

June 18, 1940.

E. SMOLA

2,204,553

AUTOMATIC STEERING OF SHIPS

Filed Oct. 9, 1937

2 Sheets-Sheet 1

Fig. 1.

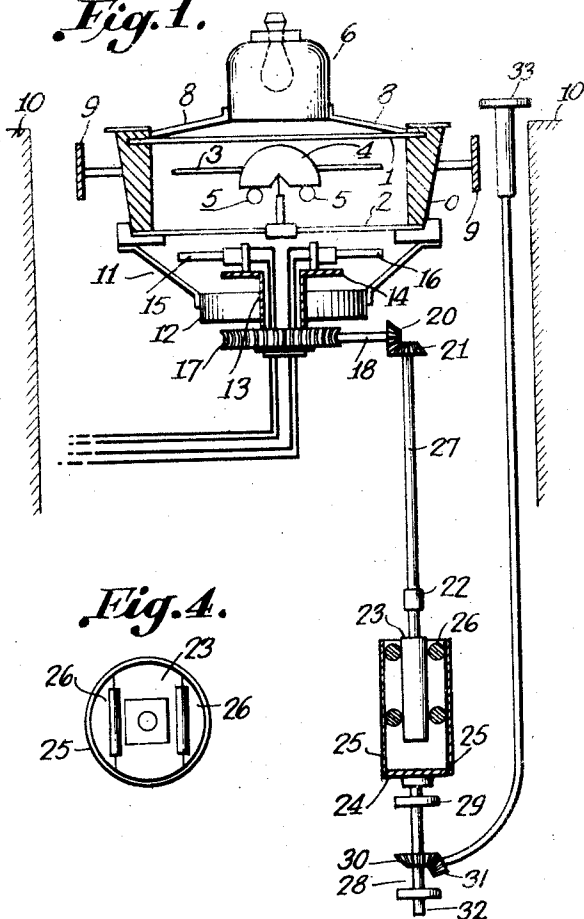


Fig. 2.

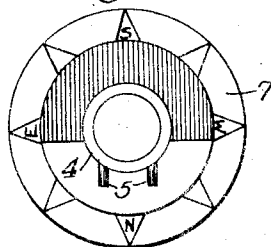


Fig. 3.

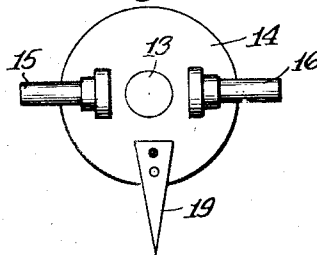


Fig. 4.

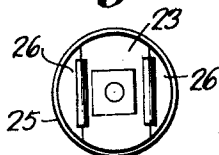


Fig. 9.

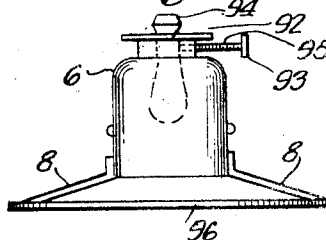
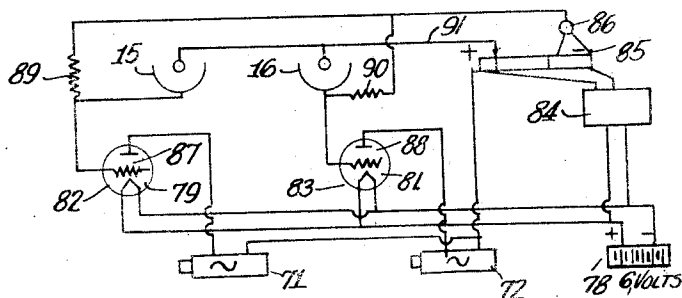


Fig. 10.



