

March 5, 1935.

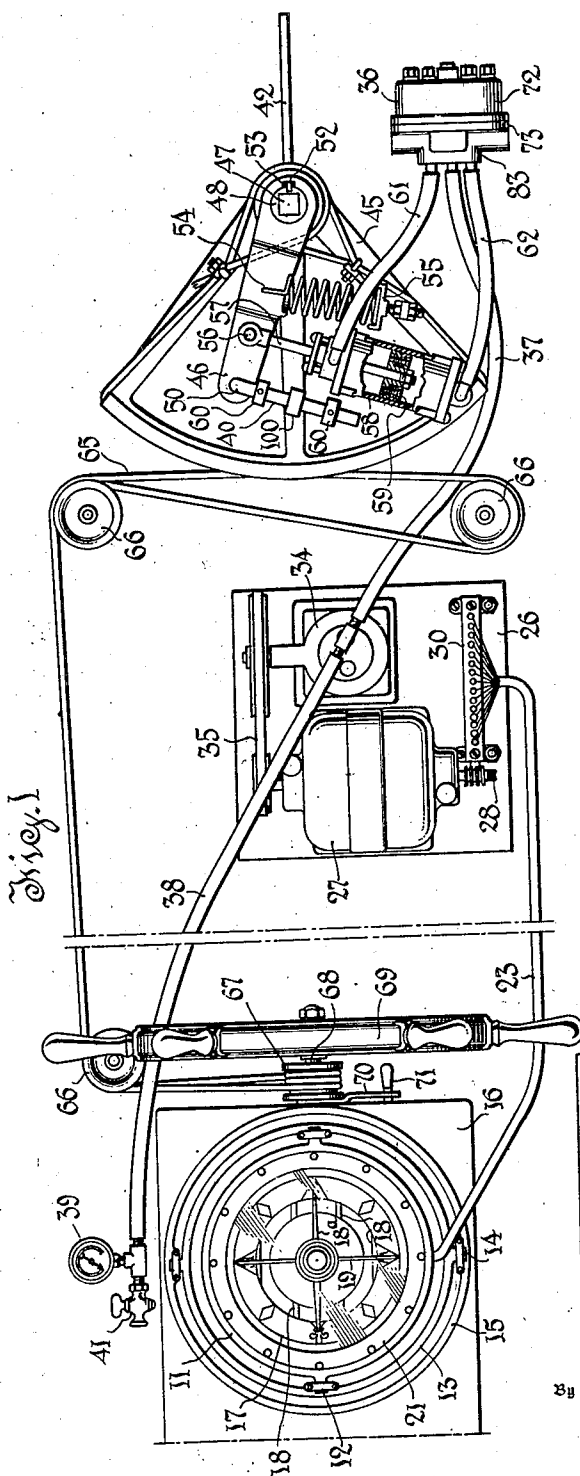
B. B. HOLMES

1,993,549

AUTOMATIC STEERING SYSTEM FOR DIRIGIBLE CRAFT

Filed July 14, 1931

3 Sheets-Sheet 1



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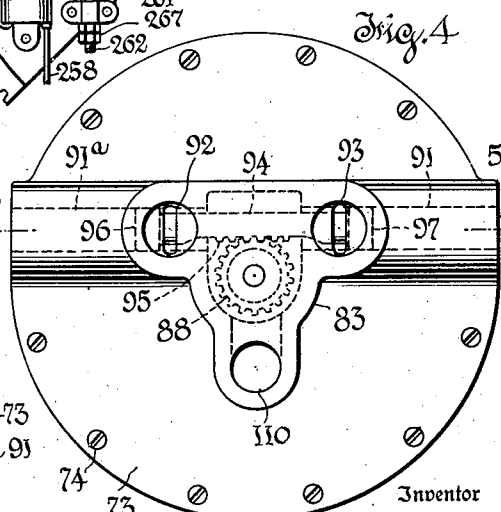
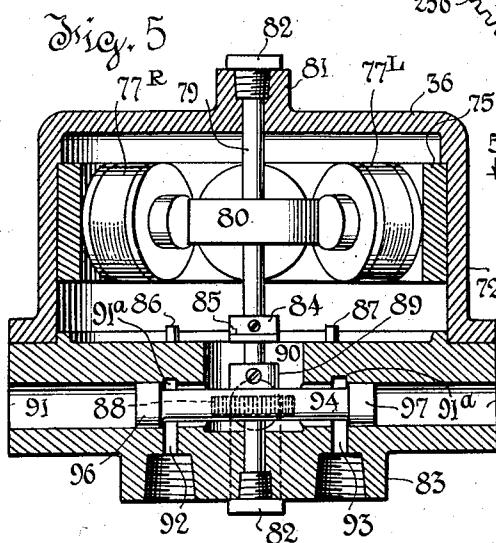
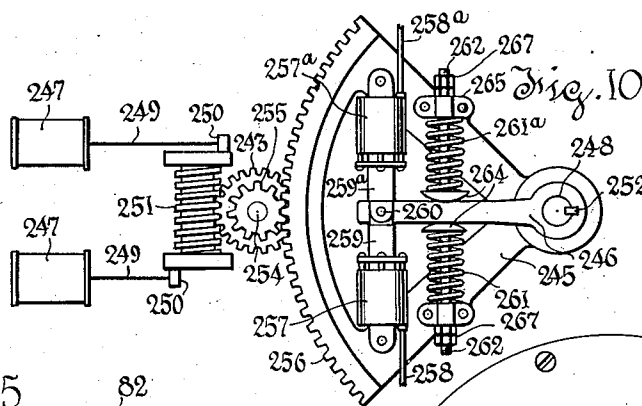
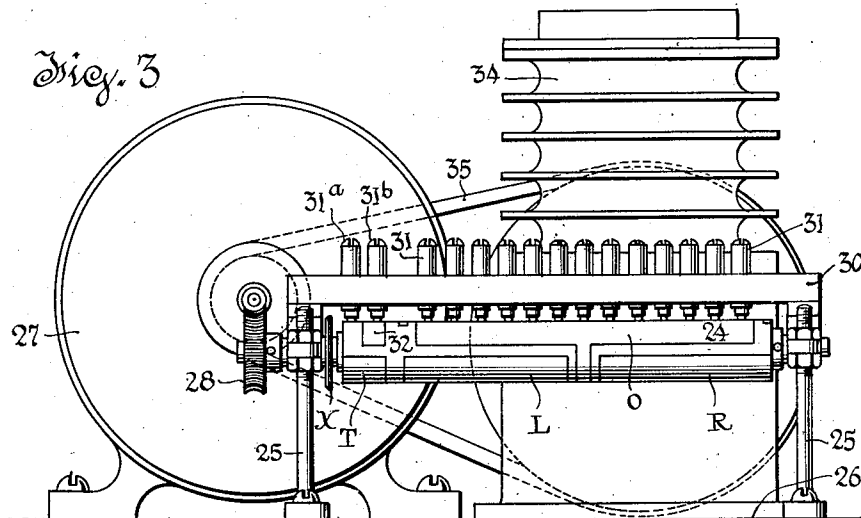
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AUTOMATIC STEERING SYSTEM FOR DIRIGIBLE CRAFT

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3 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE

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AUTOMATIC STEERING SYSTEM FOR
DIRIGIBLE CRAFTBradford B. Holmes, Stonington, Conn., assignor
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Application July 14, 1931, Serial No. 550,792

47 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, 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, 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 po-

sition 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 of installation, 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. 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 of steering embodying this invention consists 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 her course at the time each impulse is initiated. Constantly rotating timing mechanism is provided to cause the rudder to be subjected to these impulses in accordance with the indications of the compass on the craft, and in case the craft is on the true course at a time when an impulse is to be given to the rudder, the rudder position will not be disturbed. The craft is, therefore, steered by subjecting the rudder to impulses so that it acts for a part of the time, and during the remainder of the time trails freely.

