March 5, 1935. B. B. HOLMES 1,993,550

AUTOMATIC STEERING SYSTEM FOR DIRIGIBLE CRAFT

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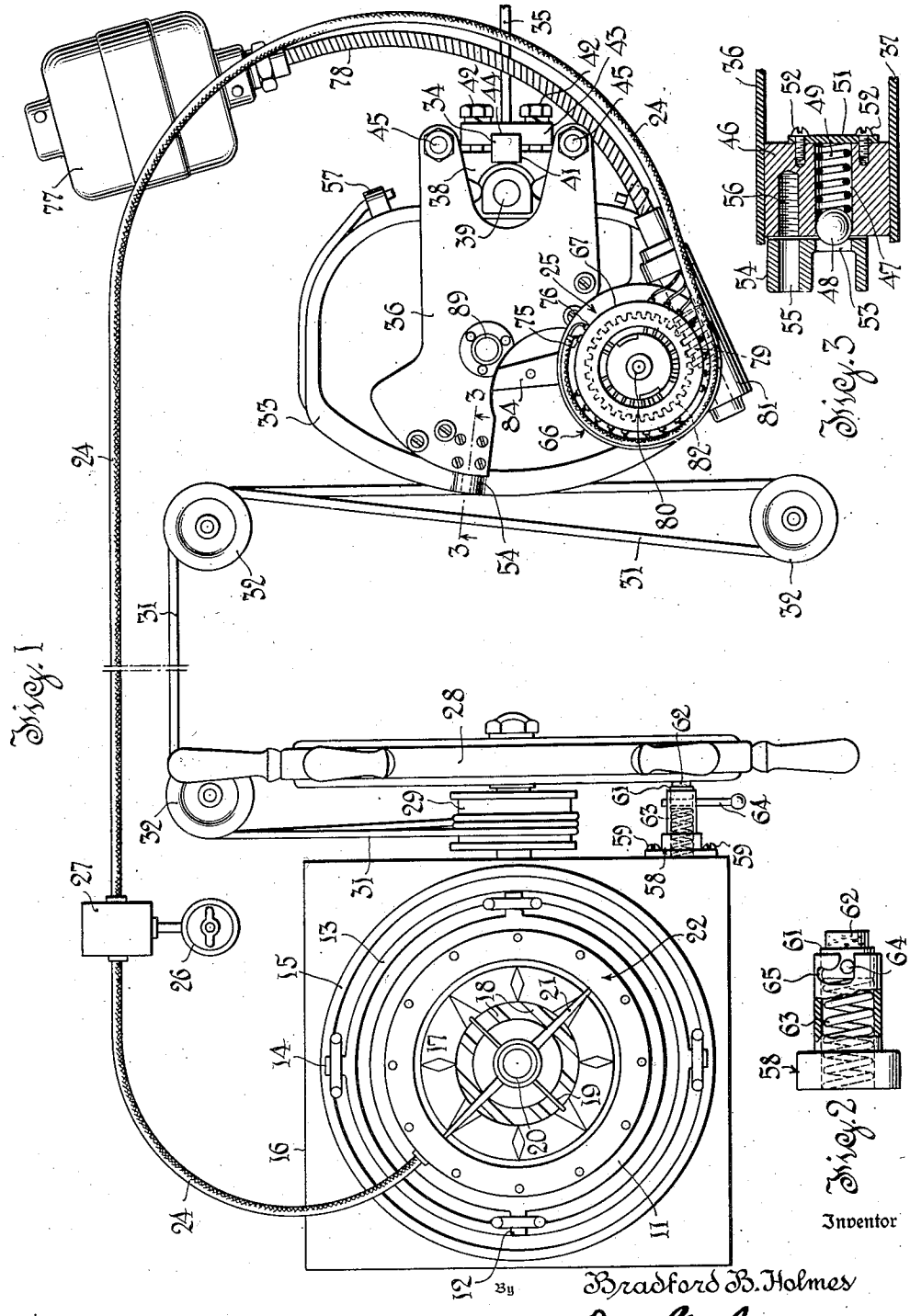


