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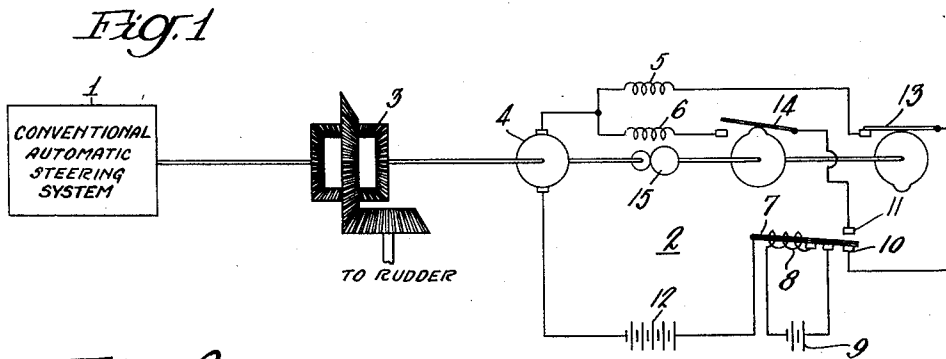
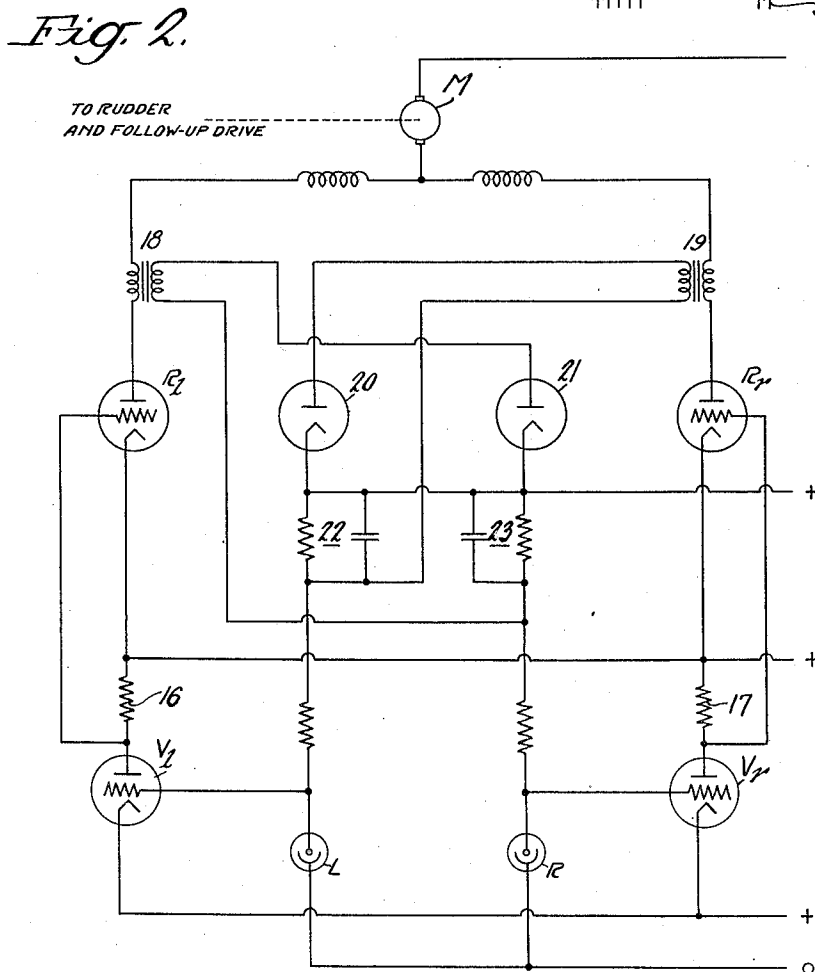
B. CHANCE