Concisely stated, the method consists in giving the rudder a series of periodic swings or impulses whenever the vessel is off her course, and allowing it to trail or assume its amidships position in the intervals between swings. The extent of the rudder swings is roughly proportioned to the amount the vessel is off her course. For instance, when the vessel is more than about 5° off her course, as in changing course or in heavy weather, the rudder swings are great enough

so that their individual effects overlap and the result on the boat is about the same as if the rudder were continuously held over. However, when the vessel arrives to within about 5° of her course, the duration and extent of the impulses are so small that their effects do not overlap, but die out during the trailing intervals and the vessel is restored to her course by a series of individual steps rather than a swing.

After each impulse the rudder automatically swings back to its amidships position, so that the craft is acted on by a series of impulses which counteract the tendency of the craft to over-swing or yaw from its true course. Inasmuch as the extent of rudder movement is varied in accordance with the position of the craft, sudden impulses through which the craft is moved depend upon the position of the craft as indicated by the compass needle at the time the rudder impulses are initiated. It is to be noted that during the swing of the craft off her course, she is acted on by a series of restoring impulses with intervals of trailing rudder between them, and not by a continuous application of rudder.

It may be assumed, for example, that an impulse is applied to the rudder once a second. Accordingly, when the craft is ½° off its course, 10° of rudder may be applied for ⅓ of a second each second.

When 1½° off the course ⅓ second each second. When 2½° off the course ⅓ second each second.

When 4½° off the course ⅓ second each second.

When 6° off the course ⅓ second each second. When 10° or more off the course ⅓ second each second.

Or the above may be varied to give a smaller angle of rudder on the small departures, as

When ½° off the course 5° rudder for ⅓ second each second.

When 1½° off the course 7½° rudder for ⅓ second each second.

When 2½° off the course 10° rudder for ⅓ second each second.

When 4½° off the course 10° rudder for ⅓ second each second.

When 6° off the course 10° rudder for ⅓ second each second.

When 10° or more off the course 10° rudder for ⅓ second each second.

The figures given above are only illustrative and on large ships the duration of an impulse might be as much as 5 to 10 or more seconds, and the rudder movement from 2° to 5° during this period. It is contemplated that the rudder will not make its complete swing during impulses of extremely short duration, the main object of the method being to apply rudder impulses at periodic intervals when the ship is off her course, and to increase the length of such impulses as the ship moves further from her course, and shorten the impulses as she returns to her course.

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 an assembled view of one form of automatic steering apparatus employing pneumatic control, and embodying this invention;

Fig. 2 is a diagrammatic view showing one form of circuit arrangement suitable for use in the system shown in Fig. 1;

Fig. 3 is a detailed view of a portion of the apparatus shown in Fig. 1, showing the details of the control switch which determines the length of the impulses applied to the rudder;

Fig. 4 is an end view of an electro-pneumatic valve, suitable for use in the system shown in Fig. 1, certain of the operating parts being indicated in dotted lines;

Fig. 5 is an axial sectional view of the valve, the section being taken on line 5—5 of Fig. 4;

Fig. 6 is a diagrammatic view of a modified form of steering system designed for electro-magnetic operation.

Fig. 7 is a detailed view of a modified tiller and quadrant arrangement suitable for use in an electro-pneumatic system such as that illustrated in Fig. 1;

Fig. 8 is a diagrammatic view of a further modified system suitable for use in steering large heavy craft, either pneumatically or hydraulically;

Fig. 9 is a detailed view of the rudder, tiller and quadrant construction for the system shown in Fig. 1; and

Fig. 10 is a plan view of a quadrant and tiller arrangement equipped for hydraulic operation, as on a large ship having a steam steering engine.

Referring to Figs. 1 and 2 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 shutting off or deranging the automatic mechanism, and manual control may be assumed at any time.

In addition to the parts employed for manual steering, this system includes means controlled by the compass for moving the rudder electro-pneumatically, the compass being provided with an electric contactor which controls the electric circuit to an electro-pneumatic valve. Air under pressure is supplied to this valve from a suitable source, and directed from this valve to a pneumatic cylinder containing a piston connected to the rudder of the boat.

Having described the system generally, the details of the various elements will now be pointed out. 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 knife-edge trunnions 14, engaging seats provided for them in the fixed supporting ring 15. The ring 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 18^a, and a rotatable contact arm 19. The magnet 18^a and arm 19 are secured together, and one end of the contact arm 19 cooperates with a series of spaced contacts (Fig. 2) carried on a settable head 21, these contacts being separated by segments of insulation 22. 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.

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 7, 1929, in which this mechanism is fully described and claimed. For the purposes of this application, it will be sufficient to say that the contact arm 19, together with its magnet 18^a, is adapted to rotate independently of the compass needle 18, but is magnetically related to it and tends to follow it in its movements whenever it is free. Furthermore, the contact arm 19 is periodically lifted into contact with the settable head 21, by the energization of solenoid 20 mounted concentrically with the axis of the compass needle and the contact arm. When the solenoid 20 is energized, the arm 19 is brought into firm engagement with one of the contacts of the settable head 21, the parts being so arranged that only one contact can be engaged at one time.

Means are provided for periodically energizing the solenoid 20, so that arm 19 follows the compass needle 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 19 is lifted.

The contacts on the settable head 21 are designated R¹, R², and L¹ and L², etc. The contacts designated R correspond to movements of the craft off its course in a starboard direction, and requiring the application of left rudder. Similarly, contacts L correspond to movements off the course in a port direction and requiring the application of right rudder. This nomenclature will be followed throughout the specification.

These contacts are each connected through a

wire in cable 23 to a rotating control switch. This switch (see Fig. 3) includes a rotatable contact drum 24 (shown developed in Fig. 2) supported by members 25 carried by base 26. The base 26 also supports a driving motor 27 which is connected to the drum 24 by a worm and worm gear 28. As here shown, the motor 27 is an electric motor and is adapted to be operated by the source of electricity on the boat and to drive the control drum continuously when the automatic steering mechanism is in use. It is to be understood that any other suitable driving means may be substituted provided it has substantially constant speed.

The drum 24 carries a plurality of conducting segments T, L, R, O and 32, the segments 32 and O being connected together by a wire 33 embedded in the insulation 29, which separates the various segments from one another. Rotatable with and mounted on the same shaft with drum 24 is an oil slinger X to prevent oil from the bearing reaching the contact drum.

Mounted above the contact drum 24 is a contact bar 30 of insulating material carrying a plurality of adjustable contact brushes 31 which engage the face of the drum and contact with either the insulation 29 or the contact segments, depending upon the position of the drum. Of the two of these brushes, designated 31^a and 31^b, 31^a is capable of contacting only with the segment T, while the brush 31^b can engage either segment T or 32. The segment T controls the periodic energization of the solenoid 20 for contact arm 19. Once during each revolution of the drum 24, brush 31^b engages segment 32 to energize the zero magnets, and positively insures a return of the rudder to its amidships position once during each revolution of the drum. In other words, at the end of each impulse given to the rudder and when solenoids 20 is deenergized, the zero positioning magnets are energized to positively return the rudder to amidships position before solenoid 20 is energized again to give the rudder another impulse.

The remaining brushes cooperate with the segments L, R or O; the segment L controlling port movements of the boat, segment R controlling starboard movements, and segment O determining the amidships position of the rudder.

In addition to driving the contact switch, the motor 27 drives an air compressor 34 by suitable means, such as a belt 35. The function of this compressor is to supply fluid pressure to an electro-pneumatic valve 36 through a pipe 37. The outlet from compressor 34 has connected to it, in addition to the pipe 37, an auxiliary pipe 38 which is extended to and terminates near the steering wheel and includes a pressure gage 39 and a relief valve 41. The gage 39 enables the operator of the boat to ascertain at all times what the pressure in the system is, and to adjust this pressure by manipulation of the valve 41, thereby discharging air from the system.

