June 6, 1944. S. KRASNOW ET AL 2,350,402

MAGNETIC DIRECTION INDICATING INSTRUMENT

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FIG. 1.

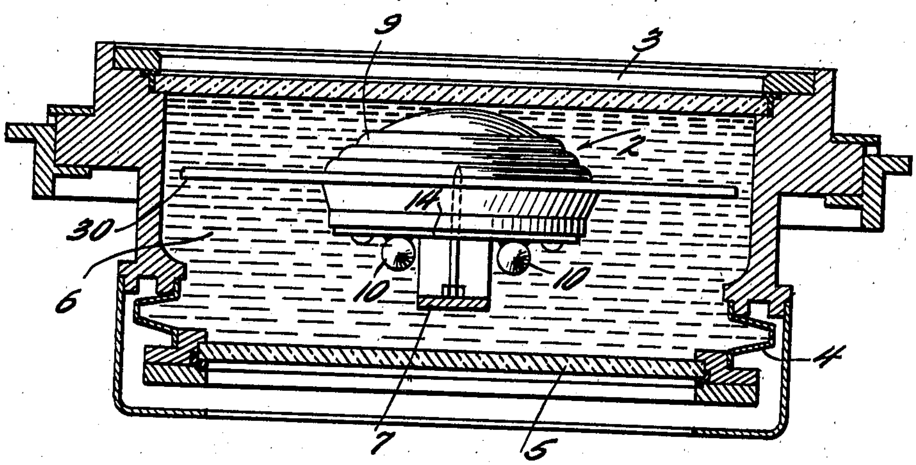


FIG. 2.

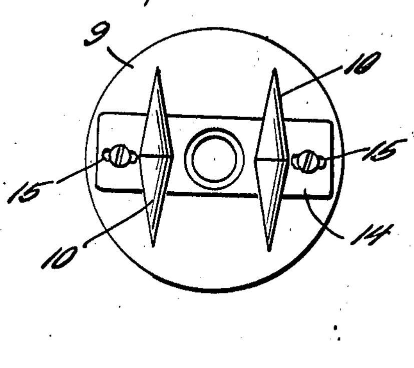
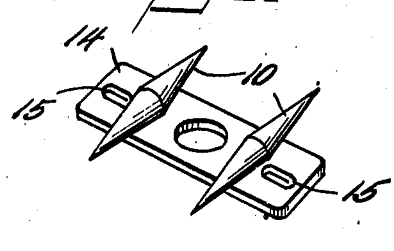


FIG. 3.



Inventors

Shelley Krasnow

Joseph M. S. Kaufman,

By Shelley Krasnow

Attorney

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MAGNETIC DIRECTION INDICATING INSTRUMENT

Shelley Krasnow, New York, N. Y., and Joseph M. S. Kaufman, Washington, D. C.

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2 Claims. (Cl. 33—223)

This invention relates to magnetic instruments such as shown in our co-pending application filed October 18, 1943, Serial No. 506,748, and particularly to magnetic instruments in which a moving element freely supported is permitted to orient itself in the direction of the earth's magnetic field, or artificial magnetic field. The invention has particular applicability to magnetic compasses of the type utilized in boats and ships for steering purposes.

In prior art methods, compasses as constructed have been unsatisfactory in operation. They have been very slow, responding to a change of direction in as long a time as 60 seconds. They have also been subject to a type of defect known as "swirl." In this, when the outer casing of the compass is rotated, the liquid contained therein causes the moving system to rotate, thus introducing an error. Prior art compasses have also been subject to an error caused by rocking the bowl of the compass. Due to the long magnets customarily used, the motion of the liquid acted on the magnets as though they were vanes or propellers, causing the moving system to rotate and to introduce an additional error. Moreover, traditional compasses have had the defect of overswing. After a change of direction had taken place, the compass would overswing and would then return, sometimes making several oscillations before settling down. Prior art compasses have also been difficult to compensate, as is necessary on board ships, and have been susceptible to magnetic material, both accidentally and intentionally placed near the compass.

It is an object of the present invention to eliminate or reduce the difficulties named above, and by a reconstruction of the magnet system along new principles and with new construction, to achieve a superior instrument. This change will be found to involve no increase in cost, and in most cases will result in reduction in cost.

