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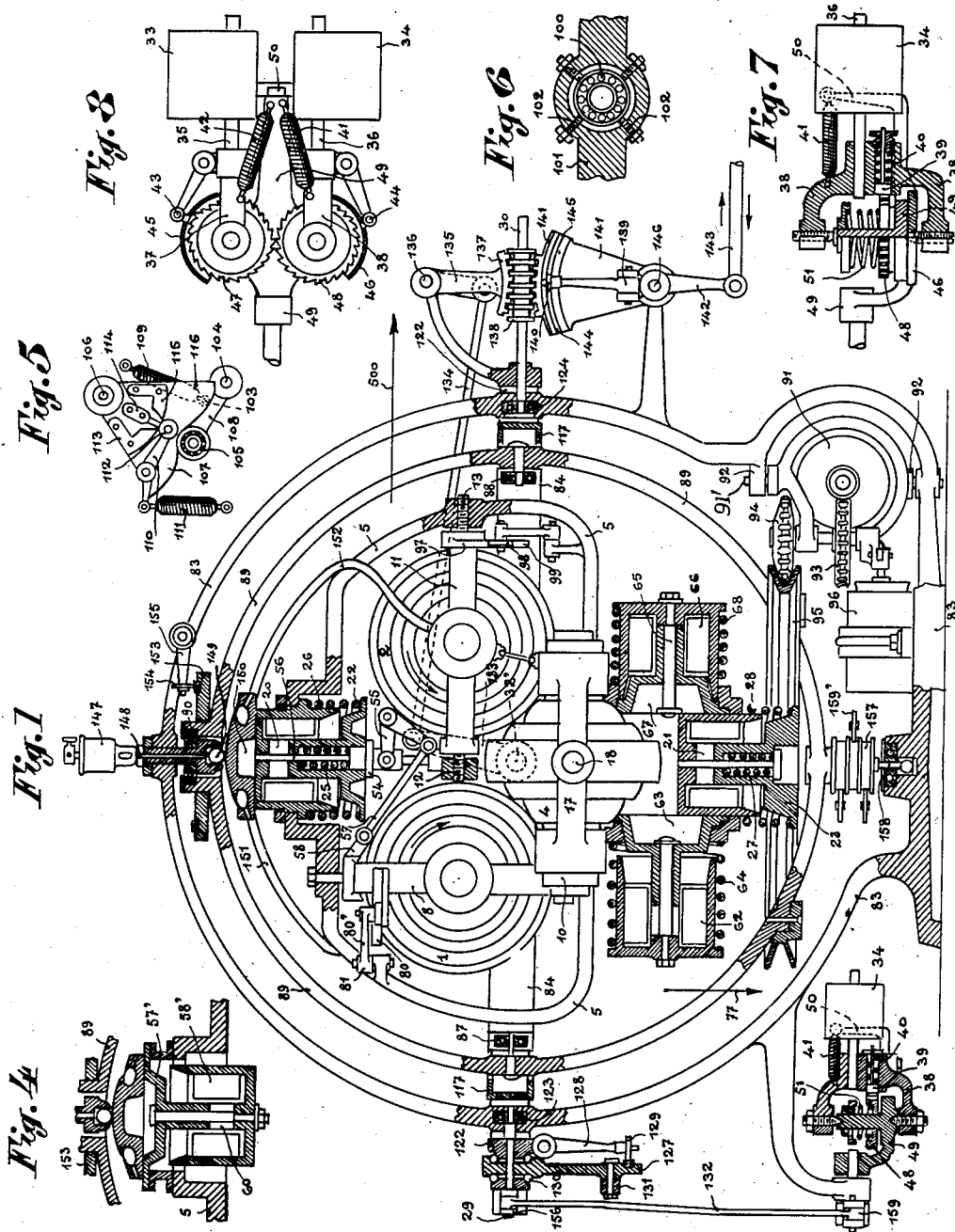
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STABILIZING AND DIRECTING GYROSCOPIC CONTROL MECHANISM

