50 may be used to materially aid in preventing the motor 40 from being accelerated beyond a predetermined speed by connecting it in series with the motor and designing it so that when the current passing through solenoid 55 drops below a predetermined amount the brake is applied with a pressure inversely proportional to the current flowing. As motor 40 is preferably shunt wound, it will be seen that by this means an accurate speed governor is attained, since the current passing through a shunt motor varies inversely as the armature speed. This braking effect is further increased by breaking the motor circuit and

applying brake 50 thereto, and when the precession of the gyroscope exceeds a predetermined amount. The switches to accomplish this result are shown at 100 and 101 in Fig. 10. It will be seen from this figure that each switch will open the circuit through one of the precession contacts, only, so that the instant the ship starts to roll in the opposite direction an uninterrupted circuit will be completed to drive the motor 40 in the reverse direction. Switches 100 and 101 may be constructed as shown in Fig. 6. Each switch comprises an arm 102 pivoted at 103 and provided with a switch blade 104 and knob 105. A cam 106 is secured to the gyro casing so as to strike either a knob 105 on arm 102 or the corresponding knob 105′ on arm 102′, when the gyro precesses on its gudgeons 2, 3 in one direction or the other. This engagement will break the contact between blade 104 and fixed blades 107 and thereby break the circuit through the armature of motor 40 and solenoid 55 made through contacts 108 and 109 of relay 95, which are held closed by the contact of either pair of precession contacts 90, 92 or 91 and 93 depending on the position of reversing switch 110. Each switch is normally held closed by a spring 100′. But just as soon as the ship starts to roll in the opposite direction, the other pair of precession contacts will be closed, causing the closing of contacts 111 and 112 of the relay and the completion of a circuit through the other limit switch 101 thus sending current in the opposite direction through armature 40.

The operation of my invention is, in general, as follows:—Whether the apparatus is to be used as a stabilizing or rolling device depends simply on the position of reversing switch 110. When the switch is positioned so that impulses will be imparted to the ship in the direction that it is rolling at the time, it will, of course, increase the roll and cause a continuous and increasing oscillation of the ship. Of course, in order to have the device operate in this manner, an initial slight roll must be imparted to the ship. In most cases this is imparted by the waves, but it may be done artificially by completing a contact between points 91 and 93 or 90 and 92, as by turning finger pieces 190. The motor 40 will then cause the ship to heel until the righting moment exceeds the gyroscoping moment or until limit switch 100 or 101 is reached, when it will be reversed by the opposite precession of gyroscope 75.

When the switch 110 is reversed, gyroscope 1 will stabilize the ship, as explained above. Upon the first tendency of the ship to roll the sensitive gyroscope 75 will complete a contact and cause the precession engine to exert a force about the precession axis of the main gyroscope, thereby exerting a stabilizing effect upon the ship before it has rolled to an appreciable extent. The principal advantage in employing an auxiliary gyroscope is here illustrated and is due to the fact that a gyroscope of the size and power required for stabilizing a ship is sluggish in responding to impressed forces so that an appreciable roll, sometimes as great as seven or eight degrees will be imparted to a ship before the main gyroscope will hold it, without the synchronizing aid of the small and sensitive auxiliary gyroscope, which is directly responsive to the angular velocity of roll. If the rolling impulse is powerful and continued, the force exerted by the ship upon the gudgeons of the gyroscope will be sufficient to cause the natural precession of the gyroscope to be greater than that caused by the precession engine. Therefore, as explained, the worm and worm wheel will act as a brake about the precession axis. If the rolling impulse is continued still longer, the gyroscope will strike limit switch 100 or 101 and thus stop the precession engine, and exert a powerful brake on the gyroscope. On or about the same instant the positive limit stop 62 will be struck. However, as soon as the ship starts to roll in the other direction, the control gyroscope 75 will complete the circuit through the other limit switch, which, as explained, is normally held closed, so that a stabilizing effect will immediately be exerted, so that the apparatus is at all times in phase with the roll of the ship. As the gyroscope swings back and forth upon its gudgeons the oil will be elevated from the lower bearing to the upper through my novel system of coiled tubing, and at the same time the entire gyroscope will be cooled by the lower bearing washing through the liquid in tank 36.

In accordance with the provisions of the patent statutes, I have herein described the principle of operation of my invention, together with the apparatus, which I now consider to represent the best embodiment thereof, but I desire to have it understood that the apparatus shown is only illustrative and that the invention can be carried out by other means. Also, while it is designed to use the various features and elements in the combination and relations described, some of these may be altered and others omitted without interfering with the general results outlined, and the invention extends to such use.

I claim:

1. In a gyroscopic stabilizing or rolling apparatus, a main gyroscope mounted for precessional movements, power means for governing the precessional movement, and a limit device on said gyroscope for causing said power means to stop.

2. In a gyroscopic stabilizing or rolling apparatus, a main gyroscope mounted for precessional movements, power means for governing the precessional movements, and a limit device on said gyroscope for rendering said power means inoperative.

3. The combination with a gyroscope, of means for controlling the oscillations thereof including a constant speed motor, a worm and worm wheel in the connections between the motor and the gyroscope and power absorbing thrust bearings for the worm.