Fig. 1

Fig. 3

Fig. 2

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Fig. 5

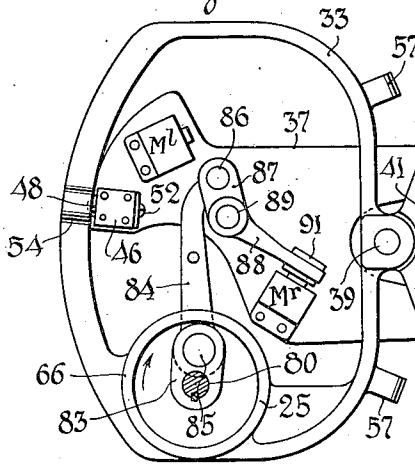


Fig. 4

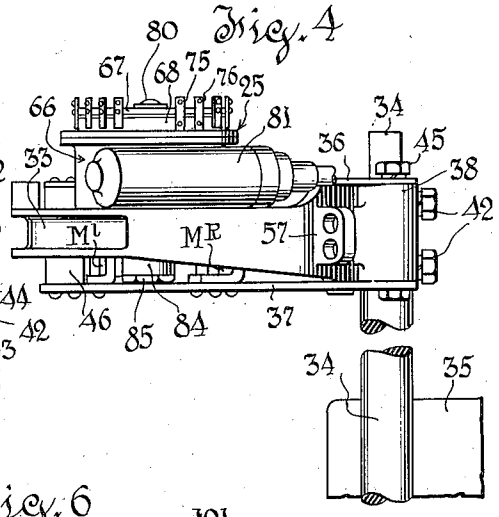


Fig. 6

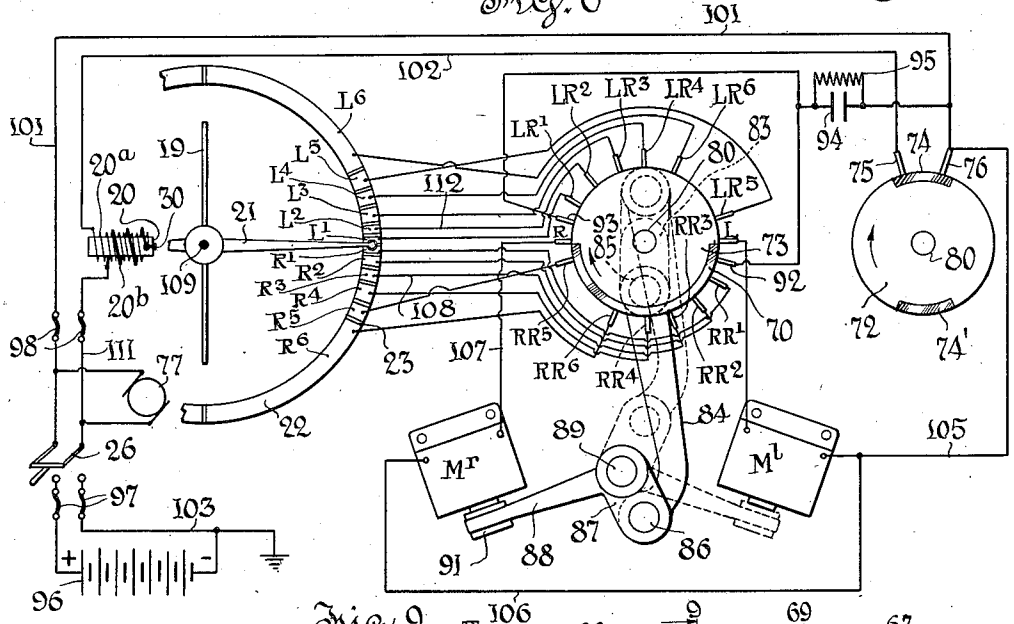


Fig. 9

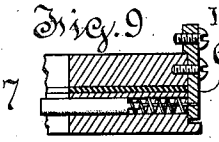


Fig. 8

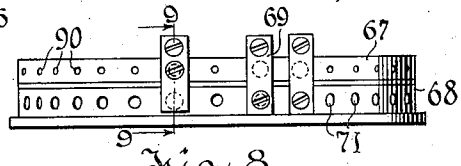
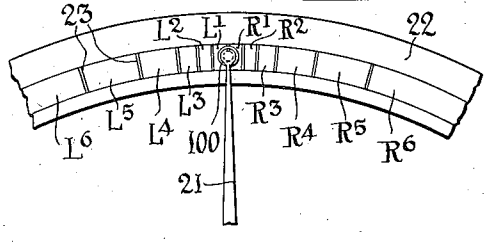


Fig. 7



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AUTOMATIC STEERING SYSTEM FOR DIRIGIBLE CRAFT

Bradford B. Holmes, Stonington, Conn., assignor to Ruth V. Holmes, Stonington, Conn.

Application January 6, 1932, Serial No. 585,122

29 Claims. (Cl. 114—144)

This invention relates to a method of and apparatus for the automatic steering of dirigible craft. It finds particular application in the steering of small ships or yachts, although it is not limited to such use and no limitations are intended, except as the scope of the claims is limited by disclosures of the prior art. It is applicable to the steering of craft provided with either magnetic or gyrocompasses, and is otherwise of general application.

In the automatic steering of dirigible craft in the prior art, for example, in steering ships, it has been customary to swing the rudder through a comparatively large angle as soon as the ship departs from her course; to add smaller increments of rudder as she departs further from her course, then to take off most of the rudder as soon as the ship starts to return to her course, and finally, to ease her back under small decrements of rudder; thus making four consecutive characteristic movements that the rudder follows for each swing of the ship.

Steering of this character is very complicated and difficult to obtain automatically because several factors have to be taken care of by the mechanism without manual manipulation.

First.—The mechanism must be so designed as to be capable of increasing or decreasing the throw of the rudder, in case external conditions cause the ship to swing back on or farther off her course, after the rudder has once been swung to a position corresponding to the initial movement of the craft from her course. These changes in rudder position must be made quickly and the mechanism should be capable of anticipating the amount of the swings of the ship from her course before such swings are completed.

Second.—Adjustable lost-motion mechanism must be provided in the rudder follow-up system in order to counteract the lost motion in the steering system, so that the movements of the rudder will correspond exactly to the movements of the ship from her course, or to be more exact, to the movements of the compass from the true course. If such mechanism is not provided for, the steering is erratic and varies in accordance with the wear on the parts of the steering mechanism. As the wear increases, the lost motion or backlash increases, and hence the movement of this mechanism tends to increase the discrepancy between the movement of the rudder and the movement of the ship.

Third.—The automatic steering device should be provided with automatic helm centering mechanism, so as to maintain the true amidships position of the helm as varying external conditions tend to cause the ship to follow, not her true course, but a course displaced from the true course, due to the swings being more on one side than the other of the true course.

Fourth.—Adjustable sensitivity mechanism must be provided to prevent undue working of the power steering mechanism when the condition of the sea is such that a "false yaw" or "corkscrewing" movement is imparted to the ship. With ordinary adjustments the mechanism would be moving the rudder continuously and violently, although such movement would have little or no effect upon the movement of the ship along her true course.

The devices set forth above involve complicated mechanism, present difficult problems, and when applied to the steering of yachts require too much especial knowledge or skill on the part of the operator to make their use practical, especially on small yachts. Furthermore, the controls have to be reset for changing sea conditions; often the change of one control necessitates changes in others.

Accordingly, this invention is intended to provide a simple system which is capable of accurate steering, and at the same time, is simple to install and comparatively inexpensive. Furthermore, a system embodying this invention does not require any special skill or qualifications on the part of the operator.

The method and apparatus embodying this invention constitutes an improvement upon my prior invention described and claimed broadly in application Ser. No. 550,792, filed July 14, 1931. In that application, the method of steering consisted in periodically and at recurrent intervals swinging the rudder from its amidships position for a length of time, or by an angular amount bearing some fixed relation to the position of the craft relative to its course at the time of each swing.

Constantly rotating timing mechanism was provided to cause the rudder to be subjected to these swings in accordance with the indications of the compass on the craft, but no swing was given to the rudder so long as the craft remained on its course. In other words, the rudder was allowed to trail between successive swings.

