United States Patent [19]

Taylor

[11] **3,780,444**

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[54] **GYROCOMPASS**

[75] Inventor: **Marvin Taylor,** Plainview, N.Y.

[73] Assignee: **AMBAC Industries, Incorporated,** Garden City, N.Y.

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[52] **U.S. Cl.** **33/327**

[51] **Int. Cl.** **G01c 19/38**

[58] **Field of Search** 33/324, 325, 326, 33/327

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Primary Examiner—Robert B. Hull
Attorney—Howson & Howson

[57] **ABSTRACT**

A pendulous gyrocompass of the type in which the rotor case if floated and the motor for driving the rotor in the rotor case is supplied with electrical power through a pair of specially-constructed electrically-conductive azimuth gimbal pivots of the needle-bearing type. The other gimbals in the gimbal support system may be relatively lower-grade bearings, with conventional arrangements for passing the motor current through or around them. The resultant gyrocompass may be of small size and low cost, and does not require servo's, pickoffs, torquers, sliprings, internal power supplies or other specialized compensating or correcting devices, yet provides an accuracy suitable for many applications.

3 Claims, 15 Drawing Figures

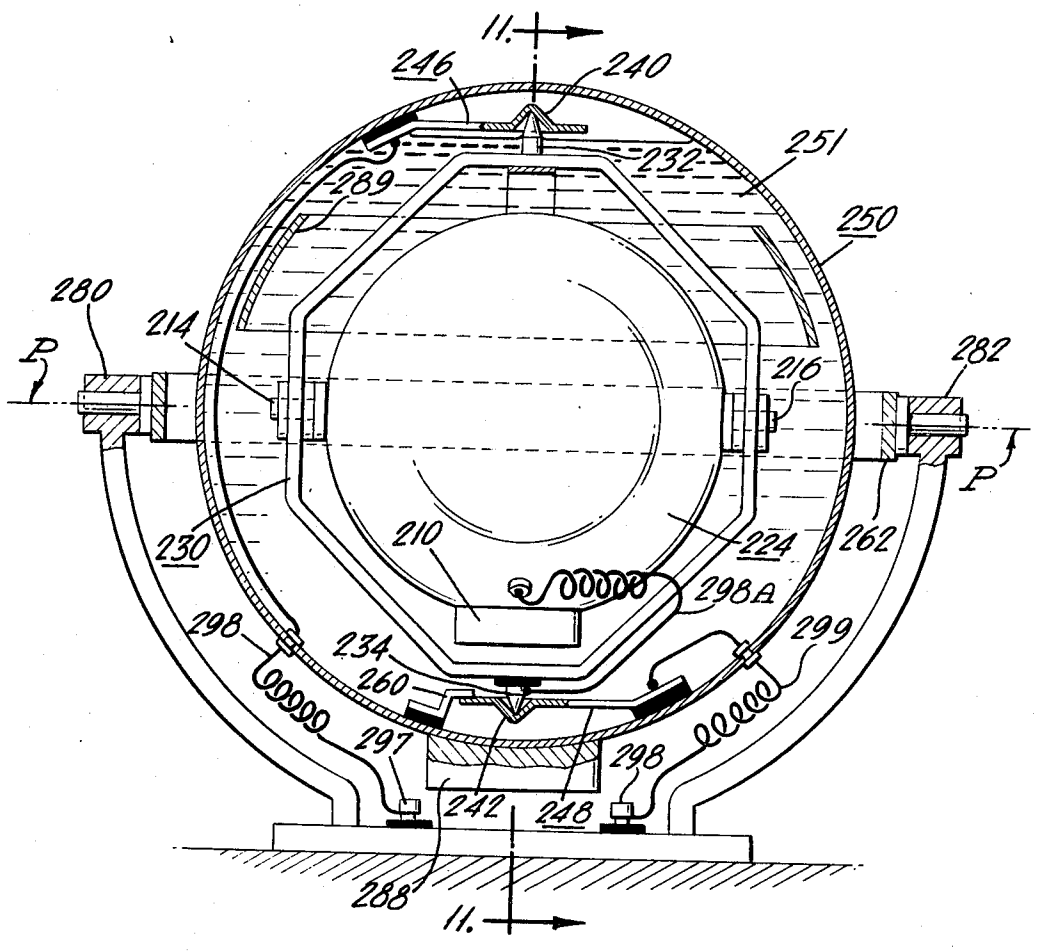


FIG. 1.

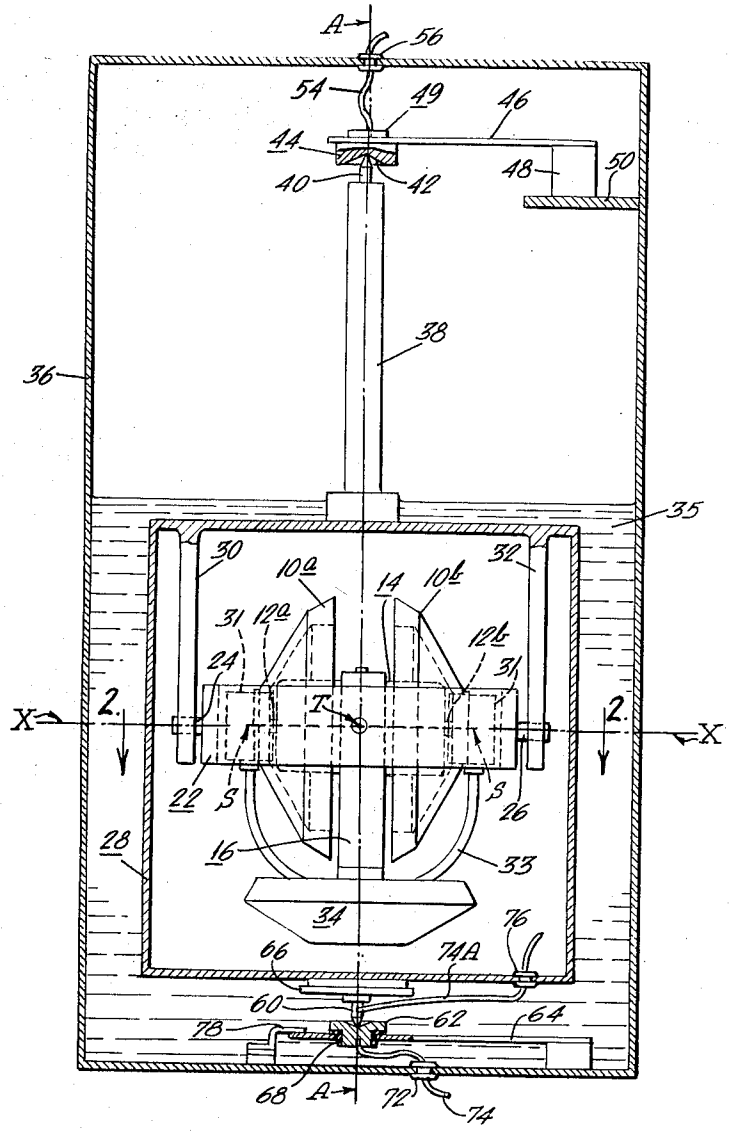
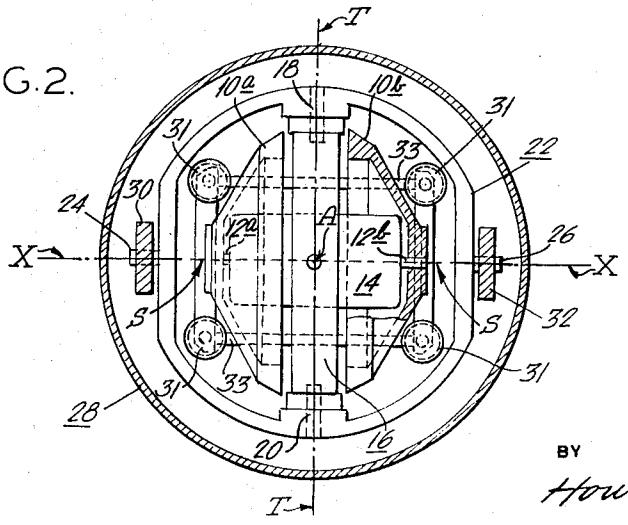