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2 Sheets-Sheet 2

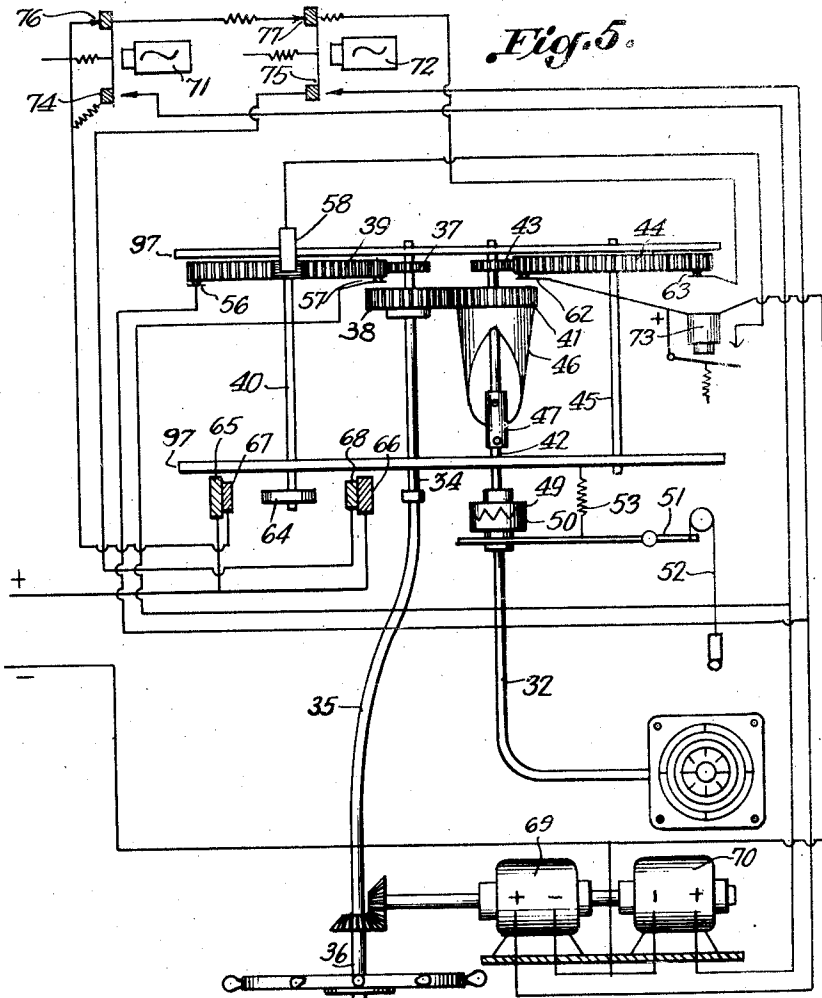


Fig. 5.

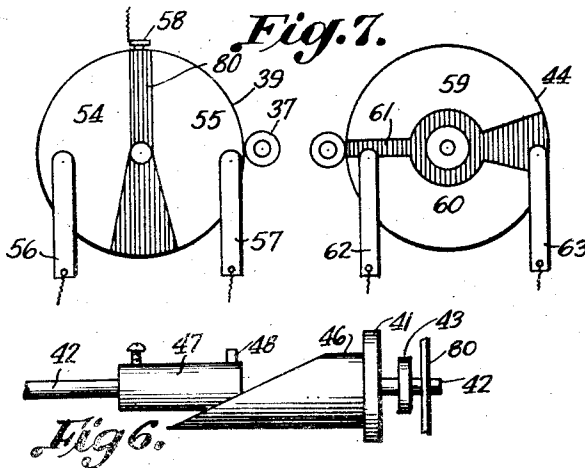


Fig. 7.

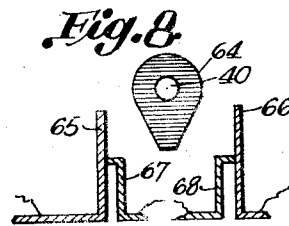


Fig. 8.

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UNITED STATES PATENT OFFICE

2,204,553

AUTOMATIC STEERING OF SHIPS

Emil Smola, Newport News, Va.

Application October 9, 1937, Serial No. 168,132

1 Claim. (Cl. 172-282)

This invention relates to compass controlled steering of ships in general and its purpose is to provide a simple and reliable photo-electric steerer which will employ the same method of steering as that used by the human helmsman, who in steering the ship on a predetermined course will keep the rudder amidships as long as the vessel does not deviate from her course; upon a deviation to the left, he will immediately apply right rudder proportionate to the deviation, and when under the impulse of the rudder the ship returns toward the course, he will take off right rudder and apply a small amount of left rudder to "meet" the ship, and when she becomes steady on the course the rudder will be shifted to center again.