The improved form of this invention not only results in a much simpler apparatus, but the tendency of the craft to yaw is counteracted sooner, with the result that the course which can be steered is straighter than was possible with the

apparatus described in the above-mentioned application.

I have found that when a craft is on its course, it tends to hold that course more steadily if, instead of allowing the rudder to remain stationary at its amidships position, it is given small periodic oscillations each side of amidships. This might be called "live" in contradistinction to "dead" rudder. The reason for this is that if the craft starts to depart from its course, the stern swings to one side. This causes the oscillation of the rudder on that side to be more effective than the oscillation on the other side. This, in itself, serves to resist any movement off the course; whereas a stationary rudder does not have the same effect.

The improved method which I have adopted consists in periodically imparting to the rudder corrective deflections, first in one direction and then in the other, with trailing intervals between successive deflections. The rudder is allowed to trail freely after each deflection, and then is actually swung beyond its mid-position so that it is subjected to substantially continual deflection, first in one direction and then in the other.

When the craft is several degrees off its course, the deflections for correcting the position of the craft are of substantial extent and are determined by the angular position of the craft relative to its course; while the impulses in the opposite direction are determined by the structural characteristics of the mechanism which actuates the rudder.

When the craft is less than 5° off its course, the small reverse motions of the rudder stop the swing initiated by the correcting swings, so that the craft is "stepped" rather than "swung" towards its course. This effects a very stable or "dead beat" method of steering, causing the craft to be positively returned to its course without tendency to overswing.

When the craft is more than 5° off its course, the rudder is subjected to alternate large and small deflections, but when it is on or very near to its course, the alternate deflections are substantially equal. The effect of this method of steering is to anticipate yaws of the craft, thereby steadying its movement and keeping the operating mechanism effective at all times, so as to counteract yawing immediately upon its inception.

Another feature of this improvement lies in the fact that there is no central energized position of the controlling compass, the actuating mechanism being operative at all times to swing the rudder in one direction or the other, and I accomplish this result by substantially two elements, viz., a compass element and actuating mechanism associated with the rudder.

Furthermore, after the rudder is subjected to a deflection, it is released and allowed to trail freely until the deflection in the opposite direction is initiated either mechanically or electromechanically.

In this specification, frequent use will be made of the term "amidships". One definition of this term is that condition of a craft wherein the helm is at its central position, and the plane of the rudder coincides with that of the longitudinal axis of the craft. This definition applies under ideal operating conditions, but practically, such conditions are seldom if ever met. The craft is usually subjected to forces from propeller thrust and from waves and wind. Movements of the helm to counteract these forces give rise to a condition wherein the helm is deflected from its central position and the rudder is deflected from the plane of the longitudinal axis of the craft in order to hold the craft on its course. This latter condition is still an "amidships" condition so long as the craft is on its course, and wherever the term is used it is intended to cover both of the conditions described.

Although, as stated above, this invention is of general application, it has been illustrated and described as applied to a ship, and particularly to a small ship or yacht, having a magnetic compass. Several forms of apparatus for carrying out this method have been illustrated, and various modifications indicated, which render the apparatus suitable for application to craft of different sizes.

The invention will be more fully understood from the following description when read in connection with the accompanying drawings, in which,—

Fig. 1 is a plan view of the complete layout of one form of apparatus embodying my invention, with parts of the mechanism broken away to show the interior construction;

Fig. 2 is a detailed view of a friction device suitable for holding the helm in fixed position;

Fig. 3 is a section on line 3—3 of Fig. 1, showing a device for holding the tiller in centralized position on the quadrant;

Fig. 4 is an elevation of the tiller and quadrant assembly showing the reducing gear for driving the controller;

Fig. 5 is a plan view of the quadrant assembly with the top tiller plate removed;

Fig. 6 is a diagrammatic view of the complete layout, showing the electric circuits employed;

Fig. 7 is a detailed view of the contact arrangement employed on the compass head to render the automatic mechanism effective at all times;

Fig. 8 is a detailed view of the contact block of the controller; and

Fig. 9 is a section on line 9—9 of Fig. 8.

Referring to Fig. 1 of the drawings, the system there shown comprises the usual elements of a manual steering system, including a compass, a wheel, a rudder, and actuating mechanism connected between the wheel and the rudder. The apparatus is so designed that the boat may be steered manually in the usual way without using the automatic mechanism, or it may be steered manually without shutting off the automatic mechanism, and manual control may be assumed at any time while the automatic mechanism is operative.

In addition to the parts employed for manual steering, this system includes means controlled by the compass for moving the rudder electromechanically or mechanically, a single means being provided for moving the rudder and driving the electric timing device which is controlled by the contacts on the compass.

In Fig. 1, the reference character 11 represents the body of the compass which is weighted at the bottom in the usual manner. The body 11 is mounted to oscillate about a geometrical point with the usual gimbals comprising knife-edge trunnions 12 which engage seats provided for them on the gimbal ring 13. The gimbal ring 13 is, in turn, carried on the knife-edge trunnions 14, engaging seats provided for them in the binnacle 15. The binnacle 15 is mounted in conventional manner on a base 16, so as to allow the compass body to move freely about two mutually perpendicular axes, and to maintain

its position in a horizontal plane in spite of rolling and pitching movements of the ship.

The compass body includes the usual rotatable compass card 17 carrying the compass needles 18, a contact arm magnet 19, and a rotatable contact arm 21. The magnet 19 and arm 21 are secured together, and one end of the arm cooperates with a series of spaced contacts carried on a settable head 22, these contacts being separated by segments of insulation 23.

The details of the compass contact system will be described generally, and for the details thereof reference may be had to my copending application, Ser. No. 412,418, filed December 7th, 1929, in which this mechanism and the method of operating it are fully described and claimed.

The broad method embodied in this case of moving a contactor into contact with selected contacts of a series according to the changing indications of a movable indicating member, is disclosed and claimed broadly in my Patent No. 1,939,775, granted December 19, 1933, reissued October 9, 1934, No. 19,338. This method consists in shifting the contactor alternately into positioning engagement with the indicating member, and out of such engagement into contact with one of a series of contacts selected by such positioning.