Filed April 28, 1928

3 Sheets-Sheet 1



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Fig. 9

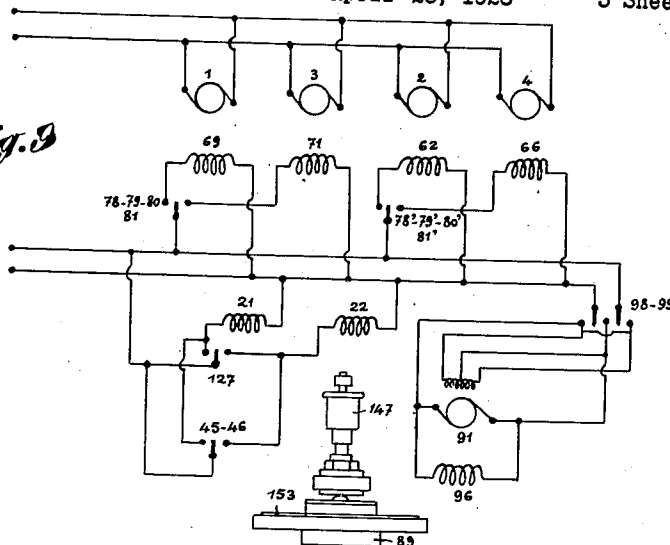
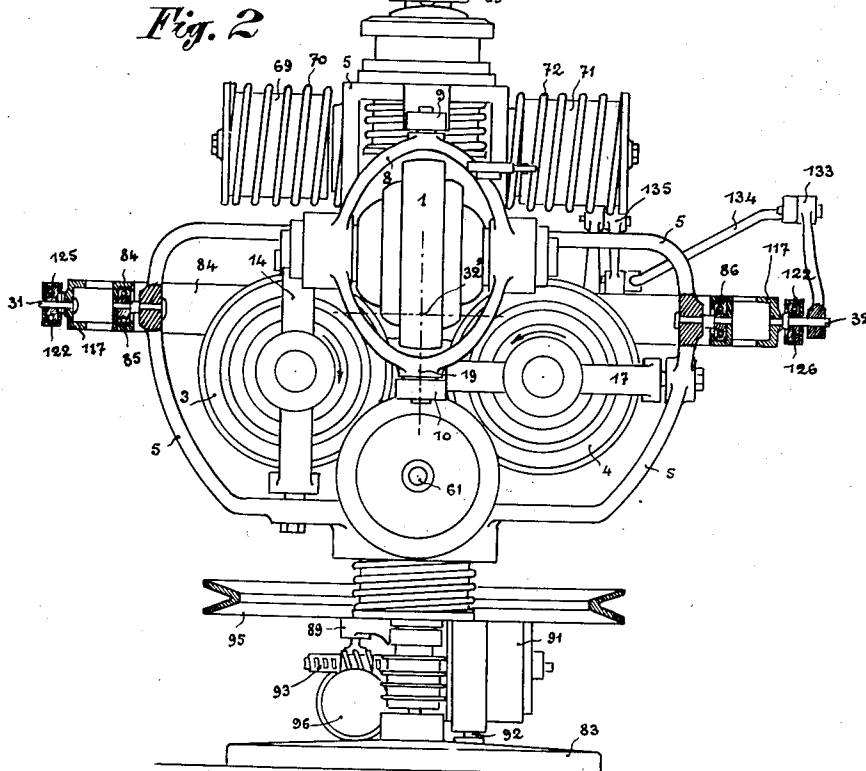


