Sept. 2, 1941. K. E. KUNZE ET AL 2,254,610

MAGNETIC COMPASS

Filed Dec. 17, 1938

FIG. 1

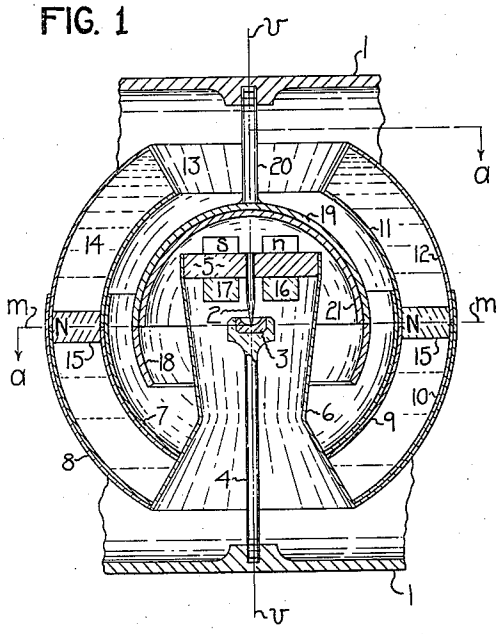


FIG. 4

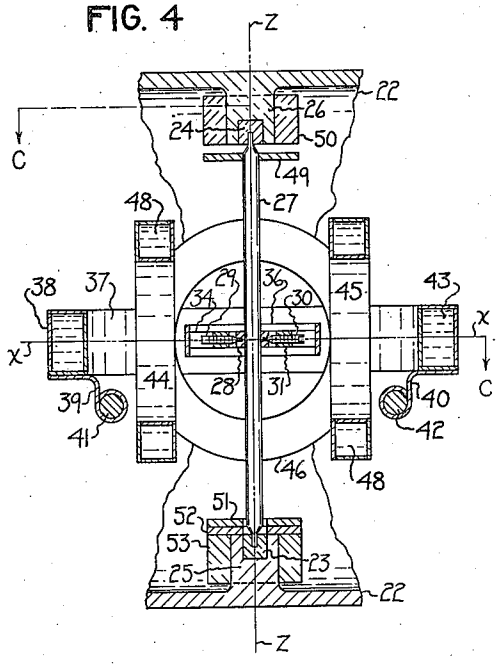


FIG. 2

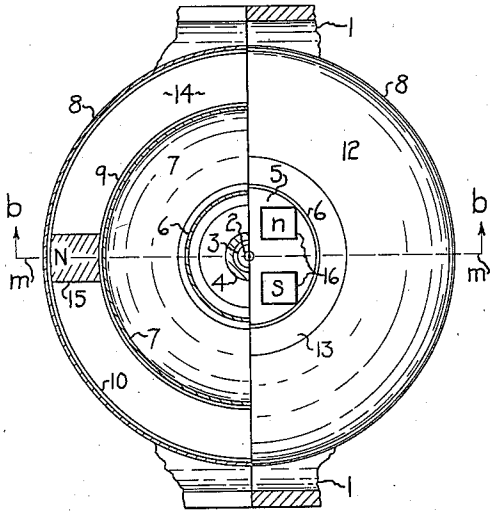


FIG. 5

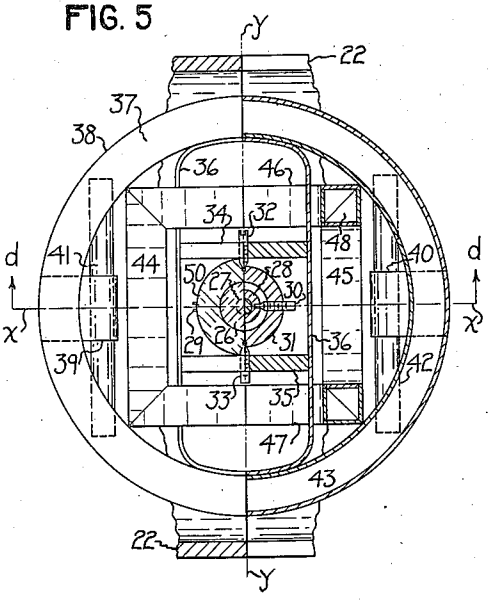
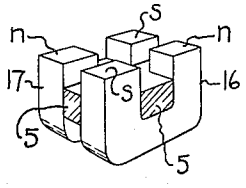


FIG. 3



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MAGNETIC COMPASS

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7 Claims. (Cl. 33—223)

The invention relates to damping devices for magnetic compasses.