FIG. 2.



INVENTOR
MARVIN TAYLOR

BY
Howson & Howson
ATTYS.

FIG. 3.

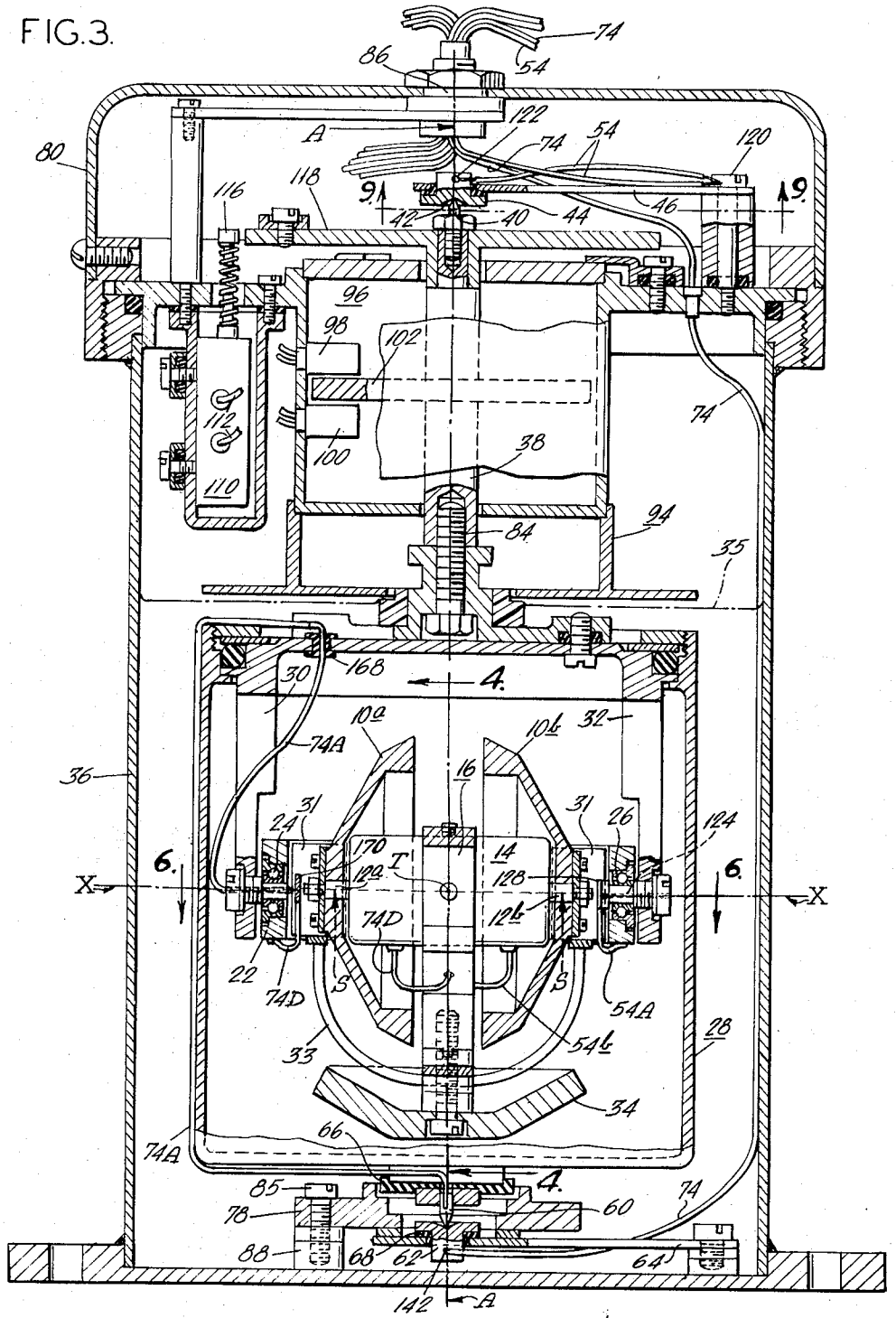
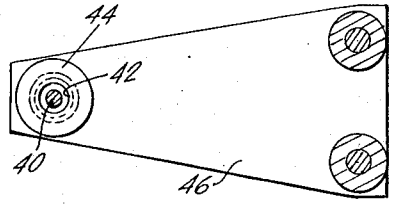


FIG. 9.



INVENTOR:
MARVIN TAYLOR

BY Howson & Howson

ATTYS.

FIG. 4.