For a more thorough and complete understanding of the invention, reference should be made now to the following specification and drawings:

Fig. 1 is a cross section of a magnetic compass, with the light source above and the light sensitive elements under it.

Fig. 2 is a top view of the compass card.

Fig. 3 is a top view of the light sensitive elements.

Fig. 4 shows a cross section of the compensating unit.

Fig. 5 illustrates the mechanical control box and its relation to the compass and steering shaft.

Fig. 6 is a side view of the lost motion device of the mechanical control box.

Fig. 7 illustrates the arrangement for returning the rudder to center.

Fig. 8 is a cross section of the limit switch.

Fig. 9 is a cross section of the light source.

Fig. 10 is the diagram of the amplifying system employed, to increase the output of the phototubes.

Referring to the drawings in more detail—

Fig. 1 is a cross section of a liquid magnetic compass bowl fitted into a binnacle with the compass bowl having a glass face 1 and glass bottom 2, the last having a pivot in its center on which rests the compass card 3 together with float 4 and magnets 5.

Fig. 2 shows a top view of the compass card, the shaded inner part representing a solid mica screen 7 from 80 degrees to 280 degrees around south, leaving the northern portion clear, so that light radiated from the light source 8 above the compass face may pass through the liquid and transparent bottom, and reach photoelectric cells 15 and 16 located under the bowl.

The light source 8 in Fig. 1 is mounted over the

compass face on legs 9 resting on a base ring. The light source frame is equipped with a 25 watt clear bulb light. The gimbal ring of the cardanic suspension is represented by 9 and binnacle by 10.

Attached to the lower portion of the bowl casting are four supports 11 carrying a heavy lead ballast 12, bored in the center, through which revolves a brass pipe 13, having a photocell platform 14 rigidly mounted over it. Platform or disc 14 carries photoelectric cells 15 and 16 180 degrees apart. The anode and cathode connections of the tubes are taken through pipe 13 to the amplifying unit shown in Fig. 11.

Fig. 3 shows the photocell arrangement in a top view, showing also pointer 19 attached to disc 14. Pointer 19 is equidistantly spaced from either photocell, and in Fig. 1 faces the observer. In size it is equal to the radius of the compass card. It rotates within $\frac{1}{2}$ " of the glass bottom and being painted white, it is easily seen from above the compass, especially with the light source turned on.

Rigidly attached to the lower part of tube 13 is a worm gear wheel 17 into which meshes a worm 18. The shaft of this worm carries a miter gear wheel 20 meshing into gear wheel 21, which is mounted on a $\frac{1}{8}$ " diam. phosphor bronze flexible shaft 27, rotating in a loose guide 22, and secured to center piece 23 of the compensating unit 24. This unit consists of a 1" diameter brass tube 25 open on top and closed at the bottom. The square center piece 23 within the tube (Fig. 1 and 4) is flanked on all sides within the tube by rollers fitted into it. The purpose of this unit is to compensate for the varying distance between points 20 and 24 during the rolling and pitching of the ship. While center piece 23 will move up and down within the rollers with freedom, the unit will act as a rigid connection, and will transmit every motion of tube 25 to flexible shaft 27. The lower part of the compensating unit terminates with the shaft 28 rotating in bearing 29 and carrying miter gear 30 meshing into gear wheel 31. This gear wheel is mounted on a flexible shaft leading up on the inside of the binnacle and terminates in a knurled knob 32 alongside the compass bowl.

From the foregoing it will be seen that, when knob 32 is rotated, the photocells will also rotate together with indicator 19 fixed to the photocell disc. The same will also happen when shaft 28 is rotated.

All the above described apparatus is within the binnacle.

To shaft 28 is coupled a phosphor bronze flexible shaft 32, which leads through the lower part of the binnacle, out at the bottom, and to the mechanical control box situated in a convenient place on a pilot house bulkhead. The control arrangement is illustrated in Fig. 5 in a top view. This control is somewhat similar to the train of a clock movement, and is contained within two brass plates 97, which receive the various shafts of $\frac{3}{8}$ " diameter. Shaft 34, which is the driving shaft, is coupled to flexible shaft 35, which in turn is secured into the steering shaft 36. To driver shaft 34 is rigidly fixed pinion 37 and gear wheel 38. Pinion 37 engages wheel 39 secured to shaft 40, while gear wheel 38 engages gear wheel 41 loose on shaft 42. Pinion 43 is rigidly secured to shaft 42, and engages gear wheel 44 on shaft 45.