The major object of the invention is to provide for damping the oscillations of the directive element of a magnetic compass by means independent of motions of the walls of the containing case.

Present-day liquid damped magnetic compasses are, universally, subject to a displacement of the directive element by the damping liquid when the latter is set in rotary motion by the case, during turns. This "swirl effect" is unavoidable with the present arrangement wherein the damping liquid is in contact with the walls of the case, which must turn with the ship, as well as with the directive element, which should remain fixed in azimuth.

We are aware that it has been proposed to overcome this inherent defect by limiting the surfaces, with which the damping liquid is in contact, to portions of the directive element, only, but this increases the weight of the directive element to a degree which results in impracticably high values of the pivot pressure.

We combine means for uncoupling the damping liquid from portions of the compass moving with the ship, and means for regulating the pressure on the bearing of the directive element. This combination results in the elimination of the swirl effect, without impairing the sensitivity of the directive element.

A secondary object of the invention is to decrease the weight of the magnetic compass by decreasing the quantity of damping liquid required.

A third object of the invention is to decrease the size of the magnetic compas by eliminating the necessity for the comparatively large spaces between the case and the directive element, required, at present, to reduce the swirl effect to a minimum.

The drawing illustrates several forms of the invention.

Fig. 1 is a center line sectional elevation of a preferred form of the invention, the drawing being the section *b—b* of Fig. 2.

Fig. 2 is a plan view of the arrangement shown in Fig. 1, the drawing being the section *a—a* of Fig. 1.

Fig. 3 is a perspective detail of the lifting magnet shown in Figs. 1 and 2.

Figs. 4 and 5 are views of another form of the invention, Fig. 4 being a center line sectional elevation taken as indicated by *d—d*, Fig. 5, while Fig. 5 is a plan view sectioned as indicated by *c—c*, Fig. 4.

In our present preferred form, the containing case, indicated by the fragments 1, Figs. 1 and 2, houses a directive element which is carried by the pivot 2, resting upon a jewel 3 in the conventional manner. A post 4, screwed into a threaded recess in a boss at the bottom of case 1, as shown, carries the jewel 3. The pivot is pressed into a central hole in a disk 5 and the disk is pressed into the upper opening of the funnel-shaped piece 6, the disk 5 and piece 6 thereby acting as a frame upon which the directive element is mounted. The framework is completed by the two pieces 7 and 8, which are shaped as portions of spherical shells and which are fastened, concentrically relative to the pivot point, upon the lower flared skirt of the piece 6, as may be seen in Fig. 1. Pieces 9, 10, 11, and 12, having the shapes of portions of spherical surfaces, together with piece 13 and the lower skirt of piece 6, form a container having the shape of a portion of a spherical shell whose center is at the point of the pivot 2. This container is partially filled with a damping liquid 14. Piece 9 fits, as an inverted cap, over shell 7 and is fastened thereto. Shell 10 conforms to the inside surface of piece 8 and is secured to the latter. The lower edges of pieces 11 and 12 are soldered, respectively, to the upper edges of pieces 9 and 10. The lower portions of shells 11 and 12 are also secured, respectively, to the upper portions of pieces 7 and 8. Piece 13, shaped in the form of the frustrum of a cone, is soldered to the upper edges of shells 11 and 12.

The directive magnet system is comprised of the two short, thick, bar magnets 15 mounted within the liquid container and secured to the shells 9 and 10. The north-seeking poles N of the two magnets point in the same direction and the common magnetic axis of the pair of magnets is the line *m—m*. The magnets 15 are formed of material of high coercive force, and the inner shell 9—11 is of magnetic material for the purpose of forming a flux path of low permeability between the adjacent poles of the two magnets.

The system so far described constitutes a north-seeking directive element mounted for universal motion about the point of pivot 2. Compass graduations, or other markings for determining azimuth, may be carried by the directive element in any of the well known ways.