2,337,589

AUTOMATIC STEERING GEAR

Filed Jan. 18, 1940

2 Sheets-Sheet 1



*Inventor:-  
Britton Chance  
by his Attorneys  
Howson & Howson*

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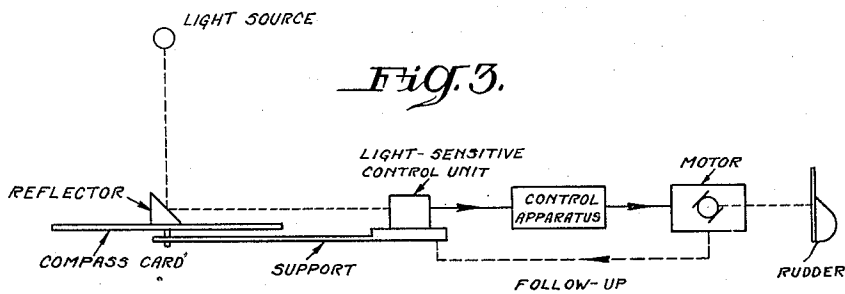
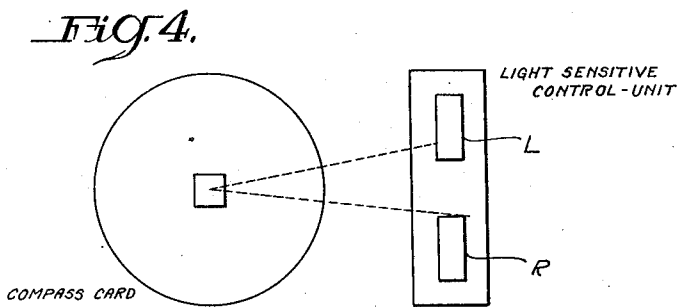
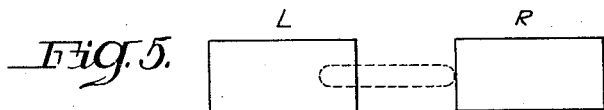
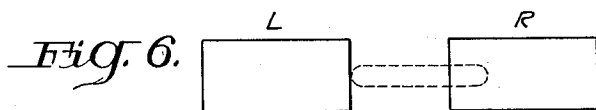
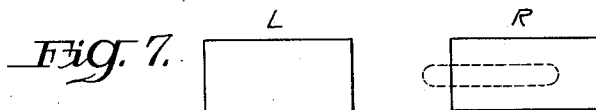
B. CHANCE

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AUTOMATIC STEERING GEAR

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2 Sheets-Sheet 2



*Inventor:-  
Britton Chance  
by his Attorneys  
Lawson & Lawson*

# UNITED STATES PATENT OFFICE

2,337,589

## AUTOMATIC STEERING GEAR

Britton Chance, Mantoloking, N. J.

Application January 18, 1940, Serial No. 314,557  
In Great Britain January 19, 1939

7 Claims. (Cl. 114-144)

This invention relates to automatic steering gear for dirigible craft having rudders and has for its object to provide a gear which will present a high degree of directional stability without the use of cumbersome or expensive additional apparatus.

Any sizable craft equipped with an automatic steering system tends to follow a certain path which is substantially a sinusoidal curve of low frequency. The frequency and amplitude of this sinusoidal path are dependent upon the structural character of the craft and the character and mode of operation of its steering system. In general, there is a tendency for the craft to adopt a state of continual large amplitude oscillation.

By the present invention, means are provided to lessen the amplitude of oscillation of such a craft so as to impart a greater degree of stability thereto. More specifically, means are provided to oscillate the craft's rudder continually at a frequency greater than the above-mentioned frequency.

One advantage to be gained by use of the invention resides in the average rudder angle's being accurately controlled in spite of large errors in the steering engine, and in the telemotor.

The invention may be clearly understood by reference to the accompanying drawings wherein Fig. 1 is a schematic illustration of one form of system embodying the invention;

Fig. 2 is a diagrammatic illustration of another form of the invention;

Fig. 3 is a diagrammatic illustration of a complete steering system embodying the apparatus of Fig. 2;

Fig. 4 is a plan view of the optical portion of the system of Fig. 3; and

Figs. 5 to 7 are explanatory illustrations of the operation of the light beam and the light-sensitive cells.

Referring to Fig. 1, there is represented schematically at 1 a conventional steering system which may be of any suitable type. For example, such system may take the form of that disclosed in my prior Patent No. 2,182,717, granted December 5, 1939. It will be understood that the steering system 1 causes the craft to follow a substantially sinusoidal path as above mentioned.