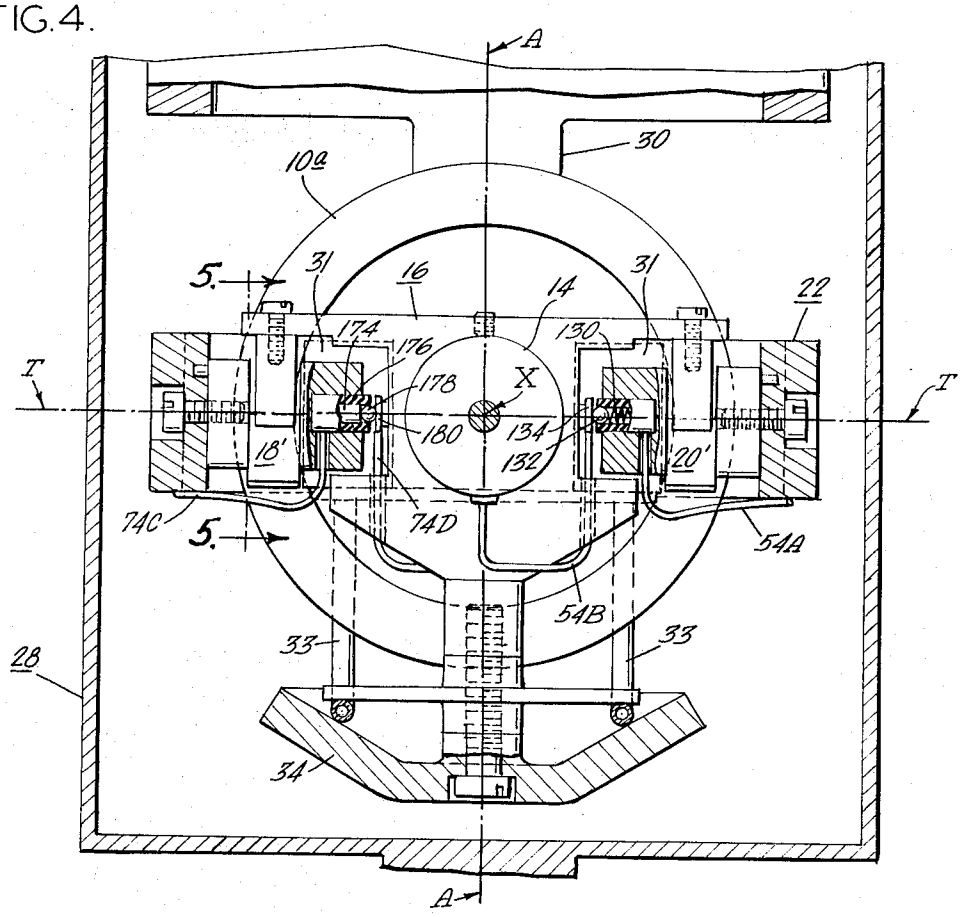


FIG. 5.

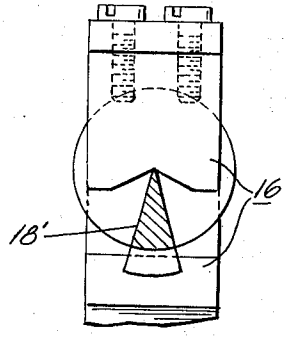
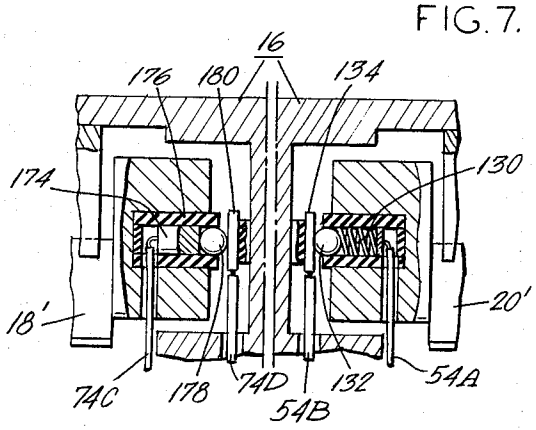


FIG. 7.



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MARVIN TAYLOR

BY

Howson & Howson

ATTYS.

FIG. 6.

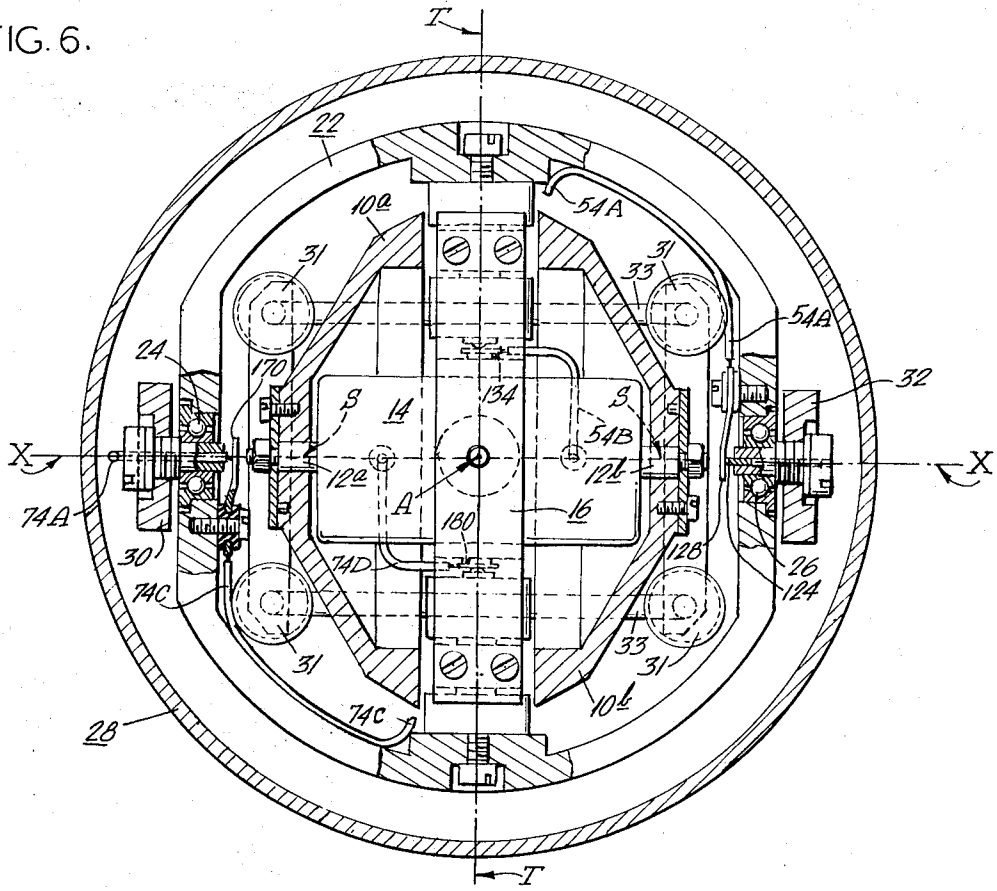
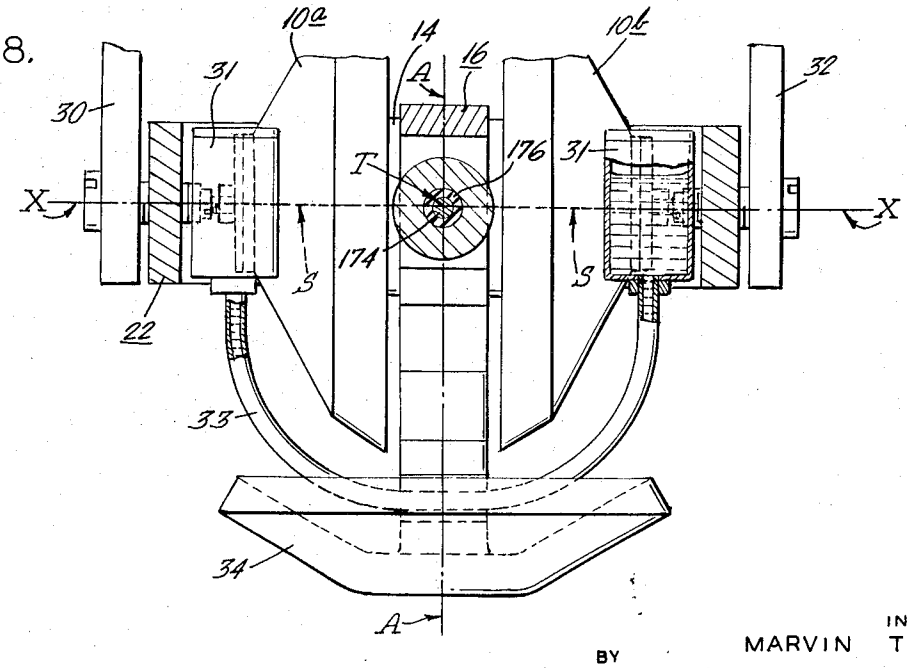