The rudder of the boat, designated 42, is carried by the usual rudder post 43, which post is squared at the top to receive a washer 44 having a squared opening in it, and adapted to act as a base for one end of a quadrant 45 and of a tiller 46. The squared top end 47 of the rudder carries an adapter 48 having a squared opening through it and a cylindrical outer surface. This adapter is rigidly secured to the rudder post and in contact with washer 44 by a pin 49. The tiller 46 carries a tubular extension 51 which fits around the outside of adapter 48 and is connected to it, by a key

52 in the adapter, and a slot 53 in the tiller extension. This arrangement allows a slight play between these two parts and assures that the tiller will always return to its zero position between rudder swings. When a single free spring is used, or two opposed compression springs are used, to center the tiller, there will be a small arc of movement when the springs may not be powerful enough to center the tiller. A slight play of key 52 in slot 53 builds up enough spring pressure before the rudder is moved, to insure a complete return of the rudder under the action of the spring. The same result may be obtained at somewhat more complication, in the case of two opposed springs, by enclosing them in cages.

Secured to the tiller midway between its ends, is a return spring 54 capable of both compression and extension, and having its base end carried in a spring saddle 55 secured to the quadrant 45. Spring 54 is capable of free extension when the tiller is moved upwardly, as shown in Fig. 1, and is guided and supported during compression movement by the saddle 55. The tiller also has pivotally connected to it, at 56, a piston rod 57, which cooperates with a cylinder 58 carried by quadrant 45 and pivotally mounted thereon. Piston rod 57 carries a piston 59 movable within the cylinder 58, one end of this cylinder being connected to the electro-pneumatic valve by a flexible pipe 61, and the other end by a similar pipe 62. Fluid pressure may be supplied to either end of this cylinder to move the piston 59 in one direction or the other, and thereby actuate the tiller 46 and the rudder connected to it. The pivotal mounting of the rod 57 on the tiller, and of the cylinder 58 on the quadrant, allows such motion to take place freely. The throw of tiller 46 is limited by a stop bar 40 pivoted to the tiller 46 at 50, and carrying adjustable stops 60. These stops limit the movement of bar 40 by engagement with an eye 100 on the quadrant. As shown in the drawings, the range of angular movement of the quadrant 45 exceeds that of the tiller 46 relatively thereto, because the tiller movement is limited by stops 60. Consequently, manual control can be assumed at any time without effective interferences from the power operated means.

This quadrant 45 carries a tubular extension 63 (see Fig. 9) which surrounds and moves about the extension 51 as a bearing, and this extension is supported at the bottom by washer 44. When the boat is to be steered manually, movement of the rudder is brought about by movement of quadrant 45 which in turn actuates the tiller 46 through spring 54.

The manual steering mechanism comprises a rope or cable 65, the two ends of which are carried around the rudder post in the usual manner, and contact with grooves 64 in the quadrant. The rope is guided in pulleys 66 to an actuating drum 67, rotatable with shaft 68 by wheel 69. When the boat is being steered automatically, the friction of the rope in its bearings is sufficient to prevent the quadrant from rotating, hence the extension 51 of tiller 46 may move within extension 63 of the quadrant without turning the steering wheel or moving the parts carried between it and the rudder post. If conditions are such that this friction will not prevent movements of the manual control, an arm 70 secured to shaft 68 may be locked to the base 16 of the compass by a pin 71, thereby positively preventing actuation of the manual steering mechanism by the automatic means.

During automatic steering, movement of the

contact arm 19 of the compass causes actuation of an electro-pneumatic valve 36 to control the admission of compressed air to the cylinder 58. The valve 36 comprises a hollow valve housing 72, the front end of which is closed by an interiorly flanged cover plate 73 secured to the housing as by screws 74. Mounted within the housing 72 is a magnet ring 75 having three pairs of electromagnets which are spaced around the ring at 60° intervals (Fig. 2). Two of these magnets, designated 76, determine the zero or amidships position of the rudder, and those designated 77^L and 77^R determine the right and left positions, respectively, of the rudder.

Rotatably mounted inside the field ring 75 is an armature 78 carried by a shaft 79. This armature has two arcuate extensions 80 in magnetic relation to the various electromagnets within the housing. One end of shaft 79 rests in a bearing 32 secured in an extension 81 of housing 72, while the other end projects through the cover plate 73 and rests in a similar bearing 82 within an extension 83 of cover plate 73. Movement of the armature 78 through an angle of more than 60° is prevented by an arm 85 having an integral collar 84 secured to the shaft 79. This arm 85 cooperates with fixed stops 86 and 87 on the inner face of cover plate 73.

Accordingly, when the magnets 76 are energized, the armature 78 occupies its neutral position shown in Fig. 2. When the magnets 77^L are energized, the armature assumes a position in which the arm 85 engages stop 86, and when magnets 77^R are energized, this arm engages stop 87.

The portion of shaft 79 inside of cover plate 73 carries a gear 88 rigidly secured to it by a flanged extension 89 within the chamber 90. Communicating with the chamber 90 and extending from one side to the other of the cover plate 73, is a circular bore 91 communicating with atmosphere at either end. Bore 91 is undercut at 91^a and also communicates with chamber 90 to which fluid pressure is supplied through an inlet port 110 (see Fig. 4) in the extension 83. Extension 83 likewise contains two outlet ports 92 and 93 which are threaded to receive suitable hose nipples for the flexible pipes 61 and 62.

Movably mounted within the bore 91 is a valve piston 94 having enlarged heads 96 and 97 moving in air-tight relation to the walls of the bore. This piston is shown as occupying its neutral position, and it may be moved either to the right or to the left by rotation of gear 88 cooperating with a rack 95 on the bottom of the piston. From this description it will be clear that when magnets 76 are energized, all the parts will occupy the positions shown in Figs. 4 and 5. The fluid pressure inlet 110 is thereby connected to both the outlet ports 92 and 93, while the escape of fluid pressure from bore 91 is prevented by piston heads 96 and 97. Consequently, the piston 94 will occupy its neutral position in the cylinder 58 because equal pressure will be exerted on both sides of it. Under these conditions, the rudder is controlled solely by the spring 54 and the drag of the rudder through the water.

The inside of the valve is under full air pressure, hence packing glands on shaft 79 are unnecessary. The valve is completely balanced against the fluid pressure at all times and will operate at any pressure because the undercut portion 91^a of the bore 91 prevents pressure from being exerted upon the piston 94 from one side

only as it passes the ports 92 and 93 during its operation.

When magnets 77^L are energized, the armature 78 is rotated until the arm 85 strikes the stop 86, moving valve piston 94 to the left, connecting port 93 to atmosphere through the bore 91, and connecting port 92 with the inlet opening 110 through chamber 90. Under these conditions, fluid pressure is supplied through the pipe 61 to move the rudder 42 to its right or starboard position. When magnets 77^R are energized, the armature 78 is rotated, moving arm 85 against stop 87 and moving piston 94 to the right so as to connect port 92 to atmosphere, and connect port 93 to the air chamber 90. With the parts in this position, air pressure is supplied to the cylinder 58 through pipe 62 so as to move the rudder 42 to its left hand or port position. It will be clear that whenever fluid pressure is supplied to the cylinder 58 through one of the pipes 61 or 62, the valve piston 94 will always assume such a position that the other side of the piston will be connected to atmosphere through the bore 91, thereby allowing the piston 59 to move freely in the cylinder to the position corresponding to the actuation of the electromagnet means.

Having described the structural elements of the system, reference will now be had to Fig. 2 of the drawings, wherein the operating circuits of the system are shown diagrammatically. In this figure reference character 98 designates a source of current which is employed to actuate the motor 27, and also to supply the energy for the electro-pneumatic valve. Although the source is here indicated as a battery, it is obvious that it may be an electric generator driven from the propeller shaft or engine in case of small boats, or it may be the generator which supplies the electric lighting plant on large boats. Likewise the compressor 34 has been shown as driven by an electric motor 27, but it is obvious that it also may be driven by the motor of the electric lighting plant on large boats, or by the engine connected to the propeller shaft in small boats. The compressed air may also be supplied to the system from an air storage tank.

A double pole switch 99, placed near the steering wheel, serves to start the motor and energize the control mechanism.