For the purposes of this application, it will be sufficient to say that the contact arm 21, together with its magnet 19, is adapted to rotate independently of the compass needles 18, but is magnetically related to them and tends to follow them in its movements whenever it is free. Furthermore, the contact arm 21 is periodically lifted into contact with the settable head 22 by the energization of a lifting magnet 20, mounted concentrically with the axis of the compass needle and the contact arm.

The magnet 20 includes a magnetic core and two coils 20^a and 20^b. Coil 20^a is composed of a great number of turns of fine wire and functions as a lifting coil for arm 21, while coil 20^b is made up of a few turns of coarse wire and functions as a holding coil. One end of each of these coils is connected to a grounded contact 30 which cooperates with a contact 109 on contact arm 21 when this arm is lifted. Contact 109 is electrically connected with contact arm 21 and forms a part of a holding circuit through holding coil 20^b when the arm is lifted. When this magnet 20 is energized, the arm 21 is brought into firm engagement with one of the contacts of the settable head 22.

Means are provided for periodically energizing the magnet 20 so that arm 21 follows the compass needles around, and then is lifted against the contacts at periodically recurrent intervals so that the mechanism controlled by the compass receives controlling impulses each time the arm 21 is lifted. In the drawings, the settable head is shown for the sake of clearness, as being below the contact arm 21, but it will be understood that in practice the parts are reversed from the positions shown, and that the contact arm 21 is biased by gravity to a position out of contact with the settable head.

The contacts on the settable head are designated R^1, R^2, and L^1, L^2, etc. The contacts designated R correspond to movements of the craft off its course in a port direction and requiring the application of right rudder. Similarly, contacts L correspond to movements off the course in a starboard direction and requiring the application of left rudder. This nomenclature will be followed throughout the specification. The compass contacts are connected through wires in a cable 24 with the contacts in a controller 25 carried on the steering quadrant. Energization of the automatic mechanism is controlled by a manual switch 26, located near the helm and having associated with it a fuse and terminal box 27.

Before describing the automatic mechanism in detail, the mechanical parts which are useful in manual steering will be described. In Fig. 1, the reference character 28 designates the usual steering wheel or helm, located in proximity to the compass and being operable to rotate a drum 29, to thereby actuate a steering cable or rope 31 passing around guide pulleys 32 to a quadrant 33.

By reference to Figs. 1, 4 and 5, it will be understood that the quadrant and tiller are carried by the rudder post 34, the rudder being designated 35. The tiller comprises top and bottom plates 36 and 37, which are bolted to a forked member 38, to which the quadrant 33 is pivotally connected by a hinge 39. The member 38 has between its ends a socket 41 adapted to receive the rudder post and capable of alteration to accommodate the particular type of rudder post on the craft where the system is used.

Also contacting with the rudder post and bolted to member 38 by bolts 42, is a clamp 43 having a socket 44 similar to the socket 41 in member 38. When the bolts 42 are tightened, the tiller and the parts carried thereby are rigidly connected to rudder post 34, and form a means for positively moving the rudder.

The tiller plates 36 and 37 are secured to member 38 by bolts 45, one of the plates being above and the other below the quadrant 33, so as to permit the tiller to swing without actuating the quadrant. The tiller plates carry certain rudder-actuating mechanism which will be described later.

Also carried by the bottom tiller plate 37 is a frictional centering device comprising a block 46 containing a chamber 47, in which is housed a ball 48 biased to its left hand position, (see Fig. 3), by a spring 49. The chamber 47 is reduced in cross section at its left hand end so as to prevent the ball 48 from escaping, while the other end of the chamber is closed by a plate 51 fastened to body 46 by screws 52. The ball 48 is adapted to enter and cooperate with a recess 53 formed in the arcuate portion of quadrant 33, this recess being of slightly greater width than the portion of the ball 48 which protrudes from chamber 47, so as to permit slight lateral movement of the tiller without carrying the ball out of the recess 53.

The arcuate portion of quadrant 33 carries an enlargement 54 having an opening 55 in line with a similar but internally threaded opening 56 in body 46. The purpose of the two openings 55 and 56 is to permit a bolt to be inserted through the opening 55 and screwed into the opening 56, to permanently secure the tiller and quadrant together when it is desired to use the manual steering mechanism exclusively.

The configuration of the recess 53 is such that the tiller may be moved substantially without interference by this frictional device and without disturbing the position of the quadrant, but the quadrant cannot move appreciably without carrying the tiller with it.

The quadrant 33 carries ears 57 to receive the ends of cable 31 completing the connection with

wheel 28. The quadrant, together with the actuating mechanism therefor, is normally held in fixed position by a brake or friction device 58 secured to the compass base 16, as by screws 59. This brake comprises a hollow body containing a plunger 61 having a friction head 62 adapted in extended position to contact with the rim of wheel 28, and being biased to this position by an expansion spring 63 inside of the body. The plunger 61 carries an extended arm 64 which cooperates with a locking slot 65. When the arm 64 is rotated in slot 65, the head 62 may be moved away from the wheel, the spring 63 compressed, and the parts locked in released position. With the parts in the position shown in the drawings, the spring 63 forces the head 62 against the wheel, so as to prevent it from changing position unless appreciable force be exerted upon it

It will be understood that by releasing friction device 58, the wheel 28 may be actuated to swing the quadrant 33, and together with it, the tiller and the parts carried thereby, to actuate rudder 35 in the usual manner. If, however, it is desired to steer the craft automatically, the brake 58 is applied, with the wheel in its amidships position, thereby holding the manual means in this position, but permitting assumption of manual control in an emergency without releasing the brake or disconnecting the automatic control.