Fig. 2



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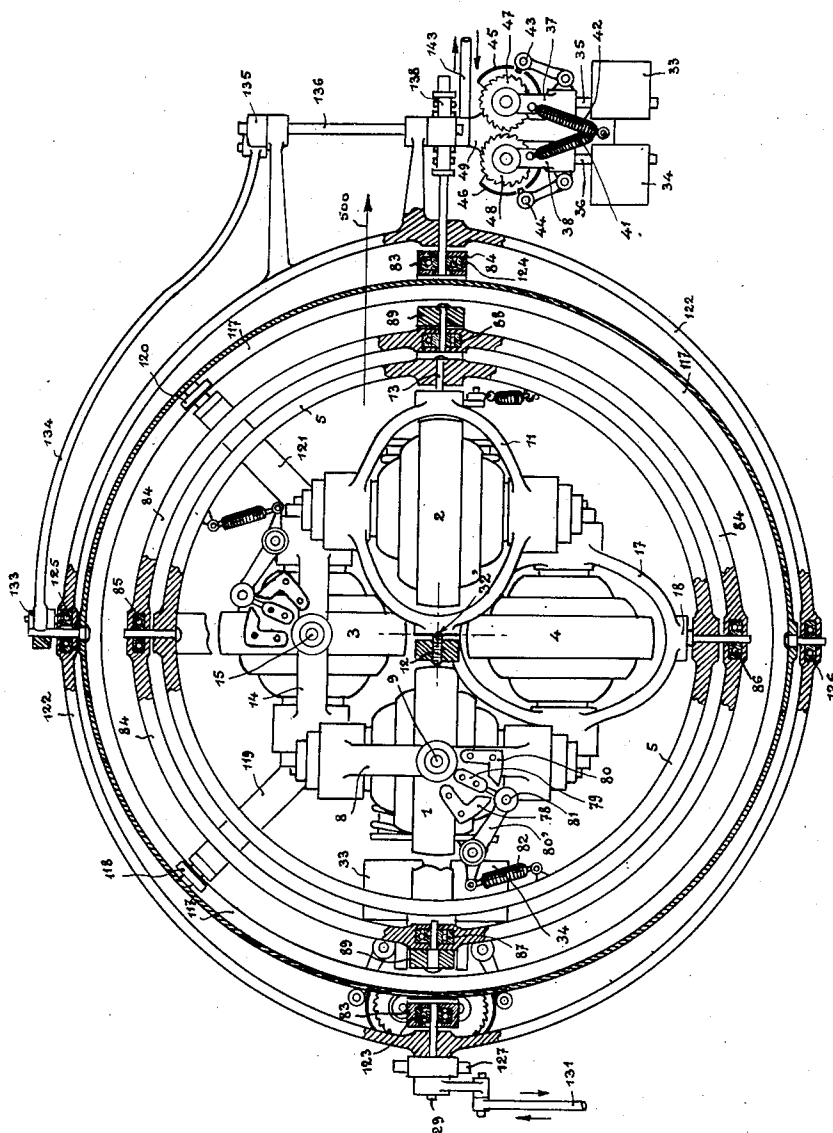
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Fig. 3



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UNITED STATES PATENT OFFICE

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STABILIZING AND DIRECTING GYROSCOPIC
CONTROL MECHANISM

Louis Marmonier, Lyon, France

Application April 28, 1928, Serial No. 273,732,
and in France May 9, 1927

15 Claims. (Cl. 74—78)

The present invention has for an object an apparatus constituted by an arrangement of several gyroscopic groups having for a common purpose the obtaining of one or more proof planes occupying respectively, in space, a fixed and invariable position. These proof planes may be utilized for longitudinal and transverse stabilization as well as for the automatic directing of movable bodies displaced in a fluid whose position is materially unstable, such as, aeroplanes, ships, torpedoes and the like, as well as the stabilization and automatic directing of all apparatus or objects placed on board these moving bodies, such as, pieces of marine artillery, telescopic sights, telemeters, repeating motors, directing and orientating tables and the like.

The invention will be readily understood from the accompanying drawings taken in connection with the following description.

In the drawings—

Fig. 1 is an elevational view with parts in section of a group of four gyrostats and their precessional compensation organs, this embodiment having for a purpose to obtain two proof planes; the first in stable position on the horizon and the second in stable position on the azimuth;

Fig. 2 is a side view partially in section of the group of Fig. 1;

Fig. 3 is a section along a horizontal plane showing the group of four gyrostats in plan;

Fig. 4 shows a modification of the device for the automatic raising of the two pendular masses of group No. 1;

Fig. 5 is a modification of the lowering device of the gyrostats in the position that they must occupy normally in the group. This figure also shows details of the precession three contact point switch;

Fig. 6 is a regulating device for the shafts of the cardan joints supporting the gyrostats for the purpose of causing coincidence of the centers of rotation of the group;

Fig. 7 is an elevational view of the automatic device indicating the variation in speed of the moving body and change in direction of this moving body;

Fig. 8 is a plan view of the device of Fig. 7;

Fig. 9 is schematic diagram showing the electrical connections.

