

Jan. 25, 1944.

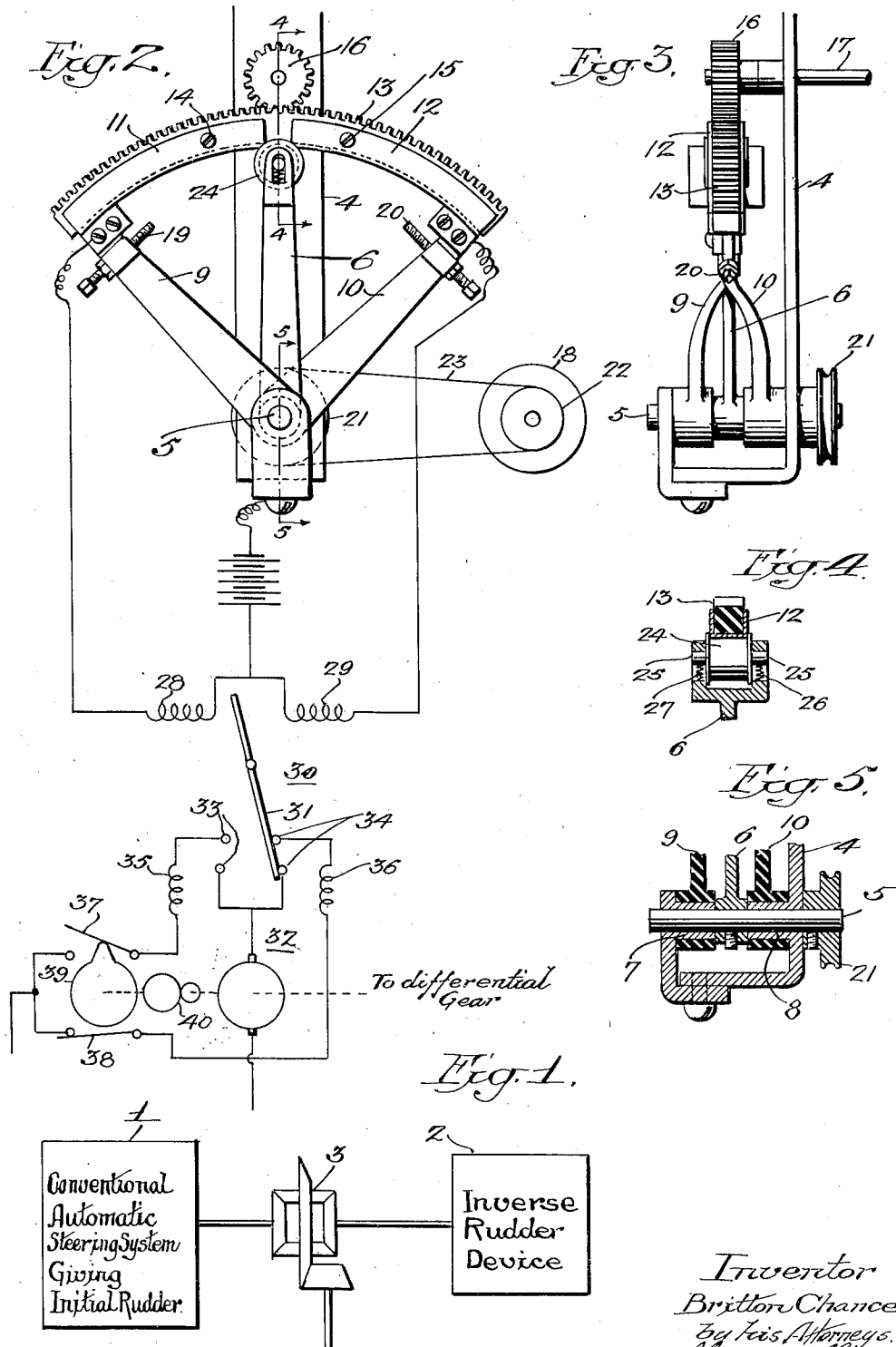
B. CHANCE

2,340,174

AUTOMATIC STEERING SYSTEM

Filed Jan. 18, 1940

3 Sheets-Sheet 1



Jan. 25, 1944.