In accordance with the present invention, there is provided a device 2 which is adapted to produce continuous oscillatory rudder effects at a frequency substantially higher than the yaw frequency. The effects of the two devices 1 and 2 are combined in a conventional differential gear

3 and the resultant effect is thus applied to the rudder as indicated.

Referring specifically to the device 2, this device comprises a multifield reversible motor 4 having field windings 5 and 6 whose circuits are alternately closed by a timing switch 7. In the specific illustration, the switch 7 comprises a simple thermostatic switch comprising a bimetallic member which is normally disposed in the position shown and is arranged to be heated, for example by a heater element 8 and a suitable current source 9. As the bimetallic arm becomes heated, it flexes upward, leaving the contact 10 and engaging the contact 11, thereby opening the circuit of winding 5 and closing the circuit of winding 6. Thereafter, the bimetallic arm cools and returns to its normal position, thereby opening the circuit of winding 6 and closing the circuit of winding 5. This thermostatic switch should have a cooling characteristic similar to its heating characteristic in order that the cycle of operation will be uniform. It will be apparent that the operation of the switch reverses the motor 4 at regular intervals, the motor being energized by source 12. Of course, any other form of timer may be employed.

The amplitude of movement of the motor in each direction is controlled by limit switches 13 and 14, which may be cam-operated switches as shown, connected to the motor shaft through suitable gearing 15. In operation in either direction, the limit switch will open its associated circuit to interrupt the motor operation, after which at the end of the timing cycle the timer 7 will reverse the connections.

Thus, it will be seen that the rudder will be continuously oscillated by the device 2 through a small predetermined angle at a rate or frequency substantially higher than the yaw frequency. The frequency of oscillation may be varied by varying the timing of the timing device 7, and the amplitude of oscillation may be varied by varying the ratio of the gears 15.

In Fig. 2, there is illustrated another form of the invention applied to a steering gear of the kind employing a beam of light orientated with respect to the craft and arranged to be directed on to photoelectric cells for the control of the steering engine. In the system illustrated, oscillation of the rudder is effected by novel means incorporated in the electron tube circuits associated with the photocells. In this system, there is produced a continuous oscillatory action to effect rudder action in addition to the action in response to the craft's yaw. More specifically, the

sensitivity of the cells is arranged to be controlled so as to change the equilibrium position of the directed light beam with respect to the cells.

Thus the cells L and R are arranged to influence the bias on one or other of two triodes  $V_1$  and  $V_r$  so as to cause current to pass through one of the triodes. The output voltage across 16 or 17 is applied to the grid controlled rectifier  $R_1$  or  $R_r$ , which operates the steering motor M in one direction or the other. In the circuit of each tube  $R_1$  and  $R_r$  is arranged a transformer 18 and 19 from which a voltage is taken and after rectification by diode 20 or 21 is applied through a timing circuit 22 or 23 to the photoelectric cell associated with the other triode to bias the said cell for a time interval. This is accomplished by the inclusion of the resistor of each time delay circuit in the circuit of the associated photo cell.

Assuming, for example, that the craft's deviation is such as to cause the light beam to fall to a greater extent upon the right-hand photo cell R, the latter thereupon causes a "right" rudder application through the associated triode  $V_r$ . In consequence, a voltage is established across the time circuit 22 and the bias applied to the left-hand photocell is changed so that its sensitivity is reduced. The follow-up then establishes an equilibrium with some light on the left cell and none on the right cell.

The sensitivity of the left cell then increases as a function of time (determined by the time characteristic of the time circuit 22) and the left cell operates after a short time, say 4 seconds. The amplifier  $V_1$  associated with the left cell thereupon operates and in turn causes a reduction of the sensitivity of the right cell by a change of bias; at the same time, of course, the steering motor is energized to cause an application of "left" rudder, and the light beam leaves the left cell and impinges on the right cell. The sensitivity of the right cell then increases as a function of time, and after the same short period (4 seconds in the example) the right cell amplifier operates to commence the cycle over again.

The rudder is, therefore, oscillated through an equilibrium position continuously at a frequency which may be very much higher than the craft's fundamental yaw frequency.