The tiller actuating and controller mechanism are mounted as a unitary structure on the quadrant 33. Accordingly, the quadrant carries a housing 66 having within it and projecting from the top thereof, a controller block made up of two separate insulating rings 67 and 68. These rings are fixedly mounted with respect to the housing 66, the top one 67 being adapted to receive a pair of brushes for operating the contact arm-lifting mechanism on the compass, while the lower ring 68 receives brushes connected to the contacts on the settable head of the compass. These brushes, together with their holding plates, are designated 69 in Figs. 8 and 9 of the drawings. Ring 68 contains a plurality of spaced openings 71 to receive these brushes, and to permit different spacing arrangements according to the controller effects desired. Ring 67 has two or more openings for brushes 75 and 76, and except for these openings the two rings are similar. Ring 67 contains a plurality of spaced screw-receiving openings 90 to receive the bottom brush holding plates.

Rotatably mounted within the rings 67 and 68 and cooperating therewith, are two controller discs 72 and 73. They are mounted upon the top end of the vertical speed reducer shaft 80. Disc 72, which is on top, is composed of electrical insulating material and contains two conducting segments 74 and 74' spaced 180° apart. This disc cooperates with the two brushes 75 and 76 carried in ring 67 and is adapted to control the lifting magnet 20 on the compass. It will be understood that as disc 72 rotates, the contacts 75 and 76 are alternately connected and disconnected as these brushes ride on and off the conducting segments. The disc 73 which cooperates with a plurality of brushes carried in ring 68, is composed of electrical insulating material with a portion of its circumference covered by a conducting segment 70.

As shown in Fig. 6, the segment 70 constitutes slightly less than 180° of the circumference of the disc, so that the segment cannot make contact with brush R or L at the same time. This segment controls the periodicity, as well as the length of time that the brushes in ring 68 are energized, when compass contact arm 21 is in engagement with contacts on the settable head. In order to make the operation more clear, the contacts in ring 68, as shown in Fig. 6, are designated by the same reference characters as those which appear on the settable head of the compass.

Accordingly, the brushes which are connected with compass contacts R^1, R^2, etc., for giving right rudder to counteract port deflections of the vessel, are designated RR, with appropriate exponents corresponding to the exponents on the compass contacts to which these brushes are connected. In similar manner, the brushes connected to compass contacts L^1, L^2, etc., are designated LR with an exponent corresponding to the compass contact to which the particular brush is connected, thus indicating that when one of the L contacts on the compass is in circuit, a corresponding LR brush will be energized at the proper time during the rotation of disc 73.

A single means is provided for driving the rotating elements of controller 25, and at the same time, furnishing a mechanical drive for the tiller of the craft. This means comprises an electric motor 77 connected through a flexible shaft 78 with a reducing gear made up of a worm 79 carried in housing 81, and a worm gear 82 mounted on shaft 80 in suitable bearings within the housing 66. In order to effect a smooth and steady operation of and ample torque for the steering mechanism, it is preferred that the reduction between worm 79 and gear 82 be very large. It has been found that gear ratios of from 60 to 100 to 1 are satisfactory, depending upon the size of the ship, although it is to be understood that this particular range of ratios is not necessary to the operation of the system.

When the electric motor 77 is being driven, worm 79 rotates, thereby driving the gear 82 constantly in a clockwise direction and at the same time, rotating the controller discs 72 and 73 in the same direction. Also mounted below housing 66 on the lower end of shaft 80, and therefore rotatable with the gear 82 and the controller discs, is a crank 83 having connected with it a connecting rod 84 pivoted about a pin 85. Connecting rod 84 is pivotally connected at 86 to one end of an arm 87, constituting one arm of a bell crank lever 88. The bell crank lever is pivoted to tiller plates 36 and 37 at 89, and carries at one extremity an armature 91 which is adapted to engage in its extreme positions, rudder-actuating magnets M^l and M^r carried between the tiller plates 36 and 37.

It will be understood that the connecting rod 84 in connection with the arm 87 of bell crank lever 88, forms a toggle and that when crank 83 rotates, the armature 91 is caused to oscillate back and forth between its two extreme positions in which it engages the rudder-actuating magnets.

Whenever the magnet with which armature 91 contacts is energized, the bell crank lever forms in effect an integral part of the tiller construction, so that movement of the crank though 180° of rotation causes the tiller together with the rudder to be moved through an angle determined by the period of energization of the magnet. When magnet M^r is energized, the rudder is moved to the right; when magnet M^l is energized, the rudder is moved to the left.

It is essential that the armature 91 make a firm and complete contact with the magnet when

such magnet is energized, and it is also desired that when the craft is near its course the rudder be subjected to a slight alternate deflection in the opposite direction from the normal restoring rudder swings. Consequently, the magnets M^r and M^l are so placed that as the armature 91 oscillates between its two extreme positions, it always contacts with one of the magnets near the end of each excursion and acts to swing such magnet, together with the tiller and rudder, a slight distance (about 1°) beyond the position which the parts occupy when the rudder is in its central or amidships position. The effect of this is to subject the rudder to small mechanical deflections, even though the rudder-actuating magnets are never energized. On the other hand, when such magnets are energized, the rudder may be subjected to larger swings electromechanically, but such larger swings are always alternated with small mechanically initiated rudder swings in the opposite direction. This has the effect of destroying the swinging tendency of the rudder, and causes the craft to "step" rather than swing back to its course.

The diagrammatic view in Fig. 6, shows the parts in position just prior to energization of the M^r magnet when there is a port deflection of the vessel which would cause energization of one of the R contacts calling for right rudder. The full line portion of Fig. 6 indicates the position of the toggle mechanism when the armature 91 engages the magnet M^r. As here shown, the controller ring 68 carries 16 brushes, 12 of which are directly connected to contacts on the compass head 22; 2 of which, those designated R and L, are connected to the rudder-actuating magnets, and the others, 92 and 93, cooperate with a condenser 94 to prevent sparking of the contacts when they are broken on the controller disc 73. The brushes 92 and 93 are so connected as to bring condenser 94 in the circuit with certain of the brushes LR and RR whenever the circuit through either of magnets M^r or M^l is broken by rotation of disc 73. A leak resistance 95 is shunted around the condenser 94 to carry off the discharge from this condenser, and to prevent the condenser from discharging through the circuit with consequent sparking when the contacts are made on controller disc 73.