When the switch occupies the closed position, as shown, and the drum 24 is in such a position that the segment T connects the brushes 31^a and 31^b together, the solenoid 20 is energized, thereby lifting contact arm 19 into engagement with one of the associated contacts. The circuit for solenoid 20 is from the positive terminal of source 98, through switch 99, wires 101 and 102, solenoid 20, wire 112, brush 31^a, segment T, brush 31^b, and wires 103 and 104, back through switch 99 to the negative terminal of the source.

When the boat is proceeding on her course so that contact arm 19 occupies the zero or neutral position as shown, and the circuit for solenoid 20, just traced, is closed, the magnets 76 are energized so as to hold valve piston 94 in its neutral position, and the two sides of piston 59 and cylinder 58 are connected together and subjected to equal pressure to hold the rudder in its neutral or amidships position under the action of spring 54 and trailing action of the rudder through the water. Under such conditions, the circuit for the magnets 76 is as follows: From the positive terminal of source 98, through switch 99, wires 101 and 105, windings of magnets 76, wire 107, brush 31 connected to the zero contact of settable head

21, the zero contact of the head 21, contact arm 19, wire 112, brush 31^a, to the contact segment T, and thence back to the negative terminal of source 98 through wires 103 and 104.

This circuit remains closed until the drum 24 rotates far enough to break the circuit between brushes 31^a and 31^b by movement of segment T. When brushes 31^a and 31^b strike the insulated portion between the ends of segment T, the solenoid 20 is deenergized to drop the arm 19 and disconnect it from the zero contact. The solenoid 20 is periodically energized and deenergized by the rotation of contact segment T, and the circuit for magnets 76 is likewise closed periodically each time the circuit for solenoid 20 is closed, so long as the boat stays on her course. Each time that brushes 31^a and 31^b ride off the segment T onto the insulation of the drum 24 so as to break the circuit of solenoid 20, deenergizing it and dropping the contact arm 19, all of the circuits for the electro-pneumatic valve are opened, because the contact arm 19 drops away from the contacts on head 21.

It is essential, in steering according to methods embodying this invention, that the rudder return to its amidships position each time after it has swung to one side or the other, and it is for this reason that segment 32 is provided on the drum 24. This segment cooperates only with brush 31^b connected to the negative side of source 98. Consequently, soon after the brushes 31^a and 31^b leave the segment T to deenergize solenoid 20, brush 31^b strikes segment 32 and completes a circuit for the neutral magnets 76, independently of the contacts on the compass head 21. This circuit is from the positive terminal of source 98, through switch 99, wires 101 and 105, magnets 76, wire 107, brush 31 connected to the zero contact of settable head 21, segment O, wire 33, segment 32, brush 31^b, and wires 103 and 104, back to switch 99, and to the negative terminal of source 98. When this circuit is closed the armature 78 is moved to its neutral position, thereby moving the pneumatic valve to its neutral position and enabling the spring 54 to center the rudder.

When the boat moves off her course in a starboard direction, and the control switch moves so as to energize the solenoid 20 and to lift the contact arm 19, this arm engages one of the contacts R², R³, R⁴, R⁵ or R⁶ in accordance with the angle through which the boat swings from her course. If the extent of the movement is such that the contact arm engages contact R⁴, the circuit for the magnets 77^R will be closed for a substantial period, because contact R⁴ is connected to segment R near the end of drum 24 and the circuit of the magnet 77^R will be closed during the interval when brush 31, connected to contact R⁴ engages the segment R.

The circuit for magnets 77^R may be traced from the positive terminal of source 98, through switch 99, wires 101 and 105, magnets 77^R, wire 108, extreme right hand brush 31, segment R, brush 31 connected to contact R⁴, contact R⁴, contact arm 19, wire 112, brush 31^a, segment T, brush 31^b, wires 103 and 104, and switch 99, back to the negative terminal of the source.

When this circuit is closed, the armature 78 is moved so that its axis aligns with the axis of electromagnets 77^R. Arm 85 engages stop 87 and piston 94 occupies its right hand position in which the port 92 is connected to atmosphere and the port 93 connects chamber 90 with the cylinder 58 through pipe 62, thereby moving the rudder

der downwardly or to its port position. This circuit remains closed until the drum 24 rotates far enough so that brush 31 rides onto the insulation between segment R and segment O. While brush 31 is in contact with the insulation 29, solenoid 20 still remains energized through segment T which is still under the brushes 31^a and 31^b. Contact arm 19 therefore is held against the contact R⁴ and when the brush 31 rides onto segment O, the circuit just traced, will be interrupted by brush 31 striking insulation 29, and the following circuit through the magnets 76 closed. This circuit is from the positive terminal of source 98, through switch 99, wires 101 and 105, magnets 76, wire 107, middle brush 31, segment O, brush 31 of contact R⁴, contact R⁴, contact arm 19, wire 112, and brush 31^a, to segment T; and thence through brush 31^b and wires 103 and 104 to the negative terminal of the source.

This change in circuit, caused by movement of brush 31 onto segment O, will move the armature 78 from its position in line with magnet 77^a, to a position in line with magnets 76, so as to return the rudder to its neutral position. After a short interval the solenoid 20 will be deenergized to disengage contact arm 19 from contact R⁴, thereby interrupting this circuit at the same time that the circuit for solenoid 20 is interrupted. If for any reason the interval in which the magnets 76 are energized is very short, or if the rudder does not return to its amidships position, the engagement of brush 31^b with segment 32 will energize magnets 76 again and complete the movement of the rudder to such position.

The operation just described is such as to tend to return the boat to her course, but if one rudder swing from contact R⁴ is insufficient for such restoration, subsequent swings through contacts R³, R² and R¹ may take place and ease the boat back to her course. When the contact arm engages the zero contact on head 21, the rudder is not moved from its amidships position, because energization of the electro-pneumatic valve maintains valve piston 94 in its neutral position.

If the boat swings off her course on the port side so that the compass needle indicates a substantial movement in that direction, contact arm 19 will follow and subsequent energization of solenoid 20 will move contact arm 19 against one of the contacts L¹, L², and so on. If it be assumed that the movement is slight, so that contact arm 19 engages contact L¹, the rudder 42 will be swung to its starboard position for a short interval because the brush 31 connected to contact L¹ will engage the segment L for only a short period, the segment being of small circumferential extent at this point. The circuit closed under such conditions is as follows: Positive terminal of source 98, switch 99, wires 101 and 105, magnets 77^a, wire 106, left hand brush 31, segment L, brush 31 of contact L¹, contact L¹, contact arm 19, wire 112, brush 31^a, segment T, brush 31^b, wires 103 and 104, and switch 99 to the negative terminal of source 98.

This circuit is closed for a short interval and when brush 31 strikes the insulation 29 between segments L and O, magnets 77^a are deenergized and then the brush engages segment O to energize the magnets 76 and move the electro-pneumatic valve to neutral position, thus restoring the rudder to its neutral or amidships position. After a short interval the brushes 31^a and 31^b will leave the segment T, thereby deenergizing solenoid 20 and allowing contact arm 19 to realine itself with the compass needle. Further

rotation of drum 24 brings segment 32 into contact with brush 31^b to thereby energize magnet 76 again and assure that the rudder is moved to its neutral position.

The apparatus just described is suitable for the automatic steering of yachts having a length of from 25 to 150 feet or greater, depending upon the characteristics of the particular vessel, and will operate satisfactorily on an air pressure of approximately 10 pounds per square inch or more, depending on the size of cylinder 58. The only adjustment necessary is to vary the amplitude of the rudder swing by adjusting stops 60 or to alter the air pressure. The system offers the advantage that manual control may be assumed at any time without deranging or shutting off the automatic mechanism. Assumption of manual control merely disturbs the set course which the craft is following, without deranging the automatic mechanism. This mechanism, accordingly, continues to try to direct the craft back to the set course, but it is, of course, affected by the disturbed amidships position of the rudder resulting from movement of the steering quadrant under the action of the manual means. As soon as manual control ceases, the automatic means becomes effective to return the craft to the set course. The manual means must, of course, be returned to its amidships position to enable the automatic mechanism to steer a proper course. Furthermore, the complete system is small and compact and may be installed on yachts having various kinds of standard equipment with simple modifications. This feature is disclosed and claimed in my copending application, Ser. No. 585,122, filed January 6, 1932.