The gyroscopic group is composed of four gyrostats 1—2—3—4 supported by a spherical framework 5 journaled in ball-bearings 85—86 fixed on a ring 84. At 90° from said first mentioned bearings said ring rests on two other ball-bearings 87—88 fixed to a ring 89 vertically dis-

posed, in order to constitute a cardan joint device allowing the gyroscopic group to remain independent of the inclinations of its support. Moreover the ring 89 rotates freely in ball-bearings 90—91 in a ring frame 83, allowing the group to escape all movement of rotation of said frame which itself is disposed on the movable body to be stabilized. To this end, the shafts 29—30 and 31—32 are accurately disposed in the same plane, and their point of intersection 32' coincides with the pivotal axis 6—7 of the ring 89. For obtaining precise centering of the shafts which is of the greatest importance in equilibrating the arrangement, the ball races of the bearings supporting the universal rings may be accurately centered with the device of Fig. 6, which is merely disclosed by way of example, numerous modifications being possible in order to produce the same result. In the device of Fig. 6, the ball-bearing 100 is adapted to be displaced in the housing with which it is provided in ring 101 by four regulating screws 102 arranged in the form of a square and provided with lock-nuts.

The rotors 1—2—3—4 of the gyroscopic group are of exactly the same weight, have the same diameter and are given the same speed. The gyrostats are grouped on their common frame 5 in such a way that the two gyrostats 1 and 2 occupy equal distances from the vertical axis 6—7 of the group and turn in opposite directions in the same plane of rotation. The disposition of gyrostats 3—4 is identical, their plane of rotation likewise passing through the vertical axis 6—7.

The gyrostat 1 turns in ball-bearings in a ring 8 which pivots about a vertical axis 9—10. The gyrostat 2, whose couple of rotation is equilibrated by the couple of gyrostat 1, turns in a ring 11 which pivots about a horizontal axis 12—13. As a result of this arrangement, the gyroscopic reaction of each of the gyrostats 1 and 2 does not take place along the same line of proof, but on two distinct lines perpendicular to each other, whereas the gyrostat 1 reacts along a vertical line of proof 9—10, the gyrostat 2 reacts along the line 12—13.

The same arrangement exists in connection with gyrostats 3—4 whose respective couples of rotation equilibrate each other, but whose gyroscopic actions are different. The gyrostat 3 pivots in ball-bearings in a ring 14 at 15—16 about an axis coinciding with the line of proof 15—16 of the reaction of this gyrostat, whereas the gyrostat 4 mounted on a ring 17 pivots about the horizontal axis 18—19 and reacts on this axis.

As in other respects the gyrostats 1—2 and 3—4 are mounted perpendicular to each other on the common frame 5, the reaction of the two gyrostats 1 and 3 whose pivotal axes are vertical, will have for an effect to stabilize the whole of the group according to a horizontal proof plane, whereas the two gyrostats 2 and 4 react in common in an azimuthal proof plane. The gyrostats 1—3 consequently assure automatic longitudinal and transverse equilibrium of the moving body which they are to stabilize while the gyrostats 2—4 concentrate their reactions in the azimuth for serving as an azimuthal direction base for orientating the moving body.

It will be noticed, however, that in order to maintain immobility integral with the horizontal proof plane of this group, it is necessary to join thereto two pendular masses which cause a definite position of equilibrium to be maintained due to the restraint of gravity. On the other hand these pendular masses present the disadvantage of being subjected to an acceleration couple resulting from variations in speed of the movable body as well as to the action of centrifugal force during turning of the moving body.

In order to restrain as much as possible the effect of these acceleration couples on the equilibrium of the gyroscopic group, I have provided a device which will now be described.

The pendular attraction of the group is obtained by two masses 22 and 23 constituting the cores of two iron-clad electro-magnets 20 and 21 fitted in the frame 5 and centered on the vertical axis 6—7, in such a way that during normal running of the moving body, the center of gravity of the two pendular masses 22—23, will be situated beneath the horizontal axis 29—30. On the other hand when a current excites both electro-magnets 20—21, the pendular masses 22—23 by being lifted move their centers of gravity closer to the axis 29—30 thus diminishing the pendular restraint that they transmit to the gyroscopic group.