Elements 41, 46, 47 and 48 constituting a lost motion arrangement, are shown in greater detail in Fig. 6. As previously said, gear wheel 41 rotates loosely on shaft 42. The $\frac{3}{4}$ " diam. brass tube 46 is obliquely cut and rigidly secured to gear wheel 41. Sleeve 47 fits over shaft 42 having a salient part at 48 and a set screw to secure it to shaft 42.

When sleeve 47 is pushed all the way in towards the gear wheel and secured to shaft 42, the elements 42, 47, 46 and 41 become rigid with no lost motion between them. By sliding sleeve 47 outward on its shaft and securing it there, the lost motion increases.

Shaft 42 (Fig. 5) or driven shaft, connects to flexible shaft 32 through the medium of a multi-jaw coupling 49 and 50. Jaw 50 can be disconnected from semijaw 49 by lever 51 operated through a cord 52 pending from above the compass. Spring tension 53 keeps jaws connected.

Gear wheels 39 and 44 are also illustrated in Fig. 7 (front view). Brass wheel 39 is built up in thickness with "Bakelite," to which in turn are secured the brass sectors 54 and 55. The dark portion 80 between the sectors is insulation. Against these sectors press two contact arms 56 and 57 respectively. On top of the wheel, contact arm 58 presses against the periphery of the wheel.

Gear wheel 44 is a similar wheel, with sectors 59 and 60 of "Bakelite" and 61 of brass. Contact arms 62 and 63 press against the inner surface of this wheel.

Circuit breaker No. 64 in Fig. 5 represents the limit switch, to cut off the current from the steering motor after the rudder has reached its hard over position. Fig. 8 illustrates this in detail. No. 64 is an insulated body secured to shaft 40.

Circuit breaker No. 64 is in the position as shown when rudder is amidships. Hardover is reached when slowly rotating circuit breaker 64 presses spring blade contact arm 65 away from contact point 67, or contact arms 66 from contact point 68.

In the mechanical control box described above there are also three relays installed, which make and break the current to two geared motors 69 and 70 rotating in opposite directions with armatures mounted on a common shaft, same shaft being bevel geared to steering shaft as shown in Fig. 5. The upper part of Fig. 5 shows two of the relays 71 and 72, which are of the double pole double throw type. The solenoids of these relays are hooked into the plate circuits of the amplifier tubes, as will be described further on.

Relay 73 is an adjustable time delay relay with time elapses or from 0 to 60 seconds.

To follow up the motor circuits, the ships supply current enters at the left of Fig. 5. The negative current is taken directly to motors 69 and

70, and also to time delay relay coil 73. The positive current is taken through the limit switches 66 and 68 and 65 and 67, thence to armature pig-tails 74 and 75 of relays 71 and 72 respectively.

When either of the relays closes (attracts its armature), either motor circuit is completed (the other remaining open), the motors thus moving the steering shaft and thereby the rudder, one way or the other.

In further following up the circuits, the positive current is also taken to contacts 76 and 77 of the relays 71 and 72. When both relays are open under spring tension of their armatures, the positive current will flow on to contact arm 63, then across segment 61 (Fig. 7) to contact arm 62 and thence to coil 73 of the time delay relay. This is the time delay relay circuit.

When the solenoid of relay 73 is energized and attracts its armature (which can not take place unless relays 71 and 72 are open), the positive current will flow to contact arm 58 (Figs. 5 and 7), where it will be blocked by Bakelite segment 80 of gear wheel 39 (Fig. 7). However in any other position of wheel 39 the current would flow either through sector 54 or 55, and then either through contact arm 56 or 57, completing the circuit to either motor 69 or 70.