The apparatus just described is well suited for large yachts in which considerable power is required to move the rudder from one position to another, particularly in rough water. In smaller yachts in which less power is required to move the rudder, the system may be considerably simplified by replacing the rudder controlling mechanism including the tiller operating cylinder and piston, by the apparatus shown in Fig. 7.

When such a replacement is made, the rudder post 43 having a squared end 47 carries the tiller 46 as before and the quadrant 45 is rotatably mounted around the sleeve on the tiller as previously described. The quadrant is, however, modified by the addition of a member 113 disposed centrally of and secured thereon. The member 113 comprises two upstanding cage members having spring sockets 114^a and 114^b to receive springs 115, one on either side of the tiller 46, and engaging sockets 120 in the tiller. Inasmuch as member 113 is secured to the quadrant, the action of springs 115 is such as to centralize the tiller when the quadrant is in fixed position. In addition to the spring sockets 114^a and 114^b, the member 113 contains pockets 116^a and 116^b, each containing a rubber sack or bag 117 entirely closed except for air inlets to which the pipes 61 and 62 are connected.

The sacks 117 engage plungers 118^a and 118^b on the tiller 46, and movement of the tiller in either direction is limited by adjustable stop screws 119^a and 119^b carried by the member 113 and preferably integrally formed with the pockets 116^a and 116^b.

It will be clear that under normal conditions when air is supplied to both of the sacks 117 at the same pressure, and the sacks are connected together, the tiller will occupy its central posi-

tion, as shown, and when both of the sacks are subjected to atmospheric pressure the springs 115 will likewise hold the tiller in the neutral position. If, however, air pressure is supplied through pipe 62 to the associated sack 117, while the other sack is vented to atmosphere through the electro-pneumatic valve, the inflated sack will expand and force the tiller 46 to the right until it engages the stop screw 119^b.

In similar manner, the tiller may be moved in the opposite direction by venting pipe 62 to atmosphere and supplying fluid pressure to the other sack 117 through pipe 61. This arrangement provides a very simple mechanism which can be installed readily, and will operate smoothly and noiselessly to move the rudder from one position to another as the electro-pneumatic valve is controlled from the compass and the control switch, and is adapted for use with very low air pressure. It will be understood that the arrangement of Fig. 7 is adapted for use in the system shown in Fig. 1, and that it merely replaces the parts carried by the quadrant 45, the quadrant being capable of control manually in the manner previously described.

The steering of small yachts can also be accomplished according to the methods embodying this invention without the use of pneumatic or hydraulic actuating means for the rudder. In such installations, it has been found that a purely electromagnetic means will furnish the necessary power for actuating the rudder, and one embodiment of means of this character is shown in Fig. 6.

Referring to Fig. 6, the parts there shown are similar to those in Figs. 1 and 2, with the exception that the pneumatic mechanism is entirely removed and the tiller actuating mechanism carried by the quadrant is altered, so that the control switch actuated by motor 27 operates directly to control operating magnets carried by the quadrant, and cooperating with an armature carried by the tiller. In this figure, the tiller designated 121 is provided with a transverse head 122 of magnetic material and having spaced pole pieces 124^a and 124^b. This head, together with its pole pieces, is secured to the tiller 121 by suitable means, such as a nut 123. Movement of the tiller, together with the head, is limited by stops on the lateral arms of quadrant 45. These stops comprises rods 125 having heads 128. The rods are carried in bosses 127 on the quadrant arms, and serve as supports for centering springs 126. Each of the springs engages the tiller 121 at one end and a boss 127 at the other.

Mounted on the arcuate portion of the quadrant and connected to the segments of the control drum 24 are a plurality of electromagnets disposed along an arc coinciding with the path of movement of pole pieces 124^a and 124^b, and in spaced relation thereto. The electromagnets are designated by the same reference characters as the corresponding segments on drum 24 to which they are connected.

The circuits, with the exception of those of the electromagnets carried by the quadrant, are similar to those of the system shown in Figs. 1 and 2, hence a brief description of them will be sufficient.

The six magnets are arranged in symmetrically disposed pairs. Magnets L, L control operation of the rudder for counteracting movements of the boat to port, and magnets R, R for counteracting movement to starboard. In sim-

ilar manner magnets O, O serve to hold the rudder in its amidships position.

A single source of current 161 furnishes energy for operating the magnets and all of the magnets have a common return wire 129. Energization of the circuits is controlled by a switch 99.

If the boat swings off her course to starboard thereby bringing contact arm 19 against one of the R contacts, for example, R², the R magnets are energized to throw the rudder to port. The circuit for magnets R is from the positive terminal of source 161, over common return wire 129, windings of magnets R, wire 167, to extreme brush 31, segment R, brush 31 connected to contact R², contact R², arm 19, wire 163, switch 99, and wire 109 to the negative terminal of the source. This circuit is only closed when solenoid 20 is energized to thereby hold arm 19 against the contact R².

The circuit for solenoid 20 is from source 161, over wire 168, brush 31^b, segment T, brush 31^a, wire 162, solenoid 20, wire 163, switch 99, and wire 109, back to the source.

Should the boat swing off her course on the port side, thereby bringing arm 19 into contact with one of the L contacts, for example L³, when solenoid 20 is energized, the L magnets would be energized to swing the rudder to starboard. The circuit for magnets L is as follows: positive terminal of source 161, common return wire 129, windings of magnets L, wire 165, extreme brush 31 associated with segment L, segment L, brush 31 connected to contact L³, contact L³, contact arm 19, wire 163, switch 99, and wire 109 back to the source.

When the boat is on its course, the magnets O are energized periodically, the rudder being held in its amidships position in the meantime by centering springs 126 and the trailing of the rudder through the water. The circuit for magnets O is from source 161, over common wire 129, windings of magnets O, wire 164, zero contact of head 21, contact arm 19, wire 163, switch 99, and wire 109, back to the source.

When the operation of the compass is such as to energize the magnets O, the tiller is held in its neutral position, as shown, because these magnets attract the pole pieces 124^a and 124^b equally. When magnets L are energized, the tiller is moved to the left, or to a position in which the armatures are in front of the magnets L, thereby moving the rudder to its starboard position. When the magnets L are deenergized, the rudder is moved to its central position by springs 126, and when segment 32 on drum 24 connects with brush 31^b, the magnets O will be energized to assist in returning the rudder to its central position. It will be understood that magnets O are energized when contact arm 19 engages the zero contact on head 21 and the associated brush 31 engages segment O. Likewise when segments R are energized, the armatures are attracted to positions in front of these magnets, thereby moving the rudder to its port position, the parts being restored to neutral position when magnets R are deenergized to allow springs 126 to act, the movement being quick and positive when magnets O are energized. The pole pieces 124^a and 124^b are of considerable arcuate extent, to insure actuation of the rudder from one position to another, even though the pole pieces be displaced from the magnets which are energized.

The steering systems above described have been indicated as applicable to the steering of

large and small yachts in which electromagnetic or electro-pneumatic controlling means may be used. The invention is, however, not limited to the steering of small yachts and boats, but is of general application. When adapted to the steering of large ships the air compressor of the system shown in Fig. 1 is preferably replaced by an oil pump, and the electromagnetic valve 36 adapted for hydraulic operation, the ends of the bore 91 being connected to the inlet of the oil pump.