It is a further object of the invention to provide a compass which will be rapidly responsive to changes in direction, will be easy to compensate, unsusceptible to magnetic materials placed nearby, unresponsive to disturbing oscillations of a mechanical nature, more economical to build and repair. The specific embodiment shown is intended to be exemplary only and not limiting, the scope of the invention being defined only by the appended claims. Other modifications will be obvious to those skilled in the art and such modifications fall within the scope of the present invention.

Reference is had to the accompanying drawing in which:

Figure 1 shows a view of a compass constructed according to the invention.

Figure 2 shows a view of the underside of the moving system of the compass shown in Figure 1.

Figure 3 shows a perspective view of the magnets mounted upon their supporting member.

1 represents the casing or bowl of a compass as ordinarily used for marine purposes and for navigation. Within the bowl is a moving system designated generally as 2. The bowl is fitted with a top cover 3, which is transparent and which permits reading the position of element 2 relative to a set of fixed lines marked upon the interior of bowl 1. At the bottom of bowl 1 is an expansion chamber 4, having a cover 5, which may or may not be transparent. Within the bowl 1 and expansion chamber 4 is contained liquid 6, the purpose of which will be hereinafter described. Across bowl 1 is a bridge 7, upon which is rigidly mounted a pivot 8. The moving system 2 is provided with a jewel bearing which bears upon the pivot 8 so as to give a relatively frictionless bearing for the moving system. In the central part of the moving system 2 is a float 9, which serves to remove all but a small fraction of the weight of the element 2, thereby reducing the load upon the pivot 8.

The float 9 has projecting from it a narrow rim to which is fastened by riveting, screws, soldering, or other means laterally extending members. At the ends of the members is fastened a rim, 30. This rim bears the figures or graduations, and serves as a dial to indicate the orientation of the entire moving system 2.

A plastic may be utilized for the rim 30, and may if desired be utilized also for the laterally extending members and the top of float 9. A suitable plastic for the dial 30 is vinyl resin. Preferably, a translucent white resin may be utilized, with figures printed thereon in black. The vinyl resin will withstand the action of the compass fluid such as the alcohol and water mixture sometimes employed and will at the same time provide a satisfactory foundation for the printed numerals and will further possess the capability of being easily formed.

The liquid 6 serves the function of helping to support the moving system, and also of damping the rotary motion and oscillation of the moving system 2, thus aiding in maintaining the said element in relatively stable condition. Affixed to the bottom of the moving system 2 is a magnetic system which is indicated as being composed of two parallel magnets 10, 10. It will be noted that the magnets 10, 10, are only two in number, and have been shown as being short compared to the outer diameter of card and compared to the diameter of the magnets themselves. In the prior art, it had been the custom to make magnets such as 10, 10 as long as possible, under the belief that more efficient operation would be obtained thereby. Our work has shown this supposition to be erroneous. The long magnets have a high moment of inertia, which grows as the square of their length. They also serve to induce motion in the liquid. A portion of the liquid appears to adhere to the magnets and to swing to and fro when the moving system oscillates. This has the effect of increasing the apparent inertia of the moving system, slowing the operation thereof, and also causing overswing. We have found that by making the magnets short, their moment of inertia is very much reduced, and the fictitious inertia added by the liquid is reduced very considerably. This results in increased speed of operation, as against what has been obtained with longer magnets. Since the magnets are not long and do not project into the liquid, movement in the liquid will leave them relatively unaffected, and will reduce the paddling or propeller effect observed with the longer magnets. Moreover, it has been found that long magnets such as are customarily used tend to form intermediate poles; that is, a north pole and another south pole may be formed within the length of the magnet in addition to the poles normally existing. It has been found that by reducing the length of magnets the tendency to the formation of such poles is measurably reduced. Furthermore, there are fewer magnets to adjust, fewer fastenings required for these magnets, and less weight of protective coating to be applied to the magnets to protect them from corrosion.

An example of a compass to which the new magnet may be applied is one employing a moving system 2 having an outer diameter of 7½ inches. In the prior art, four magnets had been used, the longer of these magnets being as much as 5½ or 6 inches long. We have found it possible to substitute a system of two magnets, these being each less than three inches long. This substitution of only two magnets in place of four results in considerable simplification of construction. Even where four magnets are to be used, we have found it desirable to make the longer of the magnets less than three inches long, the shorter magnets being of proportionate length.