Having described the mechanical structure of the apparatus embodying the invention, the electric circuits shown in detail in Fig. 6 will now be traced, in order to make the operation of these circuits clear. For the purpose of illustration, it will be assumed that the source of power for energizing the electric circuits and actuating the motor 77, is a battery 96. Motor 77 may be energized from this battery by closing switch 26, suitable fuses 97 being interposed in this circuit to protect it in case of short circuits or the like in the system. The circuit from battery 96 beyond motor 77, likewise, includes another set of smaller fuses 98 for protecting the compass and controller circuits.

When the switch 26 is closed, current is supplied to motor 77 to drive it, and to cause continuous operation of the controller and the mechanical actuating mechanism associated with it. This switch also causes energization of the controller circuits so that each time a conducting segment in disc 72 bridges the contacts 75 and 76, lifting magnet 20 is energized to lift the contact arm 21 on the compass and bring it against contacts on the settable head 22.

The circuit for lifting magnet 20 with the parts in position as in Fig. 6, is as follows:

From the positive contact of battery 96, through switch 26, wire 101, brush 76, segment 74, brush 75, wire 102, coils 20^a and 20^b of magnet 20, switch 26, and wire 103 to the negative side of the battery. This circuit is closed twice during each revolution of the controller.

Energization of this circuit causes contact arm 21 to be lifted, thereby bringing contact 109 into conducting engagement with contact 30. The circuit now established is as follows:

Positive terminal of battery 96, through switch 26, wires 101 and 105, to one of the rudder magnets M^r or M^l, (depending upon the position of controller 25), then through one of the R or L brushes to controller segment 70, through one of the brushes LR or RR to one of the L or R contacts on the compass head, and thence through the movable contact 100 on contact arm 21, contact arm 21, contacts 109 and 30, holding coil 20^b, wire 111, switch 26 and wire 103, to the negative terminal of battery 96. This circuit remains closed until controller 25 rotates far enough to break the circuit between the brushes controlled by the particular contact on settable head 22 with which contact 100 is in engagement.

The energization of the brushes associated with the ring 68 of controller 25 from battery 96, is determined by the position of the contact arm 21 relative to the contacts on settable head 22. As just described, the lifting of contact arm 21 is periodic in accordance with the energization of lifting magnet 20, and the particular contact engaged by this arm is determined by the position of the craft relative to its course.

Swinging movements of the craft relative to its course cause the magnet needle 19 to follow the compass needles and to swing in accordance with such movements, thereby moving contact arm 21 so that when magnet 20 is energized, this arm contacts with the particular portion of head 22 with which it is in line at the time of such energization.

If, for example, we assume that the top end of needle 19 is a north-seeking pole and that the craft swings in a port direction, thereby carrying the ring in a counterclockwise direction, the needle 19 will swing in a clockwise direction relative to the ring, bringing arm 21 above one of the R contacts on the compass, to thereby initiate a movement of the rudder to the right to restore the craft to its course.

In similar manner, starboard movements of the craft are counteracted by movements of the contact arm 21 into engagement with the L contacts to initiate movements of the rudder to the left, to restore the craft to its course.

As pointed out hereinbefore, it is desired that the automatic steering means be effective at all times, consequently, the two contacts L^1 and R^1 nearest to the center position of arm 21 are placed in close proximity to one another, and are separated only by a thin strip of insulation. The contact 100 on the end of contact arm 21 is wider than this strip, so that when the craft is on its course the contact 100 engages one or both of contacts L^1 and R^1, causing alternating small left and right rudder deflections in accordance with the operation of controller 25.

Accordingly, the electric mechanism is effective at all times to cause rudder movements and to anticipate yawing movements of the craft from its course. This arrangement, together with the

mechanical placing of the rudder magnets, brings about a system of "live" steering, wherein the rudder is periodically subjected to alternate deflections regardless of the position of the craft relative to its course, but the deflections in either direction may be varied electro-mechanically in accordance with yawing movements of the craft.

In order to make the operation of the circuit controlling mechanism more clear, a few examples will be given and the circuits involved will be traced in detail.

If we assume that the craft leaves its course in a port direction, so as to cause the contact arm to engage contact R^3, to give right rudder to restore the craft to its course, the steps of operation will be as follows: As soon as the craft swings away from its course carrying settable head 22 with it, the needle 19 will swing to the right, causing contact arm 21 to engage the contact R^3 when magnet 20 is energized.

When rotation of the worm reducer causes armature 91 to contact with magnet M^r, the conducting segment 70 in controller disc 73 will be in a position to connect brush RR^3, with brush R, thereby energizing magnet M^r which locks arm 88 and causes the rudder to be moved to the right to counteract the movement of the craft, and this swing will be continued until segment 70 leaves contact RR^3. During this time, arm 21 will be held up with contact 100 against the contact R^3 by the current flowing through the holding coil in series with M^r.

The circuit completed under such circumstances, is as follows: From the positive terminal of battery 96, through switch 26, wires 101, 105 and 106, magnet M^r, wire 107, brush R, conducting segment 70, brush RR^3, wire 108, contact R^3 on compass head 22, contact arm 21, contacts 109 and 30, holding coil 20^b, wire 111, switch 26 and wire 103, back to battery 96.

A similar circuit will be closed each time the contact arm 21 is lifted while the craft is off its course in a port direction, and the angular extent of the rudder swing will be determined by the length of time that this circuit is energized. The period of energization will likewise be determined by the angular relation between the craft and the course, the period being longer when the craft is farther away from its course, except in the case of contacts R^5 and R^6 for reasons given later.

The positions of the brushes LR and RR determine the time of energizing of magnets M^r and M^l, and hence the amplitude of rudder throw. The size of the R and L contacts and the arrangement of the brushes are such that from the center to the fourth contact, the rudder throw increases by four fairly regular steps, but the fifth contact gives almost double the rudder of the fourth. This is to apply heavy rudder to stop yaws in a following sea, and normally the vessel will be steered, even in severe conditions, within a range covered by the first five contacts or less.

The sixth contact gives a rudder less than the fifth and greater than the fourth. It is used in changing course where it is not advisable to use as much rudder as the fifth contact gives. The reason for this is that if too much helm is used for too long a time, it swings the craft so fast that the compass lags, causing overswing of the craft on reaching its new course. By arranging the contacts in this manner the tendency to overswing is greatly reduced.