Oscillations of the system about the pivot point are damped by the inertia of the liquid 14. The inertia of the liquid mass causes its own

oscillations, set up by the oscillations of the directive element, to be out of phase with the latter. Damping of the oscillations of the directive element follows, because of the viscous drag of the liquid upon the inner walls of its container. Azimuth oscillations, i. e., oscillations about the vertical axis v—v are damped by the entire liquid mass, while oscillations about any horizontal axis are damped by zones of liquid having the axis of oscillation as their axis. Since the damping liquid **14** and the case **1** are not in mutual contact, the liquid is never set into swirling motion by the case. Thus the "swirl effect" is absent.

In order to make practicable the use of a damping liquid carried by the directive element, as described, we employ means, other than the pivot, for carrying the largest portion of the weight of the directive element without introducing additional bearing friction or torques tending to rotate the directive element about the pivot point. Without such means for carrying the larger portion of the weight of the directive element, the use of damping liquid carried by the directive element itself would be impracticable, due to the excessive weight on the pivot. The adverse results of excessive pivot pressure are well known.

In the arrangement illustrated by Figs. 1 and 2, we use two small horse shoe magnets **16** and **17** attached to the directive element, and a shield **18**—**19** of magnetic material, fixed relative to the case **1**. The magnets **16** and **17** are pressed through holes in the disk **5**, the poles being uppermost and arranged astatically, as shown in Fig. 3. The shield, of magnetic material, composed of upper shell **19** fastened to lower shell **18**, has an inside spherical surface whose center is located at the point of pivot **2**. The shield is secured to a post **20** which is screwed into a threaded recess in a boss in the top of case **1**, as shown. A non-magnetic lining **21** is fitted to the inside surface of the shell **19**. The inside surface of the lining **21** is hemispherical and has its center at the normal position of the point of pivot **2**, this surface being of such radius that, during normal use, the directive element may oscillate about the pivot point without mechanical interference from the lining, but the clearance is, also, small enough so that the magnets **16** and **17** exert the required lift upon the directive element, due to the tractive force acting between magnets and shield. The shield **18**—**19** includes a sufficiently large portion of the entire spherical surface of which it is a part, to insure a radially-directed lift line at all times. That is, the line of the resultant force between the magnets and the shield passes through the pivot point for all positions of the directive element, since the magnets never approach the shield rim closely enough to be appreciably drawn tangentially toward the pole of the shield.

The astatic arrangement of the poles of magnets **16** and **17**, Fig. 3, produces, in conjunction with shield **18**—**19**, practically no distortion of the earth's field in the vicinity of the directive magnets **15**. Any such distortion is further reduced by the presence of the shell of magnetic material **9**—**11**, which acts as a short-circuiting path for the external field. Thus the directive element receives the required lift without the introduction of torques tending to deflect it about any axis, or additional friction tending to retard its motion in any way. The lining **21** acts as a spacer, thereby preventing the poles of the lifting magnets **16** and **17** from adhering to the shield **19** if the directive element is lifted off the jewel **3** during vertical accelerations.

A second form of the invention is illustrated by Figs. 4 and 5. Here we again show fragments, only, of a case **22**, since the particular construction of the case forms no part of this invention. A spindle **27** is carried by two bearings **23** and **24** for rotation about its own axis z—z, which is normally vertical. The bearings are fitted in bosses **25** and **26** of the case. Secured to the spindle, midway between the bearings, is a ring **28**, drilled on a diameter to receive the tips of two pivots **29** and **30**. A small gimbal ring **31** is drilled and tapped to receive the shanks of these pivots, and is carried thereby. The ring **31** is drilled on a diameter which is perpendicular to the axis of the pivots **29** and **30**, to receive the tips of two pivots **32** and **33**, Fig. 5, these pivots being threaded through the bars **34** and **35**, forming cross members of a frame **36**. The center lines of the pivots **29** and **30** are aligned in the axis x—x, while the pivots **32** and **33** determine the axis y—y. The three axes x, y, and z are mutually perpendicular.