An hydraulic arrangement of this character suitable for use on large ships provided with steam steering engines, is shown in Fig. 10. Referring now to this figure, the reference character 245 designates the quadrant connected to the rudder post 248, in a manner similar to that shown in Fig. 9. Rotatably mounted within the extension of this quadrant is an extension on tiller 246, the tiller being secured to the rudder post by a key 252. As here shown, the quadrant together with the parts carried thereby, is adapted to be actuated when the ship is being steered manually by a steam steering engine comprising two steam cylinders 247 having piston rods 249 connected to cranks 250. These cranks are mounted so as to actuate a worm 251 which in turn meshes with the worm gear 253 carried on a shaft 254, carrying a spur gear 255. The spur gear meshes with the toothed portion 256 of quadrant 245.

Accordingly, the quadrant may be moved in one direction or the other, depending upon which of the steering cylinders 247 is supplied with steam, the control of the steam to these cylinders being exercised in any suitable and well known manner. When automatic steering mechanism embodying this invention is to be applied to ships having steering apparatus of the general character disclosed, the quadrant 245 is equipped with a pair of hydraulic cylinders 257 and 257^a, to which hydraulic fluid may be supplied through inlet pipes 258 and 258^a. Each cylinder contains a piston connected to piston rods 259 and 259^a, the outer ends of which rods are pivotally secured to tiller 246 at 260. Accordingly, when hydraulic fluid is supplied to cylinder 257, the tiller is moved upwardly, and when such fluid is supplied to cylinder 257^a, the tiller is moved downwardly, it being understood that when fluid is supplied to one cylinder, the other is arranged so that the fluid therein is allowed to escape.

As previously described, in steering according to the method embodying this invention, it is desirable to have some means for returning the rudder to amidships position at the end of each impulse supplied to it. Therefore, in this instance, it is preferred to employ a pair of centering springs 261 and 261^a, mounted on the lateral arms of quadrant 245 and held in position by a spring stop bar 262. The tension of these centering springs may be individually adjusted by the cooperation of nuts 267 engaging combination guides and spring saddles 265. The free ends of stop bars 262 carry spring stops 264 against which the springs abut on one side, while the other side engages the tiller.

It will be readily understood that when the two hydraulic cylinders 257 and 257^a are subjected to equal pressure, or to no pressure at all other than that of atmosphere, the springs 261 and 261^a may be so adjusted as to tension, that they hold the tiller and the parts actuated thereby in the central or amidships position.

As pointed out hereinbefore, this system is so designed that manual control may be taken over at any time and will function independently of the automatic control.

The system shown in Fig. 1, with the modifications described, can be adapted to the steering of larger vessels, but because of the sluggishness of the movement of such vessels, it is essential to proper steering that more rudder be supplied in stopping the swing of the vessel off the course than in returning her to the course. Accordingly, it is preferred to add the relay mechanism shown diagrammatically in Fig. 8, so as to apply more rudder as the ship is leaving her course than is applied when she is returning to it.

Referring now to Fig. 8, the compass controlling mechanism there shown is similar in all its details to that already described. The control switch is likewise similar, with the exception that the relation of the left and right hand segments L and R is reversed from that shown in Fig. 1 in order to simplify the connections. In this system there is provided a set of electromagnets mounted in a magnet ring 138. Inside of this ring, and rotatable with respect thereto, is an armature 131 having pole pieces 130 which move in magnetic relation to the electromagnets on ring 138. Armature 131 is rotatable on a shaft and carries with it a contact arm 132, movable about the shaft but frictionally held against the armature by a spring washer 133 and a nut 134. Arm 132 carries a contact 135 adapted, when moved counterclockwise, for engagement with an adjustable stationary contact 136, but the arm is limited in its clockwise movement by an adjustable stationary stop 137. Hence, the arm 132 moves with its armature but is limited in its movement to the distance between contact 136 and stop 137.

Each of the contacts on the compass head 21, with the exception of contacts L⁶ and R⁶, is connected to a pair of relay magnets oppositely disposed inside of ring 138. For example, contact R¹ is connected to two diametrically related electromagnets 81. The parts are so designed that when the two diametrically related electromagnets are energized, the axis of armature 131 assumes a position in axial alinement with the energized magnets. If the zero magnets corresponding to the zero position of contact arm 19 are energized, the armature assumes the position shown in the drawings.

The contacts 135 and 136 control a pair of relay magnets 143 cooperating with an armature 144 on relay bar 141 rotatably mounted in stationary bearings 142. Rotation of bar 141 in one direction is brought about by energization of magnets 143, thereby moving the armature 144 into contact with the magnets. Rotation in the other direction, when the magnets 143 are deenergized, is caused by spring 147, the movement of armature 144 being limited by a stop screw 146 in stationary abutment 145. The circuit for relay magnets 143 is from the positive terminal of source 158, through switch 159, wire 157, contacts 136 and 135, windings of magnets 143, wire 155, and switch 159, back to the source.

In the drawings the bar 141 is shown in its half-way position for clearness, but in practice it never assumes such a position, because it is either moved against the magnets 143 when they are energized, or against the stop screw 146 by spring 147 when the magnets are deenergized.

The relay bar 141 carries a series of spaced stationary contacts 139 which are connected consecutively to the electromagnets in the lower half of the ring 138. Contacts 139 are adapted, when
 5 moved upwardly by energization of magnets 143, to engage stationary contacts 148, and when moved to their other position by spring 147 to engage contacts 149.

The circuit for solenoid 20 is similar to that
 10 of Fig. 1 and is similarly controlled. It is from the positive terminal of source 158, through switch 159, wire 153, solenoid 20, wire 152, brush 31^a, segment T, brush 31^b, wire 154, and switch 159, back to the source.

15 The contacts 148 adjacent the right hand end of bar 141 connect to brushes 31 designated E, F, G, H, I, corresponding to long intervals of rudder movement, while the remaining contacts 148, with the exception of the middle contact
 20 of brush A, are connected to brushes 31 designated B', C', D', E', F', corresponding to shorter rudder movements. In similar manner the contacts 149 at the left end of relay bar 141 are connected to brushes designated E', F', G', H',
 25 I', while those at the right are connected to contacts B, C, D, E, F. The middle one of contacts 149 is connected to brush A. The object of this arrangement is to cause the rudder to be held in its deflected position for a substantial
 30 period during movements of the ship off her course, so that the rudder is applied for long intervals when the ship is moving off her course, but for shorter intervals as she returns to her course, this action corresponding to the so-called
 35 "meeting and easing" system of manual steering.

The extreme brushes K and K' associated with drum 24 are connected to contacts L⁶ and R⁶, respectively, of head 21 and do not pass through
 40 any of the magnets of ring 138. The reason for this arrangement is that under extreme movements of the ship when rudder is applied for long intervals, it is not necessary to produce any easing action until the ship approaches her
 45 course.

One form of hydraulic valve 151 suitable for use in a system of this type, is shown diagram-
 50 matically as having four electric contacts, one being common to all the actuating magnets in the valve, and the other three, L, O, and R, being connected to brushes K, A and K', respectively. The method of operation of this valve is similar to electropneumatic valve 36, hence no detailed
 55 description need be given.

The operation of the mechanism shown in
 55 Fig. 8 is generally similar to that which has already been described in connection with Figs. 1 and 2, with the exception that whenever the ship changes her course either one way or the other, the relay is brought into operation. If,
 60 for example, the ship swings to port through a distance sufficient to bring arm 19 against contact L² and energize magnets P², the arm 132 will rotate with armature 131 until contact 135 engages contact 136 to complete the circuit of
 65 magnets 143 and move the contacts 139 over against contacts 148. This movement completes a circuit through contact F' associated with segment L; and the rudder is moved to its starboard position, and is held in that position for
 70 a series of substantial periods to counteract the swing of the ship from her course. The circuit for magnets P², under these conditions, is from the positive terminal of source 158, through switch 159, wire 153, contact arm 19, contact L²,
 75 windings of magnets P², contacts 139 and 148

to brush F, segment L, brush K, wire 160, contact L of valve 151, wire 155, and switch 159, back to source 158. As soon as the ship starts to swing back on her course, and the contact arm
 5 19 disengages the associated contact L², the magnets P² are deenergized and another contact on the ring 21 is engaged by arm 19 subsequently to energize another electromagnet nearer the neutral position.