It will be understood from the one example given, that as the craft returns to its course and magnet 20 is subjected to cyclic energization, the contact arm 21 will be lifted and dropped so as to successively bring contacts R^2 and R^1 into the circuit, to give the rudder progressively smaller swings to ease the craft back to its course.

Owing to the width of the contacts, the swings do not successively increase or decrease as there are always a number of equal swings in one direction while the craft is traversing the angle subtended by the arc of contact. Thus, as the craft leaves its course, it is checked by a series of small equal rudder swings in one direction, followed by a series of larger equal rudder swings, and so on, until the yaw is checked. On the return, it is headed towards its course by a series of equal rudder swings, followed by a series of lesser equal swings, and so on, until it reaches its course. However, between each two of these rudder swings will be interjected smaller reverse rudder swings caused by the mechanical throw of armature 91 engaging the rudder magnet M^1, which have the effect of causing the craft to move in a series of steps rather than a swing when near its course.

When the craft leaves its course in a starboard direction so as to cause contact arm 21 to engage one of the L contacts, for example L^2, the conducting segment 70 connects brush L and brush LR^2 at the time when contact arm 21 is lifted, and armature 91 engages rudder magnet M^1. Consequently, the rotation of controller 25 will cause the tiller to be moved to give left rudder for a period depending upon the spacing of the brushes in contact ring 68. This period will be relatively short, so that the series of rudder swings will be approximately two degrees each.

When this condition arises, the circuit completed is as follows:

From the positive terminal of battery 96, through switch 26, wires 101 and 105, rudder magnet M^1, brush L, conducting segment 70, brush LR^2, wire 112, contact L^2, contact 100, contact arm 21, contacts 109 and 30, coil 20^b, wire 111, switch 26 and wire 103, back to the battery. When this circuit is deenergized by segment 70 leaving the brush LR^2, the armature 91 will be released by magnet M^1 and the rudder will trail freely to return to its mid-position until the mechanical movement of armature 91 engaging magnet M^r causes a deflection to the right.

As the craft returns to its course, movement of contact arm 21 may cause energization of the magnet M^1 again to give the rudder another deflection to the left, or the movement of the craft may be such that the next energization will be that of magnet M^r because the craft has deflected in a port direction. In any case, the circuit arrangement is such that following the deviation of the craft, contact arm 21 engages one of the L or R contacts to cause energization of one of the rudder magnets when armature 91 engages it, to thereby move the rudder through an angle which is dependent upon the position of the craft relative to its course at the time contact arm 21 is lifted.

The periodicity of the rudder swings is controlled by the rotation of disc 72, while the extent of the rudder swings is determined by the position of the contact arm 21 on settable head 22, and the location of brushes LR and RR in ring 68. The mechanical deflections of the rudder which occur when the magnets M^r or M^1 are deenergized are, of course, constant in amount, and when the craft is following its course closely, the rudder oscillates periodically and has a steadying effect on the craft, making it less liable

to depart from its course than if the rudder were held stationary.

It will be clear from the foregoing, that this invention brings about a system of "live" steering wherein the response of the craft to deviations from a set course is prompt and the control is accomplished by the simplest of means. A single electric motor in conjunction with compass-controlled contacts determines the operation of all the actuating circuits, and manual control can be assumed in an emergency without shutting off the automatic control. The automatic control continues to operate, but its effectiveness is destroyed so long as the manual control is in operation.

It will be apparent that by setting the wheel 28 in a position to counteract more or less permanent conditions which tend to throw the craft off its course, the amidships position of the helm can be changed. If there is a wind on a certain quarter, or if there are variations in propeller speed conditions which tend to throw the craft always in one direction, the wheel 28 can be set with the brake on so as to determine a new amidships position, and thereby prevent unnecessary laboring of the automatic control mechanism.

If it is desired to change from hand to automatic steering, it is only necessary to set the course on the compass head by moving the rotatable head 22, place the wheel in amidships position, and close the switch 26. On the other hand, if it is desired to change from automatic to hand steering, switch 26 is turned off and the wheel 28 operated in the usual way after releasing the brake.

Apparatus embodying this invention and employing this method of steering is capable of steering to within plus or minus one-half a degree from a set course, and this is an accuracy far in excess of that which can be accomplished by simple hand steering.

Although I have herein shown and described only one form of automatic steering mechanism embodying this invention, it will be obvious that various changes may be made in the details within the scope of the appended claims, without departing from the spirit and scope of this invention.

What is claimed is:

1. The method of steering dirigible craft having a rudder, which consists in periodically imparting to the rudder corrective deflections first in one direction and then in the other at fixed recurrent intervals with trailing intervals between successive deflections, and varying the character of the deflections in one direction in accordance with the position of the craft relative to its course.

2. The method of steering dirigible craft having a rudder, which consists in periodically imparting to the rudder a series of corrective deflections in alternate directions at fixed recurrent intervals, with periods intervening between consecutive deflections in which the rudder is allowed to trail freely and return to amidships position, and varying the character of such deflections in accordance with the position of the craft relative to its course.

3. In an automatic steering system for dirigible craft having a rudder; a tiller connected to said rudder; a quadrant flexibly connected to said tiller; electromagnets on said tiller; a compass; rotating means on said quadrant and controlled by the compass for energizing said electromagnets in accordance with indications of said compass; and lever mechanism connected between said rotating means and said tiller for actuating said tiller when one of said magnets is energized.

4. In an automatic steering system for dirigible craft having a rudder; a tiller secured to said rudder; a quadrant hinged to said tiller; a rotating controller on said quadrant; compass-controlled means for selectively energizing said controller; a motor; a driving connection between said motor and said controller; and means for actuating said tiller from said controller.

5. In an automatic steering system for dirigible craft having a rudder; a swingably mounted quadrant hinged to the rudder; a tiller fixedly connected to said rudder and movable either independently of or in concert with said quadrant; a ball and socket connection between the tiller and quadrant for permitting such movement; automatic means for moving said tiller independently of said quadrant; and manually operable means for moving said quadrant and tiller in concert.