The action of iron-clad electro-magnets 20—21, is brought about by means of automatic speed variation and centrifugal force gauges represented in Figs. 7 and 8. These gauges are maintained in stable position in a constant horizontal plane and for this purpose are placed on master controlled elements as will be explained below. These gauges comprise essentially two small masses 33 and 34 perpendicularly disposed to the route which the moving body follows, for indicating the variations in speed of this moving body, or parallel to the direction of this route for registering the effects of centrifugal force during turning of the moving body. These masses 33—34 are placed at the extremities of levers 35—36 keyed to forks 37—38, loosely pivoted on a common frame 49. The two masses 33—34 are drawn, in their normal position of rest against a common abutment 50, integral with the frame 49, by means of opposing springs 41—42. The forks 37—38 each carry a ratchet, that of fork 38 being shown at 39 with its pressure spring 40. These ratchets lock on ratchet wheels 47—48, which turn in frame 49 with more or less friction tightness according to the regulation of the tension of the springs, one of which for ratchet wheel 48 being shown at 51.

When a variation in speed takes place in the moving body, one of the masses 33—34 is projected to the front or to the rear, its movement being limited, however, by spring 41 or 42. The ratchet becomes locked with the corresponding

ratchet wheel when in the position at the end of its movement and the mass returns slowly to its position of rest, this return movement being braked by the friction of the ratchet wheel on the frame.

While these various movements are taking place, one of the current receiving terminals 43—44 of switches 45—46 leads current to the contact of the corresponding switch. The contacts of switches 45—46 being in connection with the iron-clad electro-magnets 20—21 as long as the masses 33 and 34 are not in their position of rest which always takes place after the disturbance which has released their action, the pendular masses 22—23 of the gyroscopic group will remain in raised position thus reducing to a minimum the effects of these disturbances on the equilibrium of the group.

On the interior of the pendular core 22 of electro-magnet 20 is placed a spring 25, which bears at one end against this core and at the other end on a shouldered sleeve 54 which slides along a rod 56. The sleeve 54 controls a bell-crank lever 55 which acts on a rod 57, which in turn maintains the gyrostat 1 in the position which it must occupy in the group by means of a lever 58. The electro-magnet is furnished with a second spring 26 more powerful than the spring 25. When the pendular core 22 is at the end of its stroke, that is to say, in a position where the pendular restraint is at its greatest, the sleeve 54 submits to the pressure of spring 26 which it communicates to gyrostat 1 by rods and levers 55—57—58. This pressure is powerful enough to reduce to a notable degree the gyroscopic reaction of gyrostat 1. On the other hand if the pendular core 22 ascends in its housing following a disturbance recorded by the device above described, the spring 25 acts alone on the gyrostat 1 without diminishing its power of reaction.

The same arrangement is provided for the iron-clad electro-magnet 21 whose core submits alternately to the action of two springs 27 and 28, the action of spring 28 having for effect to reduce the power of reaction of gyrostat 3, while the spring 27 maintains this reaction intact.

In this way, the reaction of gyrostats 1 and 3 is greatly reduced and is not subjected to any exterior disturbance, thus leaving a certain preponderance of the action of gravity, while the two gyrostats 1 and 3 react energetically when a disturbance running the risk of rupturing their equilibrium is recorded. As this increase in power of reaction coincides with the diminution in the action of gravity on the gyroscopic group, the disturbances due to variations in speed of the movable body will have minimum effect on the equilibrium of the group.

This arrangement applies principally to gyrostats of very large diameter or turning at very high speed and consequently having a very high initial power of reaction, which may be, without inconvenience, reduced intermittently for increasing, on the other hand, the restraint of gravity for the purpose of maintaining the horizontal proof plane in an immovable position.

For gyrostats of small diameter where there is no need for reducing the gyroscopic reaction, this device is replaced by the modification represented in Fig. 4. In this device the interior core 57' of the iron-clad electro-magnet 60 is fixed to frame 5 of the gyroscopic group, whereas the polar mass 59 and its exciting winding 58' constitutes the counter-weight and raises or descends according to the excitation of winding 58'. As the polar

mass 59 as well as the exciting winding 58' are of a high relative weight and as the same arrangement is adopted for the iron-clad electro-magnet placed at the bottom of the gyroscopic group, the restraint of gravity will be increased or diminished according to whether the polar masses of the two iron-clad electro-magnets move toward or away from the center of gravity of the group.