The photo electric cell and amplifying circuits are illustrated in Fig. 10. This sensitive part of the system is operated from a 6 volt storage battery 78, making its operation independent from the voltage fluctuations of the main supply. Filaments 79 and 81 of the amplifier tubes 82 and 83 are directly fed from the battery. To obtain the higher voltages for the operation of the tubes, a power pack 84 similar to those used in automobiles to operate radio sets from a 6 volt storage battery is hooked in the battery circuit. The pack contains a vibrator, transformer, rectifier and filter, feeding a high voltage D. C. current to a voltage divider 85, which in turn is tapped on the negative end to feed a potentiometer 86 supplying the negative current to the grids 87 and 88 of the amplifier tubes across resistances (grid) 89 and 90. The cathodes of the photoelectric tubes are hooked into their respective grid circuits; that of tube 15 into 87 and that of tube 16 into 88.

The anodes of tube 15 and 16 in Fig. 10 are fed positive current from the voltage divider 85 through line 91. The plate current from amplifier tube 82 is taken to coil of motor relay 71 and thence to positive end of voltage divider 85. The plate current of amplifier tube 83 is taken to coil of relay 72 and back to positive end of voltage divider.

In following up the photoelectric cell circuits, if we suppose for the present that both cathodes are in the dark area under the compass card, and that their cathodes therefore do not emit positive current—the following takes place: Filaments 79 and 81 emit negative electrons which are blocked by the negatively impressed grid in their effort to reach their respective positively charged plates, and no increase of current will take place in the coils 71 and 72. If now cathode 15 becomes exposed to light, it will emit a small positive current, making thereby grid 87 less negative, thereby allowing a larger number of negative electrons to reach the positively charged plate, which in turn will cause the flow of current to increase in the plate circuit, returning to the positive end of the voltage divider 85 through relay coil 71. The solenoid thus energized will attract its armature

and close the motor circuit. The same takes place when photoelectric cell 16 becomes exposed to light; armature of relay 72 will close, starting up the other motor.

In operation the whole system functions in the following manner: With respect to Fig. 1 the observer is in front of the compass looking aft, with the ship heading north, the compass card screen 7 (Fig. 2) in a thwartship position, photocells under the east and west respectively as in Figs. 1 and 3, in which position the light radiated by light source 6 can not reach them, they being just at the edge of the light beam. In this position and with rudder amidships, the positions of the parts of the controls in Figs. 5, 6, 7 and 8 are as illustrated, and light source 6 is off.

Desiring to steer by compass automatically on a north course, the light source 6 is turned on. As long as the vessel remains on this course, the apparatus remains inoperative. With a slight deviation from the course to the right—north 1 degree—photocell 16 becomes exposed to the light, causing its amplifier tube grid to become less negative, thereby increasing the plate current in tube 83.

This will energize solenoid 72, which in turn will attract its armature permitting the positive current of the line to reach motor 69, which will move the rudder to the left through steering shaft 36. The turning of this shaft will also actuate flexible shaft 35, shaft 34, gearwheel 38, pinion 37, rotating thereby gear wheel 39 towards the left, bringing contact arm 58 over sector 55. Gear wheel 38 will also turn gear wheel 41 loose on shaft 42 until sleeve 46 engages salient point 48, when shaft 42, pinion 43 and gearwheel 44 will begin to move together, moving gear wheel 44 towards the right, causing brass segment 61 to move to the right from under its contact arm (Fig. 7).

As shaft 42 begins to turn to the left, it also rotates flexible shaft 32 leading to binnacle, which in turn will move the photocells around their vertical axis, until photocell 16 is rotated back into the dark, at which moment its cathode ceases to emit positive energy. The former equilibrium in amplifier tube 83 being restored, coil of 72 becomes deenergized thereby releasing its armature and breaking the circuit to the steering motor 69.

The ship is now on a north 1 degree course with left rudder on. If she continues to swing to the right and head north 2 degrees, the former operation will be repeated, because phototube 16 being secured to the bowl (hull) through steering shaft, will again be brought into the light of the light source, and motor 69 will put on additional left rudder.

It must be noted however that no lost motion occurs anymore between salient part 48 and sleeve 46 of the lost motion arrangement, and every movement of the steering shaft is now transmitted to the photocell shaft and phototube 16 will resume its former place under the screen in a shorter time than before, having also caused less rudder to be applied. If the ship keeps on swinging to the right, these stagelike operations will be repeated until shaft 40 (Fig. 5) rotated limit switch 64 to a point to the right in Fig. 8, to press contact arm 66 away from 68 and break the circuit of motor 69.