This frequency of oscillation may be adjusted by variation of the time constants of the circuits for effecting a temporary reduction of the sensitivity of the respective photo cells.

Obviously, mechanical equivalents for the electric circuit components would be substituted in the application of this principle to a gyro controlled gear.

The operation of the system shown in Fig. 2 may be more clearly understood by reference to Figs. 3 to 7. In Fig. 3, there is illustrated diagrammatically a complete steering apparatus embodying the electro-optical system of Fig. 2. A reflector is mounted at the axis of a compass card and receives light from a light source above the compass card and axially aligned therewith. The reflector projects a light beam onto a light-sensitive control unit carried by a support which pivots about the axis of the compass card and is mounted on the craft so as to be movable relative to the stationary light beam in accordance with deviations of the craft from its course in one direction or the other. The light-sensitive control unit functions to actuate the control apparatus which, in turn, actuates the motor which operates the rudder. The motor also operates

a suitable follow-up mechanism to return the light-sensitive unit to an equilibrium position with respect to the light beam. A steering system of this general character is fully disclosed in my prior Patent #2,102,511, granted December 14, 1937, and also in my prior Patent #2,185,074, granted December 26, 1939, to which reference may be had for details which per se form no part of the present invention. As shown in Fig. 4, the light-sensitive control unit comprises the two light-sensitive cells L and R of Fig. 2.

The illustrations of Figs. 5 to 7 will enable a clear understanding of the operation of the system. Let us assume first that the craft is on its course and that the sole rudder actuation is that due to the continuous oscillatory action to move the rudder back and forth through a small predetermined angle at a relatively high frequency compared to the natural yawing frequency of the craft. Assume further that the relative positions of the light beam and the light-sensitive cells are as shown in Fig. 5 immediately following actuation of cell R and its associated control circuit which will have temporarily decreased the sensitivity of the control circuit associated with cell L as described above. The light beam impinges to a substantial extent on cell L but the cell circuit does not respond at once due to its decreased sensitivity.

When the circuit of cell L regains its normal sensitivity after a short interval, as described above, it is actuated by the impinging light and actuates the motor so as to throw the rudder and also operate the follow-up mechanism. At the same time, the sensitivity of the circuit associated with cell R is temporarily reduced. The follow-up action changes the relative positions of the light beam and cells to those shown in Fig. 6. However, the circuit of cell R is not actuated at once due to its decreased sensitivity.

After the circuit of cell R regains its normal sensitivity, it is actuated by the impinging light, thereby operating the motor in a direction opposite that above mentioned. The follow-up action changes the relative positions of the light beam and cells to those of Fig. 5. After a short time interval, the circuit of cell L is actuated as described above and the cycle is repeated.

Thus, the system oscillates continuously, the electro-optical unit oscillating between the equilibrium conditions of Figs. 5 and 6, and, as a result, the rudder is actuated through a small angle.

When the craft deviates from its course in response to its natural yawing tendency, the light beam and cells will assume relative positions such as shown in Fig. 7, which depicts a deviation to the right. The amount of light impinging on cell R is relatively great and the circuit associated with that cell is actuated to operate the rudder motor in a direction to bring the craft back on its course. At the same time, the follow-up acts to restore an equilibrium position. In this instance, the throw of the rudder is relatively great to effect the desired steering action.

From the foregoing description, it will be seen that the rudder actuation comprises the composite actions above described. In response to the natural yaw of the craft, the rudder is actuated through a relatively great angle at a relatively low frequency. At the same time, the rudder is continuously actuated through a small predetermined angle about its instant positions by virtue of the continuous oscillatory action of the system as described above.

It should be noted that in a system in accordance with the invention, accurate control may be obtained by the use of very small rudder amplitudes. A small amount of oscillating rudder is more effective than a large amount of rudder given in any previous manner. For example, if the oscillation amplitude is 1°, the total rudder used for steering is only 2°, while if the oscillation is not present the total rudder required is 5°. Thus the effectiveness of the rudder for automatic steering is increased by this method.