It is understood that whatever type of magnet is used, the magnetic units are so disposed as to give dynamic balance, i. e. the moment of inertia of the moving system about one horizontal axis passing through the pivot point is the same as the moment of inertia of the system about a horizontal axis at right angles to the first. If this condition is fulfilled, as is well known in mechanics, the "ellipse of inertia" becomes a circle, and the moment of inertia has the same value for any horizontal axis passing through the pivot point.

By the shortening of magnets as described herein, it has been found possible to reduce the time required for half oscillation of the moving system from 22 seconds to 12 seconds. This has been done without increasing the relative weight of the magnet material, and indeed with a reduction in the weight of such material. Still another example which may be cited is that of a compass employing a dial 2, four inches in diameter. In the prior art it has been common to make these compasses with magnets 3⅛ inches long, almost extending out to the edge of the dial itself. We have found that superior results have been obtained by magnets two inches long and even shorter. In fact, magnets as short as one inch have been successfully used with improvement in performance. By adopting the improved design disclosed herein, it has been possible to reduce the time for half oscillation of the four inch instrument from 12 seconds to 7 seconds. Again, this improvement has been gained without any increase in the weight of the magnet material, and indeed with a decrease therein.

It will be noted that the magnets have been reduced so that their length is no more than 4/10 the diameter of the compass card. This is a much smaller ratio than had been believed possible. However, experimental work has shown beyond dispute that this reduced ratio improves the performance of the instrument. Ratios smaller than 4/10 have been utilized also and have been found satisfactory. In fact, magnets as short as 2/10 the card diameter have been utilized successfully.

Our work has shown that it is advisable to make the magnets no longer than 10 times their lateral dimension, and we have found that magnets which were as short as four or six times their lateral dimensions give very good results.

The construction described is a radical innovation over previous similar structures. Formerly it had been thought desirable, and even necessary, to make the magnets as long as possible. Our experiments have proved very conclusively that shorter magnets have the advantages described herein.

The details of the magnet structure are shown in Figures 2 and 3. Here two magnets, 10, 10 are shown. Each of the magnets is indicated as being formed in the shape of a double cone, i. e. two cones placed base to base. This construction is particularly applicable to those magnetic materials of the permanent magnet type which have a low permeability. This applies with emphasis to some of the iron, nickel, aluminum magnetic alloys. By constructing the magnet in the form of a double cone, the central portion which carries the greatest amount of magnetic flux also has the greatest magnetic conductivity. As one proceeds toward the tip of the magnet, the material carries less and less of the flux, since the lines pass into the air. Thus, less material is required towards the end. This construction is particularly fortunate for several reasons. A cone has a very much lower moment of inertia than a cylinder, and a magnet constructed as indicated for 10, has a very great magnetic moment compared to its moment of inertia. In fact, a magnet constructed as shown will respond with surprising rapidity as compared with the response of even a short cylindrical magnet.

The two conical magnets may be fastened to an underplate 14. This fastening may be done by solder, which solder can be applied after coating the magnets with tin. The mounting plate has enlarged holes 15, 15. Screws pass through these holes and serve to mount the entire structure on the bottom of the float 9. Enlarged holes permit shifting the entire system a small amount in any direction, and also permit twisting thereof so as to orient the magnet system relative to the card and adjust the same to point to true magnetic north. It has been found that if the cone magnet **10**, has a length approximately equal to six times the diameter at the largest part, the greatest effectiveness will be obtained.

The conical magnet has another very important feature. It is in effect streamlined, and will pass through liquid with least hindrance, with least turbulence, and with less tendency to error due to swirl. The distance between the magnets **10**, **10**, is chosen such that the moment of inertia about the axis passing through the center and parallel to the two magnets is the same as the moment of inertia for a similar axis passing through the centers of the magnets. By this, dynamic balance will be achieved.

While a number of magnet materials might be utilized to form the magnets **10**, **10**, it will be found that Alnico magnet material or other permanent magnet material made up of aluminum, iron, cobalt and nickel will be most suitable. Successful magnets have been built of "Red Streak" Alnico magnet material as manufactured by the Simonds Saw and Steel Company.

Although the magnets have been shown as of circular cross section, it is obvious that they may be of other cross section. Thus, they can be made of oval cross section, or even square or rectangular cross section. However, in most cases, the most efficient use of the material will be obtained with a circular cross section.