FIG. 8.



INVENTOR
MARVIN TAYLOR

BY Howson & Howson

ATTYS

FIG.10.

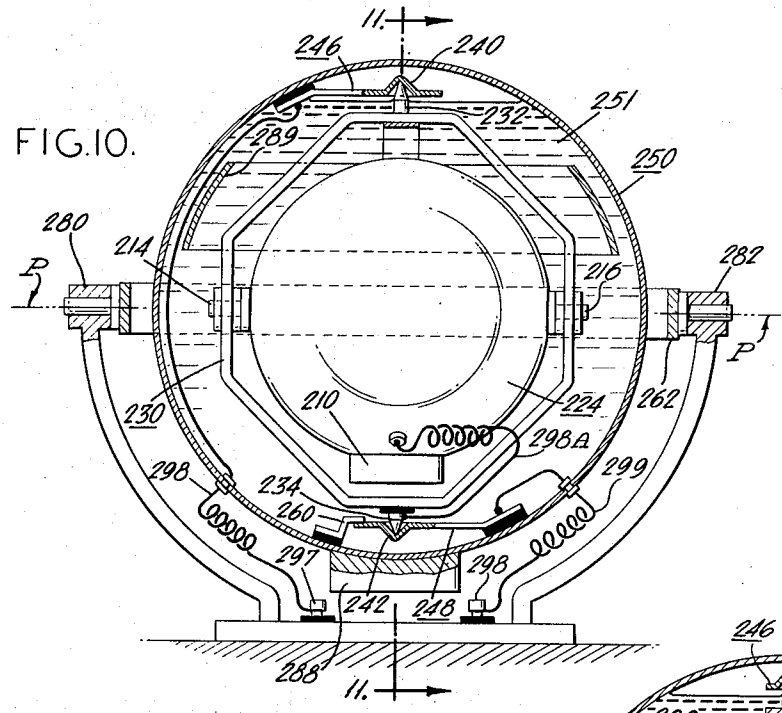


FIG.13.

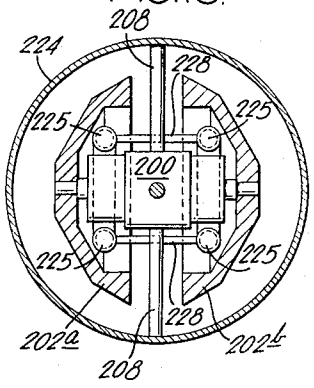


FIG.11

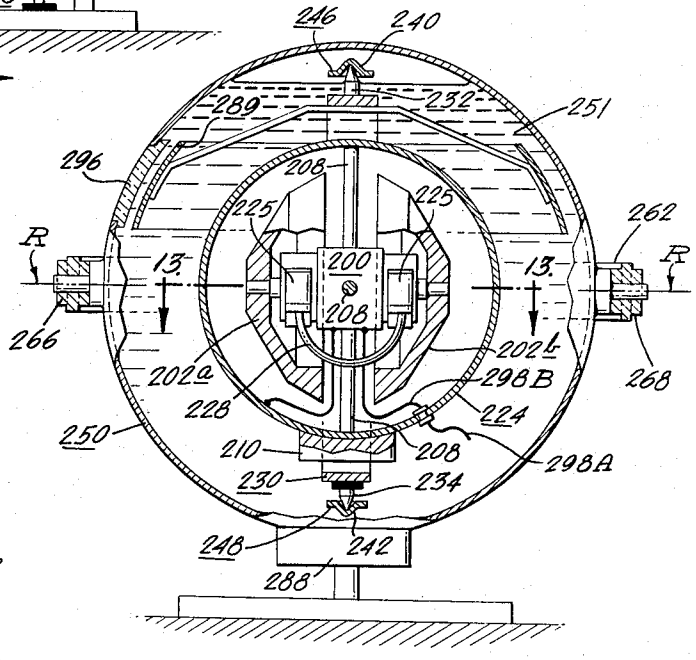
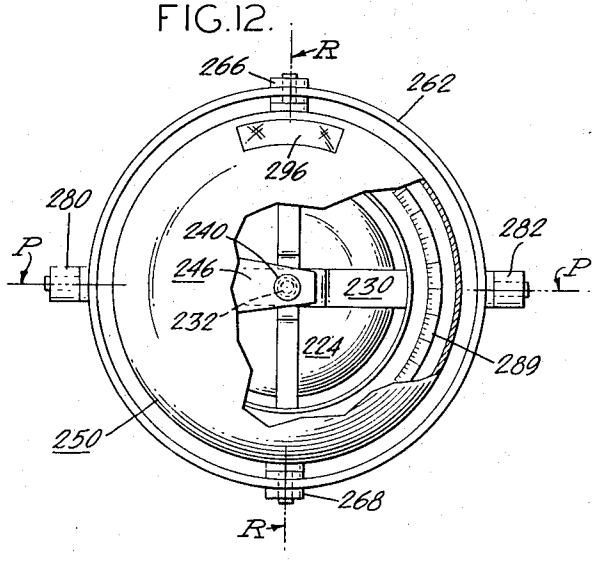


FIG.12.



INVENTOR:
MARVIN TAYLOR

BY
Howson & Howson

ATTYS.

FIG.15.