Returning to the point where the ship moved out to north 2 degrees, and two stages of left rudder have been applied. If we suppose that

$\frac{1}{4}$ of a revolution of shaft 32 was necessary to return photocell 16 to the dark, then we find, that when the ship moved from 0 to 1 degree course, the total steering shaft movement of shaft 36 was $\frac{1}{4}$ turn to take out the lost motion (as per setting in Fig. 6), plus $\frac{1}{4}$ turn to move the photocell back into the dark, altogether $\frac{1}{2}$ turn for 1 degree of deviation. For the second degree of deviation only $\frac{1}{4}$ turn is necessary to rotate the photocells back into the dark. Total rudder (steering shaft movement) was $\frac{3}{4}$ turn.

Allowing a 10 degree angular motion to wheel 39 for each $\frac{1}{4}$ turn of shaft 34, segment 80 moved to the left a total of 30 degrees, while segment 61 only 20 degrees.

Now if the ship is arrested in her swing from the course and no more deviation is taking place, the rudder remains put $\frac{3}{4}$ turns to the left. If she now returns towards the course under the impulse of left rudder and returned to north 1 degree course, photocell 16 becomes exposed to the light, coil of relay 71 becomes energized, attracts its armature and completes the circuit to motor 70, which turns steering shaft and rudder in the opposite direction from that before, turning gear wheel 39 towards the right. Since the lost motion now is exactly double of that before, steering shaft will make $\frac{1}{2}$ revolution before sleeve 46 engages salient part 48 and shaft 32 begins to move. An additional $\frac{1}{4}$ turn of shafts 32 and 35 will place photocell 15 in the dark. The steering shaft turned now $\frac{3}{4}$ revolutions for 1 degree of change in course, while wheel 39 turned 30 degrees to the right bringing contact arm 58 exactly under segment 80. Segment 61 which moved out a total of 20 degrees, has moved back 10 degrees.

With the vessel still 1 degree to go to resume her former course of 0 degrees, rudder is already amidships, but her momentum will still carry her toward the course, and when she reaches 0 degrees, photocell 15 again becomes exposed to light, relay 71 will start up motor 70, shaft 32 and 35 will move together $\frac{1}{4}$ turn to rotate photocell 15 back into dark, when motor circuit will be interrupted by opening of relay.

The steering shaft 36 (and rudder) has thus been moved $\frac{1}{4}$ turn past the center position, meeting the ship definitely on her course with opposite rudder.

Segment 80 in the meantime moved a corresponding 10 degrees to the right, leaving contact arm 58 10 degrees to the left, resting on brass sector 54. Segment 61 in the meantime returned 10 degrees, and is now under contact arms 62 and 63.

At this moment the vessel is steady on her course, having a $\frac{1}{4}$ turn right rudder. If the rudder is left in this position, it will force the ship out of her course and to the right, which would result in unsteadiness and requiring a lot of rudder movement to keep her on the course. However, if at this moment the rudder is shifted to center, all the above trouble is eliminated, and little rudder movement will be necessary to steer a good course.

The time delay relay 73 will perform the above in the following manner: The armatures of relays 71 and 72 are open at present, permitting the positive current to reach the coil of relay 73 through contact arm 63, segment 61 and contact arm 62. The relay will begin to attract its armature as soon as the vessel reached her course with relays 71 and 72 open, and will be completed when the vessel definitely settled on the course, 75

the time elapse being set for this period. This period will be found different with each vessel, depending from size, but practically constant in the same ship. The relay therefore will attract its armature after a predetermined time elapse set for. When time delay relay 73 closes its armature, the positive current will flow to contact arm 58, then across the brass sector 54 to contact arm 55 and then to motor 69, which will turn the steering shaft now in the opposite direction. This will also cause shaft 35 to rotate to the right, causing gear wheel 38 to turn towards the left until neutral segment 30 rests under contact arm 58, upon which the motor circuit being broken, motor 69 will stop.

While segment 30 moved 10 degrees to the left, gear wheel 41 and sleeve 45 have also been rotated exactly $\frac{1}{4}$ turn, bringing salient part 48 in the center of the lost motion or initial rudder arrangement.

With the ship on her course again and steady, rudder is amidship. If the ship deviates to the left from her course, the same operation will take place, but in the opposite order.