The hollow, toroidal, container **37** is fastened to, and carried by, frame **36**, the axis of the toroid coinciding, usually, with the axis z—z. This is the condition illustrated. The outer wall **38** of the container may be a compass card. Two brackets **39** and **40**, fastened to the bottom of container **37**, hold the directive magnets **41** and **42**. A damping liquid **43** partially fills the container **37**.

A system consisting of four hollow, toroidal, containers **44**, **45**, **46**, and **47** is mounted upon the inner rim of container **37**. The four containers are interconnected, as a unit, and the hollow interior spaces are open to each other. The system is partially filled with a damping liquid **48**. Containers **44** and **45** have the common toroidal axis x—x, while the axis y—y is common to the remaining pair, **46** and **47**.

For reducing the otherwise excessive pressures of the spindle **27** upon the lower bearing **23**, we provide a magnetic lifting system comprising the magnet **50**, having an hollow center, which is pressed into position over the boss **26**, and the disk **49**, of magnetic material, secured upon the spindle **27**. The lift exerted by the magnet **50** upon the directive element, through the disk **49**, is initially adjusted to allow only a small fraction of the total weight of the directive element to be carried by the sensitive lower bearing.

A compensating system which is, magnetically, practically a duplicate of the lifting magnet system, is arranged, symmetrically relative to the directive magnets, around the lower bearing, for the purpose of compensating the disturbing effects of the lifting magnet system upon the directive magnets. This compensating system consists of the magnet **53**, which is similar to the magnet **50** and of the pole strength required for the compensation, pressed over the lower boss **25**; and a disk of magnetic material **51** mounted in the same position relative to magnet **53** that the disk **49** occupies relative to the magnet **50**. However, the disk **51** is mounted upon a non-magnetic spacer **52**, which is fastened to the magnet **53**, the disk and spacer being drilled to clear the spindle **27**, as shown.

The action of this directive element is as follows:

The axis y—y is settled in the magnetic meridian by the directive magnets **41** and **42**. Oscillations of the directive element about the z

axis are damped, mainly, by the interaction between the liquid 43 and the inner walls of the container 37. The damping is due to the phase difference between the motions of the liquid and the container, the inertia of the liquid causing it to lag behind the motion of the container. The viscous drag exerted by the liquid upon the walls of the container is the actual damping force. The motion of the liquid is caused only by the accompanying reaction, i. e., the viscous drag of the walls of container 37 upon the liquid. Hence, the liquid is not set into swirling motion by the rotations of the case 22 during turns of the ship. For this reason, the swirl effect is absent. Oscillations of the directive element about the x axis are damped in a similar manner by the drag of liquid 48 upon the inner walls of the containers 44 and 45, while the relative motions between liquid 48 and the inner walls of containers 46 and 47 affect the damping of oscillations about the y axis. The three sets of containers, i. e. 37; 44, 45; and 46, 47; thus damp oscillations of the directive element about any axis, by damping the components of the oscillations about their own toroidal axes, without introducing the undesirable swirl effect.

The magnet 50, pulling upon the disk 49, reduces the pressure of spindle 27 upon the important lower bearing 23 to a workable value. The excessive weight of the directive element, as constructed according to Figs. 4 and 5, would cause the aforesaid pressure to be prohibitive, otherwise. The character of the bearings for oscillations about the x and y axes is such that a reduction of pressure upon these bearings is not necessary. Distortion of the earth's magnetic field by the lifting system 49—50 is compensated by the system 51—53. The required reduction in pivot pressure is thus accomplished without the introduction of torques which would deflect the directive element.

From the foregoing it will be apparent that we provide for the damping of the oscillations of a compass directive element through the use of liquid, in a manner which precludes the possibility of the liquid being forced into swirling motion or disturbed in any way by the compass case, in combination with torqueless magnetic means for influencing the pivot pressure.

It should be readily apparent that the amount of damping liquid required, when the damping is carried out as herein described, is much less than for the same compass damped in the ordinary way.

It should also be apparent that the space between the directive element and the walls of the containing case may be reduced to a very small value, when the damping liquid is arranged as herein described. This results in a reduction in the size of the compass, as compared with the same instrument damped in the customary manner.

We are aware that methods for reducing pivot pressures have previously been resorted to, but we believe that the combination with the carrying of the damping liquid by the directive element is unique, and that it produces a new and useful result.