6. In an automatic steering apparatus for dirigible craft having a rudder; a course-setting device; rudder-actuating mechanism; contact mechanism controlled by the course-setting device for controlling the operation of the rudder-actuating mechanism; and a single means for actuating said rudder and said contact mechanism.

7. In an automatic steering apparatus for dirigible craft having a rudder; rudder-actuating mechanism; compass-controlled contact mechanism for controlling the operation of said mechanism; and a single means for actuating said rudder and said contact mechanism.

8. In an automatic steering system for dirigible craft having a rudder; a tiller connected to said rudder; a quadrant flexibly connected to the tiller; rotating means on said quadrant; and eccentric means between said tiller and said rotating means for oscillating said tiller.

9. In an automatic steering apparatus for dirigible craft having a rudder; a compass; a tiller connected to the rudder; a quadrant flexibly connected to said tiller; mechanical means carried by the quadrant for actuating the tiller; and magnet means carried by the tiller and controlled by the compass for varying the character of the rudder deflections in accordance with the indications of the compass.

10. The method of steering dirigible craft having a rudder, which consists in deflecting the rudder from amidships position first in one direction and then in the other at fixed recurrent intervals, and varying the character of successive deflections in one direction in accordance with the position of the craft relative to its course at the time when the deflections are initiated.

11. The method of steering dirigible craft having a rudder, which consists in deflecting the rudder from amidships position first in one direction and then in the other at fixed recurrent intervals and varying the angular extent of successive deflections in one direction in accordance with the position of the craft relative to its course at the time when such deflections are initiated.

12. In an automatic steering apparatus for dirigible craft having a rudder; rudder-actuating mechanism; compass-controlled contact mechanism for controlling the operation of said rudder-actuating mechanism; a motor; and a driving connection between said motor and said contact mechanism.

13. In an automatic steering apparatus for

dirigible craft having a rudder post carrying a rudder; a tiller and quadrant assembly comprising a tiller; a separable two-piece clamp for securing said tiller to the rudder post; a bracket on said tiller; and a quadrant hinged to said bracket.

14. In an automatic steering apparatus for dirigible craft; a quadrant assembly comprising a quadrant; a rotating controller on said quadrant; a worm and gear for actuating said controller; a motor; and a driving connection between said motor and said worm.

15. In an automatic steering apparatus for dirigible craft, a tiller and quadrant assembly comprising a rudder post; a tiller secured to and movable with said rudder post; a quadrant pivotally connected to said tiller; eccentric means on said quadrant; tiller-actuating means and circuit-controlling means rotatable by and in concert with said eccentric means; a motor; and a driving connection between said motor and said eccentric means.

16. In an automatic steering apparatus for dirigible craft, a steering quadrant; a circuit controller on said quadrant; a motor; a driving connection on said motor; and speed-reducing gearing between said connection and said controller.

17. In an automatic steering apparatus for dirigible craft having a rudder and rudder post; a tiller clamped to said post, and including two plates held in spaced relation; a quadrant hinged to said tiller and having a portion movable between said tiller plates; rotatable eccentric means on said quadrant; torque-multiplying means between said eccentric means and said tiller; and a motor for driving said eccentric means.

18. In an automatic steering apparatus for dirigible craft; a rudder; a tiller secured to said rudder; a quadrant hinged to said tiller; and a friction device between said tiller and quadrant for permitting the tiller to move independently of the quadrant but requiring movement of the tiller in concert with the quadrant when the quadrant is actuated.

19. In an automatic steering system for dirigible craft having a rudder; automatic means for actuating the rudder; manually operable means for actuating said rudder while the automatic means is operating; and means associated with the manually operable means for maintaining different helm settings to compensate for changes in the amidships position of the rudder.

20. In an automatic steering system for dirigible craft having a rudder; automatic means for actuating the rudder; manually operable means for actuating said rudder while the automatic means is operating; and friction braking means associated with the manually operable means for maintaining different helm settings to compensate for changes in the amidships position of the rudder.

21. In an automatic steering system for dirigible craft, a compass; a plurality of electric contacts on said compass; a movable contact arm associated with said contacts; a lifting magnet for periodically operating said contact arm and including a lifting coil and a holding coil; a rotating controller; and a pair of contact discs in displaced relation on said controller, one of said discs controlling the circuit of the lifting coil and the other disc controlling the circuit for the holding coil.

22. In an automatic steering apparatus for dirigible craft having a direction controlling element; actuating mechanism for said element; compass-controlled contact means for controlling the operation of said mechanism; and a single means for actuating said element and said contact means.

23. In an automatic steering system for dirigible craft having a rudder; automatic means for actuating the rudder; manually operable means for actuating said rudder when said automatic means is operating; and means for giving said manual means a permanent setting to change the amidships position to centralize the swings of the rudder in accordance with the drift of the craft.

24. In an automatic steering system for dirigible craft, a tiller; a quadrant pivoted to said tiller; constantly operating actuating means carried by said quadrant; and means for connecting said actuating means to and disconnecting it from the tiller to control the movements of the tiller.

25. The method of steering dirigible craft which consists in periodically imparting to the rudder at fixed recurrent intervals, when the craft is on its course, deflections first in one direction and then the other, with trailing intervals between deflections.

26. In an automatic steering apparatus for craft having a direction controlling element; electrical actuating mechanism for said element; rotatable electric contact means responsive to changes in direction of craft movement for controlling the operation of said mechanism; and a single means for actuating said element and said rotatable contact means.

27. In an automatic steering apparatus for craft having a direction controlling element; continuously rotating means responsive to changes in direction of craft movement for controlling said direction controlling element; and a single electric means for actuating said element and said direction responsive means.

28. In an automatic steering apparatus for craft having a direction controlling element; actuating mechanism for said element; continuously operating controlling means responsive to changes in direction of craft movement for controlling the operation of said mechanism; and a single power means for actuating said actuating mechanism and said controlling means.

29. In an automatic steering mechanism for craft having a direction controlling element; continuously operating controlling means responsive to changes in direction of craft movement for controlling said direction controlling element; and a single electric means for actuating said direction controlling element and said controlling means.

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