Independently of the disturbances produced on the gyroscopic group by variations in speed or changes in direction of the movable body, which disturbances are nevertheless imperfectly compensated for by the devices previously described, other causes can disturb the equilibrium of the group, which after all, is in a state of constant instability. It would therefore be fitting to provide compensating organs which would act as soon as rupture of equilibrium would take place, and these organs must act on the horizon proof plane as well as on the proof plane in the azimuth.

For maintaining the horizon proof plane in its position of equilibrium in full, four iron-clad electro-magnets 61—65—69—71 are fixed to the frame 5 of the gyroscopic group and on which are disposed respectively the two electro-magnets 61—65 on an axis 73—74 parallel to the horizontal axis 29—30 of the gyroscopic group and of gyrostats 1—2 and the two electro-magnets 69—71 on an axis 75—76 parallel to the horizontal axis 31—32 of the gyroscopic group and of the two gyrostats 3—4. As the respective distance between the axes 73—74 and 29—30, as well as between the axes 75—76 and 31—32 is exactly the same, the four iron-clad electro-magnets 61—65—69—71 will be by themselves in a position of neutral equilibrium about the central pivot 32 of the gyroscopic group. These four iron-clad electro-magnets have, in fact, exactly the same weight and are normally in the same position. Each of these iron-clad electro-magnets is constituted by the same elements and as shown for iron-clad electro-magnet 61 comprises an exciting winding 62 placed on the interior of a polar mass and an interior core 63. This core is fixed to frame 5 of the group in such a way that the exciting winding and its polar mass can be horizontally displaced on the axis 73—74, being held away from core 63 by an opposing spring 64.

The iron-clad electro-magnet 65 is composed of a core 67 fixed to the frame 5 and an exciting winding and polar mass 66 as well as an opposing spring 68. The arrangement is the same for iron-clad electro-magnets 69 and 71 whose polar masses are moved apart exteriorly by springs 70 and 72 when they occupy their position of rest.

In case a rupture of equilibrium in the horizon proof plane takes place, one of these electro-magnets, electro-magnet 65 for example, will be excited and the exciting winding 66 as well as its polar mass approaches the axis 6—7 of the gyroscopic group immediately producing a force couple in the direction of the arrow 77 which tends to reestablish equilibrium. Being given the respective position of 90° with respect to each other, it is possible to make the four iron-clad electro-magnets 61—65—69—71 act in a suitable direction. It will be noticed that this equilibrium compensating arrangement does not necessitate any mechanical support external the frame 5 of the gyroscopic group, which constitutes one of the essential characteristics of the invention.

The placing into action of the four iron-clad electro-magnets 61—65—69—71 is produced by

the gyrostats 1 and 3 which alone control the horizon proof plane. In this end the gyrostats 1 and 3 are both furnished with a three-point switch, which for gyrostat 1 is the switch 78—79—80, a current receiving terminal 80' and a contact roller 81 thereof, this current receiving terminal 80' being held against the switch by a spring 82 secured to the frame 5.

Any precession of the gyrostat 1 will therefore have for effect to instantaneously call in one or the other of the electro-magnets 69 and 71 depending upon the direction of rotation of the gyrostat and the direction of rupture of equilibrium, whereas a precession of gyrostat 3 will act on the electro-magnets 61 or 65.

As regards the righting of the proof plane in the azimuth which is controlled by the two gyrostats 2 and 4, this righting may be obtained by various devices supported by the main frame of the group. These devices are susceptible to numerous modifications and the model described hereinafter is merely given by way of example. It comprises an electric motor 91, wound to rotate in opposite directions and pivoted at 92—92 by pivot 91' on the supporting frame 83. This motor 91 actuates a worm wheel 93, which in turn controls a conical wheel 94 which can frictionally engage a conically grooved wheel 95 under the action of an electro-magnet 96. The grooved wheel 95 is fixed to the ring 89 which itself is connected to the gyroscopic group and consequently occupies in space an invariable position in the azimuth. If a variation of the group is produced in the azimuth it is immediately recorded by the precession of the gyrostats 2 and 4 which control the azimuthal proof plane. This precession has for effect to establish contact between the roller 99 of the current carrying terminal 98 and one of the contacts of the three-point switch 97 which is placed on gyrostat No. 2. The motor 91 effects a movement of rotation at the same time that the conical wheel 94 engages in the grooved wheel 95 under the influence of electro-magnet 96. If this movement is opposite to the variation of the group in the azimuth the original position will be immediately reestablished.