The drawing and the description of the specification illustrate particular embodiments of our combination, but we wish it to be understood that the invention is not limited to these specific forms. Any compass directive element having provision for carrying the damping liquid, and arranged in combination with any suitable magnetic means for ensuring practicable values of the pivot pressure, comes within the scope of our invention.

We claim:

1. In a magnetic compass, the combination of a case; a directive magnet system; means for supporting said directive magnet system for three degrees of angular freedom, within said case; magnetic means for continuously exerting a lifting force on said directive magnet system, without inhibiting said angular freedom; and closed containers, fixed to said directive magnet system and containing damping liquid, whereby the angular oscillations of said directive magnet system are damped by liquid carried entirely by the aforesaid closed containers.

2. In a magnetic compass, the combination of a case; a directive magnet system; means for suporting said directive magnet system for three degrees of angular freedom, within said case; means for damping oscillations of said directive magnet system; and means for continuously exerting a lifting force on said directive magnet system, without inhibiting said angular freedom; the said means for damping oscillations comprising closed containers rigidly fastened to said directive magnet system and containing damping liquid, whereby the damping liquid is in contact only with surfaces moving with the directive magnet element, while the said means for exerting a lifting force comprises magnetic elements fixed to the directive magnet system and to the compass case, and co-operating to oppose the weight of the directive magnet system.

3. In a magnetic compass, the combination of a magnetic directive element; a case for said directive element; means for supporting said directive element for three degrees of angular freedom, within said case; a lifting magnet attached to said directive element; a member of magnetic material attached to said case and co-operating with said lifting magnet to exert a torqueless lifting force on said directive element; and means, comprising closed vessels containing damping liquid, attached to said directive element, whereby oscillations of the said directive element are damped by liquid carried entirely by the aforesaid closed containers.

4. In a magnetic compass, the combination of a case; a magnetic directive element within said case; a bearing for said directive element, allowing universal angular motion of the directive element about a point fixed within the case; magnetic means, comprising elements fixed, respectively, to directive element and case, said elements being arranged to continuously exert a torqueless lift on the directive element; and means, comprising closed vessels containing damping liquid, fastened to said directive element, whereby oscillations of said directive element are damped by liquid in contact only with surfaces moving with the directive element.

5. In a magnetic compass, a directive element comprising the combination of a double-walled spherical container having an inner wall of magnetic material; a damping liquid within said container, the inertia of said liquid supplying the damping forces for said directive element; short directive magnets, fixed to and in line within the walls of said container; astatically arranged horse shoe magnets attached to said directive element; a compass card; a pivot; a framework interconnecting the said card, container, magnets, and pivot, substantially as described in

connection with Figs. 1 and 2; a bearing for said pivot; a case for housing said directive element and holding said bearing; a spherically shaped shield, of magnetic material, fixed relative to said case and concentric with the point of said pivot, and which causes said horse shoe magnets to lift part of the weight of said directive system off of said bearing; and a non-magnetic inner lining for said shield; substantially as illustrated by Figs. 1 and 2 of the accompanying drawings.

6. In a magnetic compass, the combination of the magnetic directive element; a bearing for same; damping liquid; closed containers for said liquid, attached to said directive element for damping the oscillations of same; magnetic means for maintaining the pressures upon the bearing of said directive element within practicable limits without introducing torques tending to deflect the directive element, the said magnetic means comprising two lift elements, viz., a magnet and a spherically shaped shell of magnetic material placed concentrically with respect to the pivot point or center of rotation of the directive element, one lift element being attached to the directive element of the compass while the other lift element is attached to the compass case; and magnetic means for annulling the effect of the said lift elements upon the earth's magnetic field in the vicinity of the directive element.

7. In a magnetic compass, a spherically shaped shell of magnetic material; means for attaching said shell to the case of the compass, concentrically with respect to the pivot point of the compass directive element; a lifting magnet; and means for attaching said lifting magnet to the directive element in a position for movement of the poles of the lifting magnet adjacent to, but at all times at the same distance from, the inner surface of said shell, and whereby the lifting magnet exerts a continuous lift upon the directive element without impeding the motions of the latter.

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