I am aware that it is old to provide a propelling apparatus for a vessel in which a propeller blade is oscillated by forked arms to propel the vessel, and steering is effected by swinging the arms through an angle greater than their normal angle of oscillation for propulsion. Propulsion of a vessel in this manner requires a large angle of oscillation of the propeller blade, e. g. 40 to 90 degrees. Moreover the steering of the vessel is not effected by swinging the usual rudder about its pivot, but by moving the propelling blade bodily.

The present invention has an entirely different purpose and distinguishes from the above-mentioned apparatus in the following respects. The craft being steered has the usual rudder separate and distinct from the propelling means which may take any suitable form, e. g. the usual screw propeller, and exerts a propelling force in a fixed direction relative to the craft's body. The continuous oscillation of the rudder is through a small angle insufficient to have any propelling effect on the vessel and the purpose of such oscillation is to improve the steering as described above.

While the invention has been illustrated with reference to certain specific embodiments, it will be apparent that various modifications of the same are possible.

I claim:

1. In an automatic steering system for a dirigible craft having a rudder separate and distinct from the craft's propelling means, the combination of automatic steering means for producing rudder actuations at a relatively low frequency, thus causing oscillatory movement of the craft at said frequency, and additional means for continuously oscillating the rudder through a predetermined small constant angle about its instant positions at a relatively high frequency, whereby a high degree of directional stability is imparted to the system and the total course width is materially reduced.

2. In an automatic steering system for a dirigible craft having a rudder separate and distinct from the craft's propelling means and operable about a single fixed pivot, the combination of automatic steering means for producing rudder actuations about said pivot at a relatively low frequency, thus causing oscillatory movement of the craft at said frequency, and additional means for continuously oscillating the rudder about said pivot through a predetermined small constant angle about its instant positions at a relatively high frequency, whereby a high degree of directional stability is imparted to the system and the total course width is materially reduced.

3. In a steering apparatus for a dirigible craft having a rudder separate and distinct from the

craft's propelling means, the combination of an automatic steering system for producing an oscillatory mechanical motion of relatively low frequency, means for producing a continuous oscillatory mechanical motion of predetermined small constant amplitude and relatively high frequency, and means for applying both of said motions to the rudder, whereby the steering action is highly stabilized and the total course width is materially reduced.

4. In a steering apparatus for a dirigible craft having a rudder, the combination of an automatic steering system for producing an oscillatory mechanical motion of relatively low frequency, means for producing a continuous oscillatory mechanical motion of predetermined small constant amplitude and relatively high frequency, a differential gear having two of its elements connected respectively to said steering system and said means, and means connecting a third element of said gear to the rudder, whereby both of said motions are applied to the rudder so as to stabilize the steering action and to reduce the total course width.

5. In an automatic steering system for a dirigible craft having a rudder, electro-optical means including a pair of light-sensitive devices, a pair of electronic control circuits operable respectively by said devices, means operable by said control circuits to actuate said rudder, follow-up means for establishing an equilibrium condition of the system after each rudder actuation, said steering system causing oscillatory movement of the craft at a relatively low frequency, and means for effecting continued oscillatory action of the system so as to cause continuous oscillation of the rudder through a small constant angle at a relatively high frequency compared to said first-mentioned frequency.

6. In an automatic steering system for a dirigible craft having a rudder, electro-optical means including a pair of light-sensitive devices, a pair of electronic control circuits operable respectively by said devices, means operable by said control circuits to actuate said rudder, follow-up means for establishing an equilibrium condition of the system after each rudder actuation, said steering system causing oscillatory movement of the craft at a relatively low frequency, and means associated with said control circuits for continuously varying the sensitivity thereof so as to effect continued oscillatory action of the system and thus cause continuous oscillation of the rudder through a small constant angle at a relatively high frequency compared to said first-mentioned frequency.

7. In combination, a dirigible craft equipped with an automatic steering system which tends to direct the craft along a substantially sinusoidal path or curve of low frequency, whereby the craft tends to adopt a state of continual large amplitude oscillation, and means for continuously oscillating the craft's rudder through a predetermined small constant angle at a predetermined frequency substantially higher than said first-mentioned frequency, thereby to lessen the amplitude of oscillation of the craft and to impart greater stability thereto.

BRITTON CHANCE.