When a new course is desired to be steered automatically, the light source 6 is turned off, hand steering resumed, and the ship steadied on her new course. Cord 52 pending above the compass is now slightly pulled to disconnect shaft 32 from the remainder of the control. Knob 33 is then rotated until pointer 19 coincides with the north of the compass card. This performed and the ship being steady on her new course with rudder amidships, cord 52 is released, and the light source turned on.

Fig. 9 shows the light source as it appears from the west, while Fig. 1 as it appears from the north. In Fig. 9 the light socket 94 moves between two guides 92 (only one visible) secured to shell 6. Screw 95 screws into threaded hole in shell and is semirigidly secured to socket with collar on its end (not shown in drawings). By turning knob 95 one way or the other, socket and lamp will move forward or backward in its guides. The shell is supported on three legs 8 attached to a ring 96.

One of the legs is in the vertical plane of the guides 92 and also screw 93. This is the north leg of the light source. This leg should rest approximately over the meridian of the compass card when steering automatically. When so placed, the sensitiveness of the apparatus might be increased or decreased by screwing screw 95 in or out respectively, moving the light bulb towards or away from the north point of the compass. Unscrewing the screw and moving the bulb away from the north will introduce a lag in the operation of the photocells with respect to the ship's deviations, and may be used as a weather adjustment.

The novel features of my invention are the following:

A fixed central light source of simple construction without complicated parts and optical arrangements—supplying constant light to the entire compass card. It also illuminates the card, making it visible from all angles. It leaves all the lubber lines unobstructed, therefore the course steered can be easily checked at a glance. Another novel feature of the light source is the easiness, with which weather adjustments can be made from 0 to 15 degrees on either side of the lubber line, and in an indefinite number of steps.

A further novel feature is the construction of

the compass card. No extra weight is mounted over it, with the exception of the very thin mica screen in the southern semicircle. The placing of the screen in this semicircle will relieve the compass card of the extra weight which it should carry on the south point to overcome the dip of the needles. This arrangement leaves the sensitiveness of the magnetic system unimpaired, assuring long life to the pivot and eliminates sluggishness, which would affect good steering. The mica screen with its 200 degree sector, permits an arc of 160 degrees to be illuminated under the bowl, which in turn will enable the apparatus to return the ship to the course set even if she deviated a 160 degrees from it.

The construction of the photocell support under the bowl and the arrangement for rotating the photocells precisely by the steering shaft without interfering with the compass bowl's orientation in the horizontal plane, is another novel feature of this invention. As we have seen, the above is accomplished through the use of heavy ballasting of the bowl, very flexible $\frac{1}{8}$ " diam. phosphor bronze shafting and compensator.

The novel way of setting the course by a pointer under the transparent bowl, leaving the compass face unobstructed, the manner in which the photocells are disconnected from the steering shaft, and rotated by hand.

The novel way of fitting all the above within the vessel's binnacle.

A further novel feature is the introduction of adjustable lost motion or initial rudder in the control apparatus, the use of different amounts of rudder per degree of deviation, the meeting of the ship—by returning rudder to center before the ship resumed her course, and to the opposite side, when she resumed her course, and the returning of the rudder to midships through the use of a time delay relay and circuits harmonized with a steering gear shaft driven mechanical control—when she is steady on the course.

I claim:

In an automatic steering device, a pivoted transparent magnetic compass card having a light obstructing sector, a light source adjustably mounted above the compass card for movement in a horizontal plane toward or away from the north point of the compass card in a line between the north and south points of said card, a transparent compass bowl, a horizontally rotatable disc supported below said compass bowl, two spaced light sensitive elements and a pointer equidistantly spaced therefrom mounted on said disc, the light sensitive elements being in light transfer relation with the light source through the transparent portion of the compass card, means for manually rotating said disc, drive means including a flexible shaft and a length compensating device connecting the disc to a steering shaft for rotating said disc, a relay connected in circuit with each of the light sensitive elements and electric motor means controlled by said relays for operating the steering shaft, a lost motion device connected between the steering shaft and the flexible shaft, rudder centering means including an adjustable time delay relay and contacting means comprising insulating wheels carrying conductive segments cooperating with stationery contact arms for controlling the electric motor means, said wheels being gear connected to the steering shaft.