Fig. 5 represents a device having for a purpose to exactly place the gyrostats 1—2—3—4 in the position which they must occupy in the group and at the same time to allow the three-point switches which serve as precession indicators, to operate under good conditions. This device consists of a piece of ebonite 116 keyed to the gyrostat which precesses about 106. This piece is provided with two cam surfaces 107 and 108 against which bears a ball-bearing roller 105 fixed at the extremity of a lever 103 pivoted at 104 and supported by the spherical frame 5 of the group. The pressure of lever 103 against cams 107—108 is obtained by a spring 109. Moreover the ebonite member 116 carries the switch composed of three contacts 113—114—115, a current carrying lever 110 carrying a contact roller 112 as well as a tension spring 111. The precessional movements of the gyrostat are therefore damped out by the roller 105 which tends to restore it to its initial position.

According to the foregoing the gyroscopic group occupies in space an invariable position on the horizon and in the azimuth. In order to allow this group to control the longitudinal and the transverse stabilizing planes of the moving body to be stabilized as well as the automatic directing

thereof it has been provided with a series of elements which will now be described.

The group being fixed on the moving body to be stabilized and automatically steered in the direction of the arrow 500 (Figs. 1 and 3) which indicates the direction of motion of the moving body, the longitudinal and transverse stabilizing control is obtained by ring 117 of channel-shaped section disposed concentric to the axis 32' of the group. In this ring circulate two ball-bearing rollers 118 and 120 fixed to circular brackets 119 and 121, themselves fastened to the spherical frame 5 of the gyroscopic group. The channel-shaped ring 117 is suspended by a cardan joint on two ball-bearings 125—126 whose trunnions are fixed to a ring 122 which pivots itself on ball-bearings at 123 and 124 on the ring support 83. The intersection of the pivotal axes 125—126 and 123—124 of ring 122 coincides with the central pivotal axis 32' of the gyroscopic group.

Transverse stabilization of the moving body is controlled by a current carrying terminal 128 fixed to ring 122 and carrying a contact roller 129. The latter is connected to a three point switch 127 which turns on ball bearings at 130 and which is connected on the other hand with the servo-motor actuating transverse stabilization planes of the moving body by the return lever 131 of the servo-motor.

The control of the longitudinal stabilization is assured by the lever 133 which is fixed to trunnion 125 of channel-shaped ring 117. The lever 133 acts on a rod 134 on lever 135, on shaft 136, on which is keyed a toothed sector 137 which meshes with a block 138 having circular grooves. This block 138 slides laterally on shaft 30 and drives in turn the toothed sector 141. This sector carries a three-point switch 144—145 on which is connected the roller 140 of the current carrying terminal 139. The lever 139 is integral with the return lever 142, this latter being connected at the other end with the servo-motor which actuates the longitudinal stabilizing planes by means of the return rod 143.

The control of the direction is assured by a three-point switch 153 which is fixed on the ring 89 of the gyroscopic group in an invariable position on the azimuth and by a contact roller 154 fixed at the extremity of a current carrying terminal 155 supported by the frame support 83.

Automatic lubrication of the ball-bearings of the gyrostats is effected by a drop-count lubricator 147 fixed on the supporting frame 83. The oil runs through a conduit in shaft 148 which supports the ball-bearing 90. At the end of this conduit is placed a ball 149 which is supported by a receptacle 150 fixed on the electro-magnet 20 fastened to the frame 5 of the gyroscopic group. From this receptacle 150, the oil is led to each gyrostat through stiff conduits 151 and flexible conduits 152. The ball 149 falls back on its seat and arrests the flowing of oil when the supporting frame axis does not coincide with that of the gyroscopic group.

As was previously described, the two indicators of variation in speed and change in direction of the moving body (Figs. 7 and 8) must maintain absolute horizontality for suitable functioning. These two indicators are therefore fixed on elements under control of the gyroscopic group. The indicator of variation in speed, of longitudinal stabilization, is fixed on shaft 146 on which is keyed the return lever 142 of the servo-motor, while the change in direction indicator is con-

nected with the transverse stabilization servo-motor through lever 156 forming part of the controlled element, rod 132 and lever 159. The movement of the ring 117 relative to the main frame thus serves to hold these two gauges always horizontal in the same manner that it stabilizes the object through the controls. That is, any tendency to deviate from the horizontal will turn shafts 29 and 146 and thereby the gauge assemblies so that tilting of the moving object will not result in any movement of the gauges away from a horizontal position.