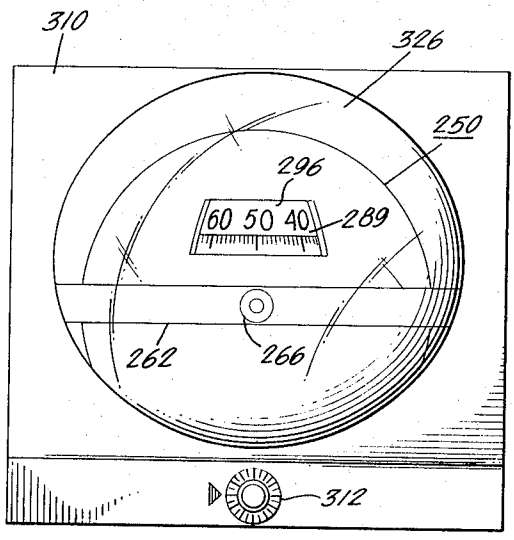
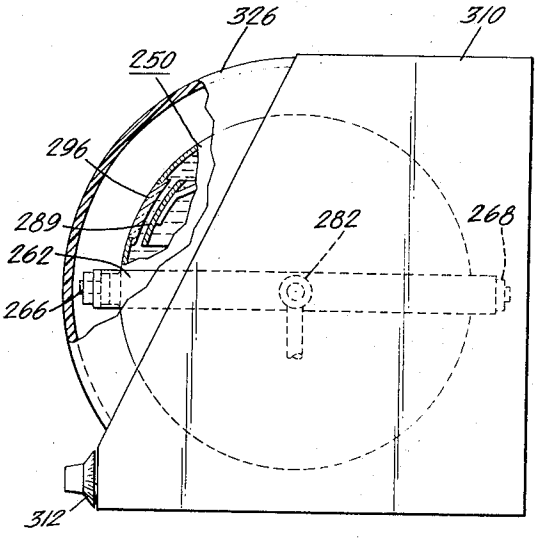


FIG.14.



INVENTOR:
MARVIN TAYLOR

BY

Howson & Howson

ATTYS.

GYROCOMPASS

BACKGROUND OF THE INVENTION

This invention relates to improvements in gyrocompasses, and particularly to improvements which result in greater simplicity and lower cost of pendulous gyrocompasses of the floated-case type.

Gyrocompasses have long been known in the art, and utilized very widely for purposes of marine and terrestrial navigation and the like. They are in fact standard on nearly all large ships, and serve the function of indicating the direction to the polar axis of the earth's rotation. In the usual form, the gyrocompasses utilizes, in effect, a pendulously mounted gyro rotor which, when set spinning, tends to maintain the direction of its spin axis fixed in inertial space. If at any time the spin axis is not pointing toward polar north, the rotation of the earth carrying the gyrocompass will result in an apparent raising of one end of the spin axis, although this axis is actually tending to remain fixed in direction in inertial space. Due to the pendulosity of the device, a torque will be exerted on the rotor in the direction to urge it back toward its apparently horizontal position with respect to the earth. However, due to the well-known precessional properties of a gyroscope, the resultant torque will in fact cause the spin axis to move instead about the vertical toward a position in which the spin axis points north. After some initial oscillation, the spin axis will point north, and will continue to do so despite rotation of the earth.

The principal advantage of the gyrocompass over the magnetic compass is that it is not dependent upon the direction of the earth's magnetic field, and hence is not sensitive to distortions of that field due to adjacent metal, such as the metal structure of a ship or other vehicle, nor to local or temporal variations in the earth's magnetic field, nor to stray magnetic fields of varying strengths. The gyrocompasses now available are generally very complex devices costing many thousands of dollars. While they are able to provide high accuracy, they may typically employ any or all of a number of relatively complicating, expensive devices, such as servo's pickoffs, torquers, sliprings, internal power supplies, speed correctors, temperature controllers, etc.

One of the problem areas resulting in such complexity relates to the need for supplying electrical power to drive the motor operating the rotor. Merely connecting wires directly from a base-supported power supply to a motor supported on the gimbal assembly will normally result in excessive inaccuracy due to the torques exerted by the electrical leads, and in many cases this will also interfere with completely full, free, azimuth rotation of the spin axis, such as is desirable to enable operation for any heading of the vehicle carrying the gyrocompass.

Attempts have been made to overcome this by including an electrical power source, such as a battery, within the rotor case itself, but this creates additional problems relating to the longevity and voltage regulation of the power source, as well as problems related to providing for replacement of the power source from time to time. One of the more sophisticated types of gyro compasses available attempts to overcome some of these problems by utilizing pickoffs which sense the azimuth angle deviation of the rotor case with respect to a surrounding outer case, and employs torquers and servo's to cause the outer case to follow the rotor case slowly in angular position about the azimuth axis, with the result that leads extending between the outer case and the gyro rotor will not be appreciably flexed during operation, and hence will not exert appreciable torques on the rotor, and will not be "wound up" by complete azimuth rotations of the gyro. The compass bearing is then determined by measuring the angular position of the outer case. Not only is such an arrangement expensive, but, due to its inherent complication, it tends to be unreliable and unstable, at least to some degree, and introduces more possibilities of malfunction. In some gyrocompasses sliprings have been utilized as a way of supplying the necessary electrical power across the various gimbals in the gimbal suspension but, particularly whenever relatively large numbers of such electrical connections are required, the sliprings exert undue frictional restraint and hence exert disturbing torques on the rotor.

Accordingly, it is an object of the invention to provide a new and useful gyrocompass.

Another object is to provide such a gyrocompass which is of low cost and size, and yet of an accuracy adequate for many purposes.

It is also an object to provide such a gyrocompass which does not require servo's, pickoffs, torquers, sliprings or batteries within the rotor casing.

BRIEF SUMMARY OF THE INVENTION

In accordance with the invention, these and other objects are achieved by the provision of a pendulous gyrocompass comprising a floated rotor case which contains gyro rotor means and electric motor means for spinning said rotor means about its spin axis, the gyrocompass also comprising azimuth axis gimbal means supporting said rotor case and permitting it to turn about the azimuth axis of the gyrocompass, and a pair of separate current-conductive paths for supplying operating current to the motor means, wherein the azimuth axis gimbal means comprises a pair of azimuth gimbal pivots the bearing surfaces of each of which are electrically conductive and positioned on the azimuth axis, the bearing surfaces of each of these pivots being electrically isolated from those of the other of said pivots, and one of the current conductive paths extending through the bearing surfaces of one of said pivots and the other of said current conductive paths extending through the bearing surfaces of the other of the pivots.

Preferably the two opposed bearing surfaces of each of the pivots are spring-tensioned against each other, and preferably one element of each of the pivots is a pivot pin having at one end a hard metal bearing surface symmetrical about the azimuth axis and of small radius of curvature, while the other element of each of the pivots is a pivot seat of hard metal in the form of a depression symmetrical about the azimuth axis. The above-mentioned spring-tensioning is preferably provided by a corresponding pair of cantilevered leaf springs which not only urge together the bearing surfaces of the pair of pivots but also serve as the positioning means for the azimuth axis of the gyrocompass.