If, for example, contact L¹ is engaged, so as to
 10 energize magnet P¹, the movement of armature 131 will be sufficient to disengage contacts 135 and 136, thereby deenergizing relay coils 143 and allowing spring 147 to move the relay bar 141 to its bottom position. In this position contact 139
 15 connected to magnets P¹ will engage contact B resulting in the rudder being swung to starboard for a series of comparatively short intervals so as to tend to ease the ship back on her course. If the ship subsequently swings off her course again
 20 in the same direction as she returned from the prior swing, so that contact R¹ is energized, the relay being deenergized, contact E¹ will be energized causing a series of impulses of substantial duration. If the ship swings in the opposite di-
 25 rection from which she returned from the prior swing, the direction of rotation of armature 141 will be reversed, the relay thrown to the energized position and contact E excited. In any case a swing of the ship off her course in either direction
 30 starts a series of rudder impulses of considerable duration. After the swing has been checked and the ship starts to return to her course, a series of rudder impulses of substantially less duration is started. This action takes place regardless of
 35 whether the swing of the ship be to starboard or port, and whether it be large or small.

It will be understood that the above operation takes place at periodically recurrent intervals,
 40 and that the position of the hydraulic valve 151 is determined by the position of the contact arm 19 associated with the compass needle. Rotation of the drum 24 causes periodic energization of the solenoid 20, and movement of the rudder to either
 45 starboard or port for a period depending upon which brush 31 associated with control drum 24 is energized. The above mechanism is not necessary on small craft that respond quickly to the rudder, but desirable on large ships or heavily
 50 loaded ships which are sluggish in their rudder response.

From the foregoing description, it will be noted that if relatively low air pressure and heavy centering springs are used, the extent of rudder
 55 throw as well as the time of its duration will increase as the craft departs farther from her course, as there is not time enough for the air operating under this condition to move the rudder to the stop against the combined water and spring resistance. If relatively light springs and heavy
 60 air pressure are used the rudder can be completely thrown during each period.

With an intermediate condition of moderate spring and air pressure, the extent as well as duration of the rudder swing will increase with
 65 the first few contacts from zero, and then the extent will be limited by the stops, and the duration only increase to the final contact. Thus the combination of fixed spring and manually variable air pressure form a very simple and effective rudder control.

Although the modifications of the above invention and the method of applying the various em-
 70 bodiments have been illustrated in connection with the steering of ships or boats, it is to be understood that the method is of general appli-
 75

cation in the steering and control of dirigible craft of all kinds and it is not desired that the claims be limited in scope other than is necessitated by the prior art.

What is claimed is:

1. A method of steering dirigible craft having a rudder, which consists in subjecting the rudder to successive deflections at predetermined recurrent intervals, and timing the duration of the deflections according to the angle through which the craft has deviated from its course at the time of the deflection.

2. That method of steering dirigible craft having a rudder, which consists in swinging the rudder from its amidships position at predetermined fixed recurrent intervals, and varying the duration of the swings according to the amount of angular deviation of the craft from its course at the time of the swing.

3. The method of steering dirigible craft having a rudder, which consists in periodically swinging the rudder from its substantially amidships position by a substantially constant amount, varying the duration of each swing in accordance with the angular deviation of the craft from its course at the time the swing is initiated, and returning the rudder to substantially amidships position after each swing.

4. The method of steering dirigible craft having a rudder, which consists in periodically swinging the rudder from its substantially amidships position by a substantially constant amount, varying the duration of each swing in accordance with the angular deviation of the craft from its course at the time the swing is initiated, and returning the rudder to a position tending to hold the craft on its course after each swing.

5. The method of steering dirigible craft having a rudder, which consists in swinging the rudder from and returning it to a substantially amidships position at periodically recurrent intervals whenever the craft is off its course, and varying the duration of each swing according to the angular position of the craft relative to its course at the time the swing is initiated.

6. The method of steering dirigible craft having a rudder, which consists in swinging the rudder at predetermined intervals from its substantially amidships position a varying amount in accordance with the angular deviation of the craft from its course at the time the swing is initiated, and returning the rudder to a substantially amidships position after each swing.

7. The method of steering dirigible craft having a rudder, which consists in swinging the rudder at predetermined intervals from its substantially amidships position, varying the duration and extent of each swing in accordance with the angular deviation of the craft from its course at the time the swing is initiated, and returning the rudder to a substantially amidships position after each swing.

8. The method of steering dirigible craft having a rudder, which consists in swinging the rudder from and returning it to a substantially amidships position at periodically recurrent intervals whenever the craft is off its course, and varying the extent of each swing according to the angular position of the craft relative to its course at the time the swing is initiated.

9. The method of steering dirigible craft having a rudder, which consists in swinging the rudder from and returning it to a substantially amidships position at periodically recurrent intervals whenever the craft is off its course, and varying the extent and duration of each swing according

to the angular position of the craft relative to its course at the time the swing is initiated.

10. A steering system for dirigible craft having a rudder, comprising rudder actuating means; compass controlled means for periodically energizing the rudder actuating means; and automatic means for controlling the length of the periods during which the rudder actuating means is energized.

11. An automatic steering system for dirigible craft having a rudder, comprising rudder actuating mechanism; a compass; and automatic timing means controlled by said compass for rendering said rudder actuating mechanism active for periods varying with the position of the craft relative to its course.

12. An automatic steering system for dirigible craft having a rudder, comprising a compass; electric contact mechanism on said compass; periodically operated means for controlling said mechanism in accordance with the position of the craft; rudder actuating mechanism; and means connected to the contact mechanism on the compass for controlling said rudder actuating mechanism, said last-mentioned means including mechanism for varying the length of the periods in which said rudder actuating mechanism is active.

13. An automatic steering system for dirigible craft having a rudder, comprising a compass; electric contact mechanism on said compass; periodically operated means for controlling said mechanism in accordance with the position of the craft; rudder actuating mechanism; and means connected to the contact mechanism on the compass for controlling said rudder actuating mechanism, said last-mentioned means including mechanism for varying the extent of rudder throw.

14. An automatic steering system for dirigible craft having a rudder, comprising a compass; electric contact mechanism on said compass; periodically operated means for controlling said mechanism in accordance with the position of the craft; rudder actuating mechanism; and means connected to the contact mechanism on the compass for controlling said rudder actuating mechanism, said last-mentioned means including mechanism for varying the length of the periods in which said rudder actuating mechanism is active, and the extent of rudder throw.

15. An automatic steering system for dirigible craft having a rudder, comprising a compass; electro-pneumatic means for actuating the rudder; and automatic rotating reading transmitting mechanism electrically connected with said compass for controlling said electro-pneumatic means in accordance with the indications of the compass.

16. An automatic steering system for dirigible craft having a rudder, comprising a compass; electro-pneumatic means for actuating the rudder; means on said compass for controlling said electro-pneumatic means in accordance with the indications of the compass; automatic means for varying the length of the periods in which the rudder actuating means is active; and means on said compass for rendering the rudder actuating means active or inactive in accordance with the position of the craft relative to its course.

17. An automatic steering system for dirigible craft having a rudder, comprising a compass; fluid pressure means for actuating said rudder; a source of fluid pressure; and a rotating reading transmitting mechanism electrically connected

with the compass for controlling the supply of fluid pressure to said fluid pressure means, in accordance with the compass indications.

18. An automatic steering system for dirigible craft having a rudder, comprising a compass; fluid pressure means for actuating said rudder; a source of fluid pressure; means for controlling the supply of fluid pressure to said fluid pressure means, in accordance with the compass indications; and automatic means for varying the length of the active periods of said fluid pressure means.

19. An automatic steering system for dirigible craft comprising a rudder; electromagnetic means for actuating said rudder; a compass; electric contact means on said compass; and electric timing means for controlling the energization of said electromagnetic means in accordance with the compass indications.

20. An automatic steering system for dirigible craft comprising a rudder; electromagnetic means for actuating said rudder; a compass; and electric contact means controlled by the compass for energizing said electromagnetic means for periods varying in length with the position of the craft relative to its course.