The lengths of the magnets shown in Figure 2 should best be less than 10 times the width at the central portion thereof, in other words, each cone should have a length no greater than five times the dimension at the base. A very satisfactory dimension has been found to be six to one for the ratio of over-all length to base diameter; in other words, a ratio of three to one for each conical portion.

Any of the standard permanent magnet materials may be used for the structures indicated herein. However, Alnico magnet material has been found particularly suitable. Sintered or cast Alnico or Vicalloy material will be found highly applicable.

The structure shown herein will be of particular advantage when used in connection with the standard binnacle used for mounting and compensating magnetic compasses. In the conventional binnacle of this type, there are a pair of iron spheres to correct for the effect of iron in the ship, a vertical iron bar known as the Flinders bar to correct for the further effects of iron in the ship, and a number of permanent magnets to correct for the permanent magnetism of the craft. These various magnets and bodies or iron produce a distorted field in their immediate vicinity, and this field becomes more and more uniform as one approaches the pivot point of the compass mounted in the binnacle. From this, it would appear that the most effective length for a magnet used under such circumstances to actuate the moving system of a compass would be zero. Obviously, the magnet must have dimensions, but the closer the approach to a point, or in other words, the shorter the magnets, the more uniform the field in which they will operate. In addition, it has been found that the magnets of the compass itself will tend to induce magnetism in the correcting iron spheres of the compensating binnacle. The induced magnetism will again react on the magnets, tending to cause an error. By the use of the construction shown herein, this effect has been reduced in two ways. For one, the magnets are made shorter, and are thus at a greater distance from the corrector spheres. For another, since the magnets have been made more effective, and the disturbing effects of the liquid have been reduced, they may be made weaker without any loss in speed of response. In other words, for a given performance of the compass, a weaker magnet can be used. And the weaker the magnet, the less serious the disturbances mentioned above. This fact makes the operation of the compass more precise, makes compensation easier, and makes compensation hold to within more accurate limits, even for change of magnetic latitude.

With the standard type of compass, the change in the strength of the earth's field such as is experienced in different latitudes changes the effect of the spheres upon the magnetic system. This necessitates the recompensation and readjustment of the magnets and spheres in the binnacle. In the construction adopted herein, it is found that the compass will maintain accuracy for changes in magnetic latitude, which would cause an ordinary compass to become seriously in error.

Since the magnets are short, they will necessarily have their poles more distant from any disturbing material which tends to exist in the vicinity of the compass. Since the attraction between the pole and such material will vary as the inverse square of the distance between the two, the shorter the magnet the more distant its poles will be from exterior objects. Thus the disturbing effects of such objects will be reduced.

Furthermore, if the bowl itself, or appurtenances attached thereto happen to be somewhat magnetic as may occur by accident, the effect will be considerably reduced since the poles of the magnets are more distant from the bowl than in the case of the usual type of magnetic construction.

In general, the design of the magnets for a ship compass is not a simple matter and cannot be deduced from the general principles in connection with design of magnets. A ship compass magnet must fulfill several conditions at once. It must be affixed to a moving element, so that its moment of inertia and its disposition relative to the axis of rotation of the element will be proper. It must have the proper magnetic moment so as to give the most effective torque to the moving system. It must be designed relative to the fluid in which it is to rotate. Often this fluid is liquid. It must also be properly designed so as to be least responsive to accidental magnetic materials in its vicinity, and to behave properly with respect to the compensating iron and compensating magnets which are mounted about it, and which are used to correct for the errors caused by magnetism, and iron in the vessel. Thus it is seen that the principles used in stationary magnet design, that is in magnets which remain stationary in normal operation, will not necessarily apply in the design of magnets for a ship compass.