4. The combination with a gyroscope, of means for controlling the oscillations thereof including a motor, a worm and worm wheel in the connections between the motor and the gyroscope, power absorbing thrust bearings for the worm, and means for stopping said motor at a predetermined portion of the oscillations, whereby the oscillations of the gyroscope are limited.

5. The combination with a ship's gyroscope, a precession engine for controlling said gyroscope, a controller for said engine adapted to reverse its action when the roll of the ship reverses, and a limit means adapted to render the said controller inoperative to cause said engine to operate in a predetermined direction while leaving said engine free to be operated in the reverse direction by said controller.

6. The combination with a ship's gyroscope, a precession engine for controlling said gyroscope, a controller for said engine adapted to reverse its action when the roll of the ship reverses, and a limit means mounted on the gyroscope adapted to disconnect the operative side of the controller and the engine when the precession in one direction exceeds a predetermined amount while leaving the other side of the controller free to actuate said engine in the reverse direction as soon as the ship starts to roll in the opposite direction.

7. The combination with a ship's gyroscope, of a controlling motor therefor, and a governing means for said motor including a shut-off device responsive to the precession of said gyroscope.

8. The combination with an oscillatory body of a gyroscope thereon mounted for precession with respect thereto, and a yielding limit stop for said gyroscope adapted to prevent precession of said gyroscope beyond a predetermined angle.

9. The combination with a ship's gyroscope, of a controlling motor and a brake therefor, and a governing means for said motor including a shut-off device responsive to the precession of said gyroscope for stopping the motor and applying the brake.

10. A cooling system for gyroscopes comprising a rotor, a bearing frame therefor mounted for oscillation about a horizontal axis, a receptacle adapted to contain a liquid mounted adjacent the base of said gyroscope, whereby a portion of said frame is washed through the liquid by the oscillation of the gyroscope.

11. In a vertical gyroscope having upper and lower rotor bearings and mounted for oscillation about a horizontal axis, an oiling and cooling system comprising means for raising the oil from the lower bearing to a point adjacent the upper bearing, means whereby the oil may be transferred to the lower bearing, and extraneous cooling means for said oil.

12. In a vertical gyroscope having upper and lower rotor bearings and mounted for oscillation about a horizontal axis, an oiling and cooling system comprising means for raising the oil from the lower bearing to a point adjacent the upper bearing, means whereby the oil may be transferred to the lower bearing and a receptacle adapted to contain a liquid mounted adjacent the base of said gyroscope whereby the lower rotor bearing is washed through the liquid by the oscillation of the gyroscope.

13. In a vertical gyroscope having upper and lower rotor bearings and mounted for oscillation about a horizontal axis, means for raising oil from the lower bearing to a point adjacent the upper bearing comprising a pipe coiled in such manner as to cause the gradual elevation of the oil by the oscillations of the gyroscope on its horizontal axis.

14. In a vertical gyroscope having upper and lower rotor bearings and mounted for oscillation about a horizontal axis, means for raising oil from the lower bearing to a point adjacent the upper bearing comprising a pipe coiled in a series of reverse bends connected by portions which are inclined at such an angle that their directions of inclination are reversed when the gyroscope is oscillated.

15. In a gyroscope mounted for oscillation with reference to its support, a journal bearing therefor, means for causing a circulation of oil through the bearing comprising a pipe or duct shaped in such a manner as to cause a gradual elevation of the oil from a lower to a higher point of such bearing by successive oscillations of the gyroscope.

16. In a gyroscope mounted for oscillation with reference to its support, a journal bearing therefor, means for causing a circulation of oil through the bearing comprising a pipe or duct coiled in a series of reverse bends connected by portions which are inclined at such an angle that their directions of inclination are reversed when the gyroscope is oscillated.

17. In a device subject to oscillations

about a horizontal axis, the combination with a bearing therefor of means for causing a circulation of oil through the bearing, comprising a pipe or duct shaped in such a manner as to cause a gradual elevation of the oil from a lower to a higher point of such bearing by successive oscillations of the device.

18. The combination with a gyroscope, of means for controlling the oscillations thereof including a motor, and means responsive to the speed of the motor for applying a brake, whereby the rate of precession is limited.

19. The combination with a gyroscope mounted for precession about an axis, braking means connected therewith, a control device for said means brought into operation by the extent of precession, and a second control device for said means brought into action by the speed of precession of said gyroscope.

20. The combination with a gyroscope, of means for braking the same about a precessional axis, and means responsive to precession beyond a predetermined limit for applying said braking means.

21. The combination with a gyroscope, of means for controlling the oscillations thereof including a motor, a brake for limiting the oscillations of the gyroscope, yielding means normally holding said brake applied, and electromagnetic means in circuit with said motor for withholding the brake, whereby the brake is applied whenever the current passing through the motor is reduced below a predetermined amount.

22. In combination with a gyroscope, of means for braking the same about a precessional axis, means responsive to the speed of precession for applying said braking means and means responsive to precession beyond a predetermined limit also for applying said braking means.

In testimony whereof I have affixed my signature.

ELMER A. SPERRY.