The electric operating circuit of the gyrostats as well as the electro-magnets is established by means of a rotary distributor 157 mounted on a shaft 158 fixed to the ring 89 at one end and to the ring support 83 at the other end. Current is brought in through contact rollers 159' supported by the frame 83.

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

1. In a gyroscopic control assembly, a gyroscope supporting frame, a first pair of gyroscopes, means supporting said gyroscopes on said frame whereby they are capable of precessing about parallel axes, said gyroscopes having rotors positioned to rotate in intersecting planes, a second pair of gyroscopes, means supporting said second gyroscopes on said frame whereby they are capable of precessing about axes positioned at right angles to the precessional axes of the first pair of gyroscopes, said second pair of gyroscopes having rotors positioned to rotate in intersecting planes, means for driving said gyroscopes, a second frame, means movably supporting said gyroscope supporting frame on said second frame, control means for causing the return movement of said gyroscopes to their normal position after displacement therefrom, and instrumentalities whereby said control means is actuated by movement of the gyroscopes relative to the said gyroscope supporting frame.

2. A structure as defined in claim 1 in combination with a mass vertically slidable on the gyroscope supporting frame and means for vertically displacing said mass.

3. A structure as defined in claim 1 in combination with a mass vertically slidable on said gyroscope supporting frame, means operative to displace said mass towards and away from the center of gravity of the assembly supported on the gyroscope supporting frame, and means independent of said gyroscope supporting frame to control said displacing means.

4. A structure as defined in claim 1 in combination with a mass vertically slidable on the gyroscopic supporting frame, and means controlled by accelerated movement of said gyroscopes through space to displace said mass.

5. In a gyroscopic control assembly, a gyroscope supporting frame, a first pair of gyroscopes, means supporting said gyroscopes on said frame whereby they are capable of precessing about vertical parallel axes, said gyroscopes having their rotors rotating in planes perpendicular to one another, a second pair of gyroscopes, means supporting said second gyroscopes on said frame whereby they are capable of precessing about horizontal axes, said second gyroscopes having rotors rotating in planes perpendicular to one another, means for driving said gyroscopes, a second frame, and means for suspending said gyroscope supporting frame universally from said second frame.

6. A structure as defined in claim 5 in combination with control means actuatable by the relative movement of said second frame and said gyroscope supporting frame.

7. A structure as defined in claim 5 in combination with a mass vertically slidable on the gyroscope supporting frame, and means controlled by accelerated movement through space of said structure to vertically displace the said mass.

8. A structure as defined in claim 5 in combination with means operative to correct tilting of said gyroscope supporting frame relatively to any fixed horizontal plane.

9. A structure as defined in claim 5 in combination with means operative to correct tilting of said gyroscope supporting frame relatively to any fixed vertical plane.

10. A structure as defined in claim 5 in combination with a plurality of masses movably mounted on the gyroscope supporting frame, and means controlled by a tilting movement of said gyroscope supporting frame relatively to any horizontal plane to displace one of said masses substantially horizontally.

11. A structure as defined in claim 5 in combination with a solenoid having a winding and a core displaceable with relation to one another, said solenoid being mounted on said gyroscope

supporting frame, and means controlled by precession of one of said gyroscopes to energize said solenoid.

12. A structure as defined in claim 5 in combination with means operative to correct tilting movements of said gyroscope supporting frame relatively to fixed horizontal and vertical planes.

13. A structure as defined in claim 5 in combination with means controlled by precessional movement of one of said first pair of gyroscopes to tilt said gyroscope supporting frame.

14. A structure as defined in claim 5, in combination with means controlled by precessional movement of one of said first pair of gyroscopes to tilt said gyroscope supporting frame, said last means including a solenoid having a core and a winding displaceable with relation to one another, said solenoid being carried by said gyroscope supporting frame, and means controlled by precession of one of such gyroscopes to energize and de-energize said solenoid.

15. A structure as defined in claim 5 in combination with a first mass pivotally supported on the second frame, a second mass movably mounted on the gyroscope supporting frame, and means controlled by displacement of said first mass to vertically displace said second mass.

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