It has been believed and has been almost axiomatic in ship compass design that the magnets ought to be made as long as possible. As is known, the magnetic moment of the magnet or the torque exerted by it is equal to the pole strength times the length of the magnet. By increasing the length one increases the magnetic moment, consequently the effort tending to turn the card of the compass in the correct direction. Despite this, our work has shown, and quite unexpectedly, that the shortening of the magnets produces a desirable effect and produces results which are superior to those obtained with long magnets. Although it is true that by shortening the magnet, the magnetic moment is reduced, the pole strength of the magnet is increased in proportion to its weight. This is due to the more efficient use of the magnetic material, particularly when such material is of the newer types of iron, nickel, cobalt, aluminum alloy. But the improvement due to this is even greater than might be expected on this basis alone. This follows from the fact that the shortening of the magnet reduces the moment of inertia. By shortening the magnet the moment of inertia goes down as the square of the length while the pole strength goes down only as the first power of the length. Thus a gain in responsiveness is produced. Moreover, the inertia due to the liquid dragged along with the magnet is reduced and the moment of inertia of this dragged liquid is also reduced, since with long magnets some of the liquid which drags along is far from the axis of rotation and acts as though it were a mass out at the end of the magnet. There is still a further effect which comes from shortening the magnet. Magnets of whatever type must have some means for clamping or holding. The more numerous the magnets are and the thinner they are, the more must be the weight of the holding devices related to the weight of the magnetic material. Using a short stout magnet, the dead weight, which only adds to the inertia, and the liquid drag, can be reduced in proportion to the total weight of the moving system and in proportion to the weight of the magnets themselves. The advantages of the shorter magnet are so great, even in cases where it is found that it is desirable to have a slower card, it is found preferable to gain this by using a card of large diameter which will be of light weight, but large radius. This will give a relatively large moment of inertia, tending to slow down the operation of the compass without increasing the load which must be put on the pivot. While iron, nickel, cobalt, aluminum alloys have been described, other alloys may be utilized with great gain. Thus the alloy known as Vicalloy, that known as Nipermag, the cobalt magnet steels, the tungsten magnet steels, and the chromium magnet steels may be utilized.

Aside from all other considerations, there is a sizeable reduction in cost in being able to use two small relatively stout chunks of magnetic material instead of a lot of slender bars or slender wires as formerly used. The cost of rust-proofing or otherwise coating slender bars or wires, of holding them in place, and of magnetizing is very great compared with the use of the short stout pieces.

Not only is the weight of the holding structure reduced, but due to the shortened lengths and shorter radius of the magnet, the holding means can be nearer to the center. Thus the moment of inertia of the clamping and holding means will be much reduced. This will further increase the speed of operation of the compass.

While the compass shown herein will still continue to operate with the liquid emptied therefrom, the pivot load may become objectionably high and the damping too low. It is therefore desirable that a liquid be used. A traditional type of liquid has been a mixture of alcohol and water. However, this has certain undesirable properties, such as a high viscosity, a low specific gravity, and a great change of viscosity with temperature. The low specific gravity of the alcohol-water mixture, for instance, makes necessary a larger float. This will in turn have a larger area in contact with the liquid, which will tend to increase the difficulties with swirl and overswing. Suitable liquids are chloroform, carbon tetrachloride, and benzotrifluouride. Other liquids having similar properties may be used.

The advantages gained by the magnet system and structure shown herein are greater if such a fluid as benzotrifluoride is used in connection therewith.

The scope of the invention is indicated by the appended claims.

We claim:

1. In a magnetic compass for indicating the direction of the magnetic meridian, a moving dial supported so as to be rotatable in a substantially horizontal plane and to point in the direction of the magnetic meridian, a plurality of magnetic elements affixed to the said moving system so as to cause the orientation thereof the said magnetic elements being rigidly interconnected to form an integer, the said integer being movable relative to the remainder of the moving system to permit adjustment of the magnetic elements relative to the moving system, and clamping means to clamp the integer containing the magnetic elements after adjustment has been made, the said magnetic elements being in the form of tapered members, being tapered in both the horizontal and vertical planes, and, having their enlarged portions nearest to the center of rotation, and their smallest portions remote from the center of rotation, the said disposition serving to reduce the moment of inertia of the magnets about the center of rotation and further serving to cause a minimum of disturbance in the fluid in which the magnets are immersed when rotation takes place.

2. In a magnetic compass, a movable system, adapted to orient itself so as to indicate the direction of the earth's magnetic field, a plurality of magnetic members, each member being formed in a double tapered shape, with the thickened portion at the center, the said elements being mounted parallel to each other upon a unitary member, so as to form an integer, with the said elements substantially in the same plane, the said integer being adjustable relative to the moving system, and means to clamp the integer containing the said elements after adjustment has been made.

SHELLEY KRASNOW.
JOSEPH M. S. KAUFMAN.