It has been found that this type of gyrocompass is substantially less sensitive to undesired torques about its horizontal axes than to those about its azimuth axis, and that simple and inexpensive means of connection may be employed for supplying the electrical motor power across the gimbals of the horizontal axes; for example, the electrical current may be passed through

ball-bearing supports, through any of various forms of rubbing or rolling contacts, or even through flexible wires of small diameter. The gyrocompass is substantially more sensitive to undesired torques around its azimuth axis, and the preferred form of azimuth gimbal axis support, comprising pivots turning about and on the azimuth axis itself, provide a low-friction bearing arrangement in which such restraining frictional forces as do develop between the pivot surfaces are on, or so close to, the azimuth axis as to exert very little restraining torque. In the arrangement of the invention, these azimuth pivots themselves are used to supply the motor current, without introducing disturbing torques about the azimuth axis due to the means for supplying the motor current across the azimuth gimbal. Because of the floatation of the motor case, the load on the azimuth pivots is maintained very small so as to reduce any remaining frictional restraints about the azimuth axis. Positive electrical contact and definite positioning of the rotor case in the vertical direction is assured by use of the spring tensioning arrangement. Preferably the lower of these spring-tensioning arrangements which urges the rotor case upwardly is arrested in its upward motion by appropriate stop means, the upward urging force being sufficient to overcome the downward urging force due to the other spring means, thereby assuring a definite vertical position of the rotor case during normal operation, but providing the desired resilience to assure continuous electrical contact for accommodating sudden random or accidental accelerations along the azimuth axis without harm to the gyrocompass or its azimuth pivots.

BRIEF DESCRIPTION OF FIGURES

These and other objects and features of the invention will be more readily understood from a consideration of the following detailed description, taken in connection with the accompanying drawings, in which:

FIG. 1 is a schematic elevational view, partly in section, illustrating one form of the invention;

FIG. 2 is a sectional view taken along lines 2—2 of FIG. 1;

FIG. 3 is a vertical sectional view of a form of the invention shown in greater detail than in FIG. 1;

FIG. 4 is a sectional view taken along lines 4—4 of FIG. 3;

FIG. 5 is a sectional view taken along lines 5—5 of FIG. 4;

FIG. 6 is a sectional view taken along lines 6—6 of FIG. 3;

FIG. 7 is an enlarged fragmentary view of a portion of the apparatus as shown in FIG. 4, with portions omitted;

FIG. 8 is an enlarged fragmentary view of a portion of the apparatus as shown in FIG. 3;

FIG. 9 is a sectional view taken along lines 9—9 of FIG. 3;

FIG. 10 is a schematic elevational view, partly in section, showing another form of embodiment of the invention;

FIG. 11 is a sectional view taken along lines 11—11 of FIG. 10;

FIG. 12 is a plan view of the apparatus of FIG. 10;

FIG. 13 is a sectional view taken along lines 13—13 of FIG. 11;

FIG. 14 is a side view of one physical form of realization of the apparatus of FIG. 10; and

FIG. 15 is a front elevational view of the apparatus of FIG. 14.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

Referring first to the embodiment of the invention illustrated schematically in FIGS. 1 and 2, in which the parts are not necessarily to scale and various unnecessary details have been omitted in the interest of clarity of exposition, there is shown a gyro rotor 10*a*, 10*b* in this instance made in two parts which are mounted respectively on the two motor shafts 12*a* and 12*b* extending from opposite ends of the electric motor 14, so that when the motor 14 is supplied with electrical operating power the gyro rotor is spun rapidly about the spin axis S. The motor 14 is held by a rotor mount 16 encircling the motor, and the motor mount in turn is rotatably supported for easy turning about the tilt axis T by means of the opposed tilt axis pivots 18 and 20. The tilt axis pivots 18, 20, in turn are fixed to a gimbal ring 22 supported at opposite sides thereof by a pair of pivots 24 and 26 for easy turning about an axis X disposed at right angles to the tilt axis and to the azimuth axis A. The latter pivots, 24, 26 are affixed to the interior of the sealed rotor case 28 by the supports 30, 32. A pendulous weight 34 is affixed to the motor mount 16 to render the motor and the rotor assembly pendulous about the two axes T and X. Appropriate damping means for damping out gyrocompassing oscillations about the azimuth axis may be provided in the form of the four liquid-containing chambers 31 and appropriate interconnecting tubing such as 33, which may be filled with a heavy liquid such as mercury to provide damping in known manner.

The rotor case 28 is suspended in substantially neutral buoyancy within the liquid 35, which may be a conventional gyro floatation liquid of low viscosity, low volatility, and high electric resistivity, held within an outer casing 36. By appropriate selection of the size of the rotor casing with respect to the weight of its contents and of the parts affixed thereto, and with respect to the density of the floatation liquid, the rotor casing and the external elements affixed thereto are caused to have little substantial tendency to sink or rise within the liquid over a substantial temperature range, and are substantially weightless.

The arrangement and construction thus far described with reference to FIGS. 1 and 2 may be generally conventional in form. In accordance with the invention, the rotor case is supported and positioned, and electrical operating currents applied to the motor 14, in the manner now to be described.

A metal shaft 38 affixed to the top of rotor case 28 extends upward along the azimuth axis and carries at its upper end an upwardly-directed pivot pin 40 ending in an upwardly-directed conical point or end of small radius and of hard material such as steel. The upward tip of pivot pin 40 is seated in the bottom of a generally conical concavity 42 in the pivot seat 44. Seat 44 is of hard, electrically-highly-conductive material such as a hardened precious metal alloy. Pin 40 has a radius at its tip that is considerably smaller than the radius at the bottom of concavity 42. The pivot seat 44 is retained in the outer end of a cantilevered leaf spring 46, the other end of which is secured to a suitable mount 48 affixed to a projection 50 on the interior of the outer casing 36. Spring 46 is pre-tensioned downwardly so as to

urge pivot pin 40 and pivot seat 44 against each other.

In the form shown, the pivot seat has an upwardly-extending portion 49 of reduced diameter extending through an opening in the leaf spring, to which upper portion an appropriate electrical lead 54 is conductively secured. The latter lead exits from the outer casing by way of an appropriate bushing 56 and, during operation of the gyrocompass, will be supplied with operating current from one terminal of the electrical supply source. As an example, this may be the ground terminal of the supply source and, due to the electrically conductive path through the pivot seat, pivot pin and shaft 38 and the rotor casing 28, the supports 30, 32 are maintained at the potential of the lead 54, in this example ground.

At its bottom end, the rotor case 28 is supported by another azimuth pivot comprising pivot pin 60 and pivot seat 62, the latter pivot seat being supported in turn at the outward end of the cantilever spring 64 mounted on the outer casing 36. The azimuth pivot below the rotor casing may be like that described previously for use above the rotor casing, with the exception that both the pivot pin 60 and the pivot seat 62 are insulated from the rotor case, and from the outer casing, by means of insulating supports 66 and 68 respectively. In this example the rotor case 28, the shaft 38, and the upper and lower azimuth pivots constitute the azimuth gimbal means of the gyrocompass.