21. An automatic steering system for dirigible craft comprising a rudder; means for actuating said rudder; a compass; compass controlled means for controlling the rudder actuating means; means for timing the length of the active periods of said rudder actuating means; and means interposed between said timing means and said compass for causing said rudder actuating means to be active for longer periods when the compass indicates that the craft is departing from its course than when it indicates that the craft is returning to its course.

22. An automatic steering system for dirigible craft comprising a rudder; means for actuating said rudder; a compass; compass controlled means for controlling the rudder actuating means; means for timing the length of the active periods of said rudder actuating means; and means interposed between said timing means and said compass for causing said rudder actuating means to be active for longer periods and to throw the rudder a greater amount when the compass indicates that the craft is departing from its course than when it indicates that the craft is returning to its course.

23. An automatic steering system for dirigible craft, comprising a rudder; a tiller; a member pivotally connected to said rudder and adapted to be controlled by the ship's steering wheel; a compass; fluid pressure means for actuating said rudder relative to said manually controlled member; a source of fluid pressure; and means for controlling the supply of fluid pressure to said fluid pressure means in accordance with the compass indications.

24. An automatic steering system for dirigible craft comprising a rudder; a tiller operatively connected to said rudder; manually operable means for actuating said rudder; and fluid pressure operated means interposed between said tiller and said manually operable means, said manually operable means being capable of swinging said rudder whether said fluid pressure operated means is active or inactive.

25. An automatic steering system for dirigible craft comprising a rudder; a tiller operatively connected to said rudder; a quadrant operatively connected to said rudder; manually operable means for actuating said quadrant; and fluid

pressure operated means interposed between said tiller and quadrant.

26. An automatic steering system for dirigible craft comprising a rudder; a tiller operatively connected to said rudder; manually operable means for actuating said rudder; fluid pressure operated means interposed between said tiller and said manually operable means; and resilient means for centering said tiller when said fluid pressure operated means is inactive.

27. An automatic steering system for dirigible craft comprising a rudder; a tiller operatively connected to said rudder; manually operable means including a quadrant for actuating the rudder; automatic means carried on said quadrant for actuating said tiller; and resilient means for centering said tiller with respect to said quadrant.

28. An automatic steering system for dirigible craft comprising a rudder; a tiller operatively connected to said rudder; manually operable means for actuating said rudder, said means including a quadrant operatively connected to the tiller and electromagnetic operating means carried by said quadrant and interposed between said tiller and said manually operable means.

29. An automatic steering system for dirigible craft comprising a rudder; a tiller operatively connected to said rudder; manually operable means for actuating said rudder; electromagnetic operating means interposed between said tiller and said manually operable means; and resilient means for centering said tiller when said electromagnetic means is inactive.

30. A method of steering dirigible craft having a rudder, which consists in subjecting the rudder to periodic swings in a corrective direction whenever the craft is off its course, the duration of such swings being controlled according to the turning movement of the craft in such manner that the swings are of longer duration when the craft is turning from its course, than when it is turning toward its course.

31. A method of steering dirigible craft having a rudder, which consists in subjecting the rudder to periodic swings in a corrective direction whenever the craft is off its course, the extent of such swings being controlled according to the turning movement of the craft in such manner that the swings are of greater extent when the craft is turning from its course, than when it is turning toward its course.

32. A method of steering dirigible craft having a rudder, which consists in subjecting the rudder to periodic swings in a corrective direction whenever the craft is off its course, the duration and extent of such swings being controlled according to the turning movement of the craft in such manner that the swings are of greater duration and extent when the craft is turning from its course, than when it is turning toward its course.

33. In an automatic steering system for dirigible craft having a rudder; a swingably mounted quadrant movable relative to the rudder; a tiller fixedly connected to said rudder and movable either independently of or in concert with said quadrant; automatic means for moving said tiller independently of said quadrant; and manually operable means for moving said quadrant and tiller in concert.

34. An automatic steering system for dirigible craft comprising a rudder; a tiller operatively connected to said rudder; a quadrant operatively connected to said rudder; manually operable means for actuating said quadrant; and power-

operated means interposed between said tiller and quadrant.

35. In automatic steering apparatus for dirigible craft, a rudder including a rudder post; a tiller connected to said post; a quadrant hinged to said tiller; manually operable steering means connected to said quadrant; and automatic steering means reacting between said tiller and said quadrant.

36. The method of steering dirigible craft along a set course which consists in imparting to the rudder a plurality of series of swings when the craft is off its course, each of the swings of a series being of equal amplitude but those of successive series being of progressively larger amplitude as the craft is departing from its course and of progressively smaller amplitude as the craft is approaching its course.

37. An automatic steering system for dirigible craft comprising a rudder; a tiller operatively connected to said rudder; manually operable means for actuating said rudder; and power means interposed between said tiller and said manually operable means, said manually operable means being capable of swinging said rudder whether said power operated means is active or inactive.

38. An automatic steering system for dirigible craft comprising a rudder; a tiller operatively connected to said rudder; manually operable means for actuating said rudder; power operated means interposed between said tiller and said manually operable means; and resilient means for centering said tiller when said power operated means is inactive.

39. Automatic steering mechanism for dirigible craft comprising a rudder; a control member for moving the rudder; a manually operable member mounted adjacent and for cooperation with said control member to steer said craft; and power operated means operatively connecting said control member and said manually operable member for controlling movement of said control member relatively to said manually operable member.

40. An automatic steering system for dirigible craft, having a rudder and comprising a quadrant and manual means for operating it; a member capable of pivotal movement with respect to the quadrant and operatively connected to the rudder; and power operated means interposed between said quadrant and member.

41. An automatic steering system for dirigible craft, having a rudder and comprising a quadrant and manual means for operating it; a pivoted member carried by the quadrant and operatively connected to the rudder; and power operated means connected to said quadrant and to said member for moving said member relatively to said quadrant.

42. An automatic steering system for dirigible craft, comprising a rudder; means for actuating the rudder; a compass; compass controlled means

for timing the length of the active periods of said rudder actuating means; and means for varying the length of the active periods of said rudder actuating means in accordance with the direction of movement of the craft with respect to its set course.

43. An automatic steering system for dirigible craft, comprising a rudder; means for actuating the rudder; a compass; compass controlled means for timing the length of the active periods of said rudder actuating means; and means responsive to a change in direction of turning of the craft for varying the length of the active periods of the rudder actuating means.

44. An automatic steering system for dirigible craft, comprising a rudder; rudder actuating mechanism; a timing means for rendering the rudder actuating mechanism active for certain periods of time; a compass; compass controlled means for rendering said timing means responsive to changes in heading of the craft; and automatic means responsive to changes in direction of movement of the craft relative to its course for varying the length of the periods during which the rudder actuating mechanism is active.

45. In an automatic steering system for dirigible craft, a rudder; rudder actuating mechanism; a controller for said mechanism; compass controlled means for varying the response of said mechanism to said controller; and automatic switching means responsive to turning of the craft toward or away from its set course for varying the degree of response of said mechanism to said controller.

46. In an automatic steering system for dirigible craft, a rudder; electrical rudder actuating means; a controller including a plurality of electric contacts for causing operation of the rudder actuating means; compass controlled means, including a plurality of electric contacts adapted to be selectively connected with the controller contacts to render the controller responsive to changes in heading of the craft; and automatic switching means for connecting certain of the contacts when the craft is departing from its course, and certain others of the contacts when the craft is moving toward its course.

47. In an automatic steering system for dirigible craft, a rudder; electrical rudder actuating means; a controller including a plurality of electric contacts for causing operation of the rudder actuating means; compass controlled means for rendering said controller responsive to changes in the heading of the craft, said compass controlled means including a plurality of electric contacts; and automatic switching means responsive to turning of the craft for selectively connecting certain of the controller contacts to certain of the compass controlled contacts to vary the rudder action in accordance with the direction of movement of the craft toward or away from its set course.

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