To supply electrical motor power across the lower pivot, the external motor lead 74 is passed through a bushing 72 in the outer casing and conductively connected to the pivot seat 62, and a lead 74A is conductively connected from the pivot pin 60 through an appropriate sealing bushing 76 to the interior of the rotor case. The latter lead 74A may then be connected to the ungrounded or "hot" supply terminal of the motor 14 in any convenient manner which will not introduce undue restraint on the gyro rotor, for example, by insulated leads passing through and along the horizontal support axes for the rotor, or even by a direct flexible wire connection. In this way, again, the conductive path for supplying current to operate the motor is passed through the pivot on the azimuth axis, thereby minimizing undesired torques about the azimuth axis. This pivot arrangement again also provides a very low friction support for permitting free turning of the rotor case in azimuth, and positions the rotor case vertically along the azimuth axis as well as centering it in position on a horizontal plane due to the symmetrical concavity forming the pivot-seat bearing surface.

As shown, a stop 78 is preferably secured to the outer casing in a position to arrest the upward motion of the lower pivot during normal operation, the lower cantilever spring 64 being biased upwardly sufficiently strongly to cause the pivot to remain urged against the lower surface of the stop. This provides a definite vertical positioning of the rotor case under conditions of normal operation, while at the same time providing sufficient spring tension to maintain the azimuth bearing surfaces in appropriate contact under low load, and to assure the desired electrical contact by which the motor power is supplied across the azimuth pivots. For example, utilizing the rotor case arrangement shown in FIG. 1, the lower spring 64 may exert an upward spring force of about 2 ounces against the stop 78, and the upper spring 46 may exert a downward force of about 1 ounce, providing the desired azimuth axis centering, vertical positioning and electrical contact.

Referring now to FIGS. 3–9 which show in more detail a representative embodiment of the invention shown schematically in FIG. 1, parts corresponding to those of FIG. 1 are indicated by corresponding numerals.

There are again employed the outer casing 36 in this case provided with a top cover 80 which is screwed on to the upper part of the casing; the rotor case 28, in this example in the form of a metal cylinder; the shaft 38 secured to a bushing on the top of the rotor case 28 by means of a bolt 84; the upper and lower pivot pins 40 and 60 respectively; the upper and lower pivots seats 44 and 62 respectively; the upper and lower cantilever springs 46 and 64 respectively; the motor 14; the motor mount 16 with the pendulous weight 34 at the bottom end thereof; the damping arrangement consisting of the four chambers such as 31 and the interconnecting tubing 33; the stop 78 mounted by screws such as 85 on a boss 88 secured to the bottom of the interior of the outer casing; the two-part rotor 10*a*, 10*b*; the leads 74 and 54 for supplying electrical operating power to the motor, which in this embodiment enter through an appropriate bushing 86 in the outer casing cover 80; the gimbal ring 22; the ball-bearing pivots 24, 26 for turning about the X axis; and several additional details of construction preferably utilized in this embodiment and to be described hereinafter.

As is shown particularly clearly in FIG. 5, the tilt axis is provided in this example by knife-edge bearings 18′, 29′, the knife edges serving to support the motor and rotor assembly for tilt motion thereof. However, other arrangements such as ball-bearing pivots may be utilized for the tilt pivots if desired, as in the case of the pivots 24, 26.

The floatation liquid level, as shown in FIG. 3, is above the rotor case 28 but below the liquid baffle structure 94. The latter baffle structure is preferably used to impede the flow of the liquid into the region occupied by the shaft encoder 96, when the gyrocompass is tilted. The shaft encoder 96 may be of conventional form, including for example a light source assembly 98 and a photocell assmbly 100 cooperating with an optically-coded disc 102 secured to shaft 38. Appropriate leads from the exterior of the outer casing are passed through bushing 86 to supply the lamps in the light source assembly, and appropriate output leads from the photocell assembly 100 pass outwardly through the bushing 86. The voltages on the latter set of photocell leads provide a direct external voltage indication of the angular position of the rotor case 28 with respect to the outer casing, and may be utilized to operate any exterior angle-indicating device or to supply information to a computer, for example.

Also shown in this example is a slewing motor 110 having motor leads 112 connected to an external source of power by way of the bushing 86 for rotating a spiral spring 114 when an external operator's switch is actuated, the spring supporting at its upper end a weight 116. When motor 110 is operated and spring 114 and weight 116 caused to spin, the weight 116 executes a wobbling circular motion, departing from the axis of the spring sufficiently to strike the periphery of the disc 118 secured to the shaft 38, causing the latter disc to turn on one direction of rotation; when the direction of the motor 110 is reversed by means of the ex-

ternal control, the circular motion of the weight **116** is in the opposite direction and tends to turn the disc **118** in the opposite sense. In this way the rotor case **28** and its contents may be moved rapidly to a desired angular position with respect to the outer casing at a more rapid rate than would be the case if one merely waited for the normal gyro precessional motion to occur.

The particular manner of supplying the motor electrical motor power from the exterior will now be outlined. Lead **54** from the exterior of casing **36** passes through the bushing **86** to the screw terminal **120** and then to a connection point **122** on the pivot seat **44.** From here the conductive path extends through the pivot pin **40** and the conductor shaft **38** to the rotor case **28,** the thence through the metal supports **30, 32** to the gimbal **26.** Although conduction through this gimbal may be by way of the ball-bearing assembly contained therein, it is preferred in this example to include a conductive pin **124** (see especially FIG. **6**) aligned with the X axis of that gimbal, which at its inner end makes sliding electrical contact with a blade **128** secured to the conductive gimbal ring **22.** Again, although conduction through the gimbal ring **22** may be relied upon in this example lead **54A** is employed which extends quarter way around the gimbal **22** to the tilt axis (see especially FIG. **4** and FIG. **7**), where it connects to a spring **130** which contacts and urges outwardly a conductive ball **132,** thereby urging the latter ball against a conductive plate **134** to provide a rolling conductive contact across the tilt axis. The plate **134** is in turn connected by the lead **54B** to the motor to supply the necessary operating power. The current path just described, as mentioned above, may reprsent the ground connection for the motor.

The other, or "hot" conductive path for supplying currrent to the motor starts with external lead **74,** which passes downwardly to make electrical contact at **142** with the lower pivot seat **62.** The insulator bushing **68** provides electrical insulation from the spring **64.** The conductive path then extends to the pivot pin **60,** which is electrically insulated from the rotor case **28** by the insulating washer **66.** The lead **74A** then extends from pin **60** around the outside of the rotor case to the sealed feed-through **168** and thence to the X-axis pivot **24.** The lead with its surrounding insulation extends along the X axis through this pivot and through the gimbal ring **22,** and is exposed at its outer end to form a sliding contact with the blade **170** mounted in insulating fashion on the gimbal ring **22.** From the blade **170,** the lead **74C** then extends quarter way around the gimbal ring **22** to the tilt axis and then, as shown in FIG. **7,** makes contact to a metal slug **174,** insulated from its surroundings by the insulating bushing **176.** The slug **174** is in contact with the ball **178,** which is adapted to contact the disc **180** mounted on the motor side of the tilt axis. From the disc **180** the lead **74D** then extends to the "hot" terminal of the motor.

FIGS. **10** through **15** illustrate another embodiment of invention utilizing the same type of azimuth axis pivot for azimuth axis support and for the supply of motor current to the interior of the floated rotor case, but utilizing a different gimbal support system and a different arrangement for providing output indications of azimuth angle. In particular, FIGS. **10–13** show schematically a type of floated rotor-case gyrocompass comprising a spin motor **200,** a two-part rotor **202*a*, 202*b*** mounted to be spun by the motor about the spin axis; a motor-support **208** having a pendulous portion **210** for making the motor and rotor assembly pendulous about a tilt axis provided by the tilt pivots **214** and **216,** which may, for example, be ball-bearing pivots. However, in this case, the rotor case is a spherical metal shell **224** and the motor and rotor assembly contained therein is fixed to the interior of the rotor case, the rotor case and the motor and rotor assembly being mounted as a unit on the tilt axis bearings. A suitable damping arrangement comprising liquid chambers such as **225** and interconnecting tubes such as **228** is provided, also as a part of the unitary assembly within the rotor case.

The tilt axis pivots are mounted on the generally-vertical gimbal ring **230,** on which the azimuth pivot pins **232** and **234** are provided, lying along the azimuth axis on opposite sides of the vertical gimbal ring. The azimuth pivot seats **240** and **242** are mounted on respective cantilever springs **246** and **248,** which in turn are supported on the interior of the outer casing **250.** The outer casing contains a floatation liquid **251.** The lower pivot seat is again electrically isolated from the other metal parts of the gyrocompass, in this case by mounting the lower cantilever spring and the stop **260** on insulating blocks.

The outer casing in this example is mounted upon a generally-horizontal gimbal ring **262,** which in turn is free to turn about a roll axis R by virtue of roll-axis pivots **266** and **268.**

The roll-axis pivots in turn are supported on an outermost pitch gimbal ring **262** for turning about the pitch axis P by means of pitch axis pivots **280** and **282,** the latter pivots then being fixed to the supporting substructure on which the gyrocompass is mounted. The outer casing is also rendered pendulous by means of th pendulous weight **288,** whereby the azimuth axis is maintained vertical as desired.

Output azimuth-angle indications may be provided by means of a card **289** in the form of a ring mounted on the vertical azimuth gimbal ring **230** and bearing angle-representative indicia viewable through a transparent window **296** in the outer casing blank.

One motor lead is supplied with power from the binding post **297** by way of the lead **298** which extends through the outer casing to the upper cantilever spring and then through the upper pivot, thereby grounding the vertical gimbal ring **230** and the metal structure supported thereon, including the rotor case and motor support, to which support the ground connection of the motor may be connected. The "hot" lead extends from binding post **298** through lead **299** into the outer casing and to the lower cantilever spring, whence the conductive path passes through the lower pivot pin **234** through the lead **298A** to the floated rotor case **224,** and through the wall of the rotor case to the interior, where it may be connected to the "hot" motor lead terminal by lead **298B.**

Accordingly, in this configuration also the azimuth gimbal axis means comprises the pair of pivots each having their pivot points on the azimuth axis, and again the parts of each pivot are urged lightly together by spring means which also act on opposite sides of the azimuth axis structure, the conical nature of the pivot seats providing lateral positioning of the azimuth axis. The stop means **260** together with cantilever spring **248** again provides a fixed vertical position for the azimuth axis, as described previously. The rotor case is floated

by means of the liquid **251** so as to reduce the weight on the lower azimuth pivot to a very small value. There has thereby been provided a simple, small, inexpensive gyrocompass in which accuracies of **2** to **4** degrees are easily obtained, and which is particularly useful on marine vessels.

FIGS. **14** and **15** show one general physical embodiment of a product embodying such a gyrocompass, wherein there is provided an external housing **310** having an on-off power switch **312** for controlling the supply of current to the gyro spin motor, and supporting and housing a gyrocompass like that illustrated schematically in FIGS. **10–13,** corresponding parts being indicated by corresponding numerals. The outer casing **250** and the window **296** thereof extend outward from the slanted front of the external housing, with the azimuth-angle card **289** providing visible indications of the azimuth angle between the rotor case and the outer casing and hence of the angular deviation from true north of a reference line fixed to the external casing and to the vehicle on which it is mounted. The external generally-horizontal gimbal ring **262** also protrudes somewhat from the slant in front of the external housing, and the entire exposed front face of the assembly is covered with a clear plastic cover or bubble **326** to protect the gyrocompass from the external environment. Such a unit is inexpensive, small, easy to utilize and yet of sufficient accuracy for many purposes.

While the invention has been described with particular reference to specific embodiments thereof in the interest of complete definiteness, it will be understood that it may be embodied in a variety of forms diverse from those specifically shown and described without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. In a pendulous gyrocompass comprising a floated rotor case containing gyro rotor means and electric motor means for spinning said rotor means about its spin axis, said gyrocompass also comprising azimuth axis gimbal means supporting said rotor case and permitting it to turn about the azimuth axis of the gyrocompass, and a pair of separate current-conductive paths for supplying operating current to said rotor means, the improvement wherein:

said azimuth axis gimbal means comprises a pair of azimuth gimbal pivots the bearing surfaces of each of which are electrically conductive and positioned on said azimuth axis, the bearing surfaces of each of said pivots being electrically insulated from those of the other of said pivots, and one of said current-conductive paths extending through the bearing surfaces of one of said pivots and the other of said current-conductive paths extending through the bearing surfaces of the other of said pivots; and means for spring-tensioning the bearing surfaces of each of said pivots against each other.

2. The gyrocompass of claim **1,** in which said means for spring-tensioning comprises a pair of cantilevered leaf springs for urging together said bearing surfaces of said pair of pivots.

3. The gyrocompass of claim **1,** wherein said means for spring-tensioning is arranged to spring-bias downwardly the upper pivot of said pair of pivots and to spring-bias upwardly the lower pivot of said pair of pivots, and comprising stop means secured to said outer casing limiting the upward movement of said lower pivot, the upward spring-bias of said lower pivot being sufficient to maintain said lower pivot in its upwardmost position as determined by said stop means during normal operation of said gyrocompass.

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