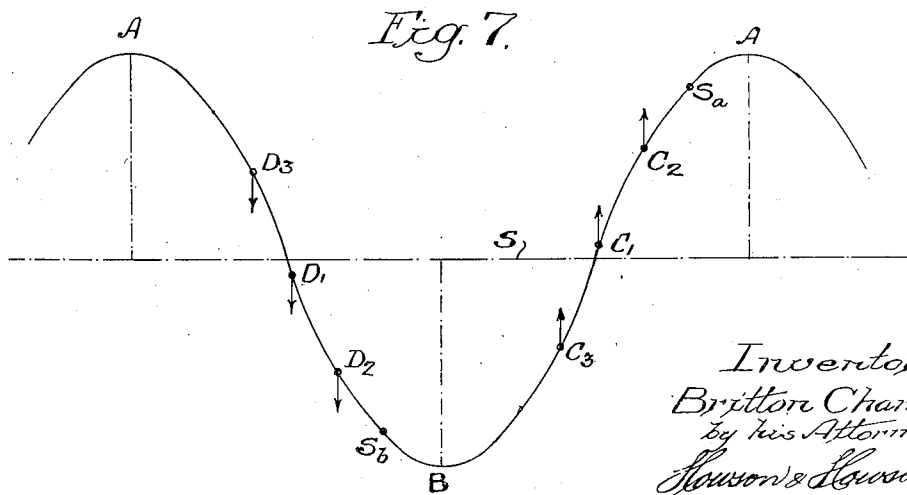
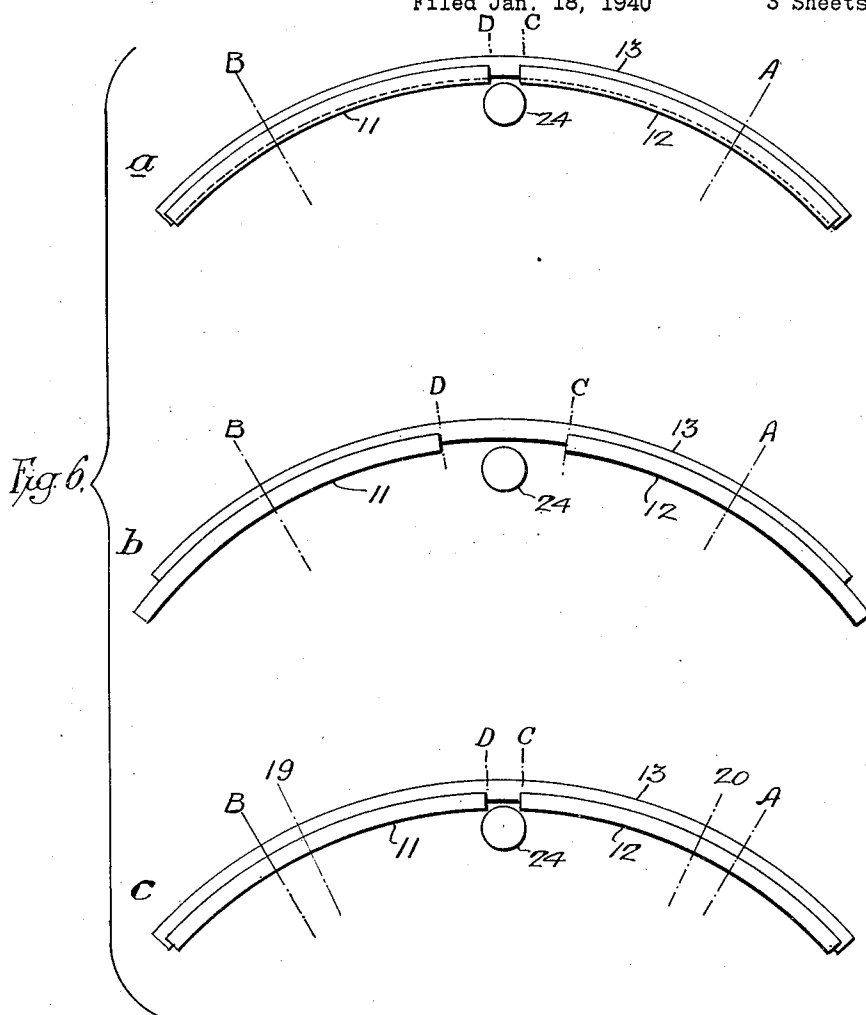
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3 Sheets-Sheet 2



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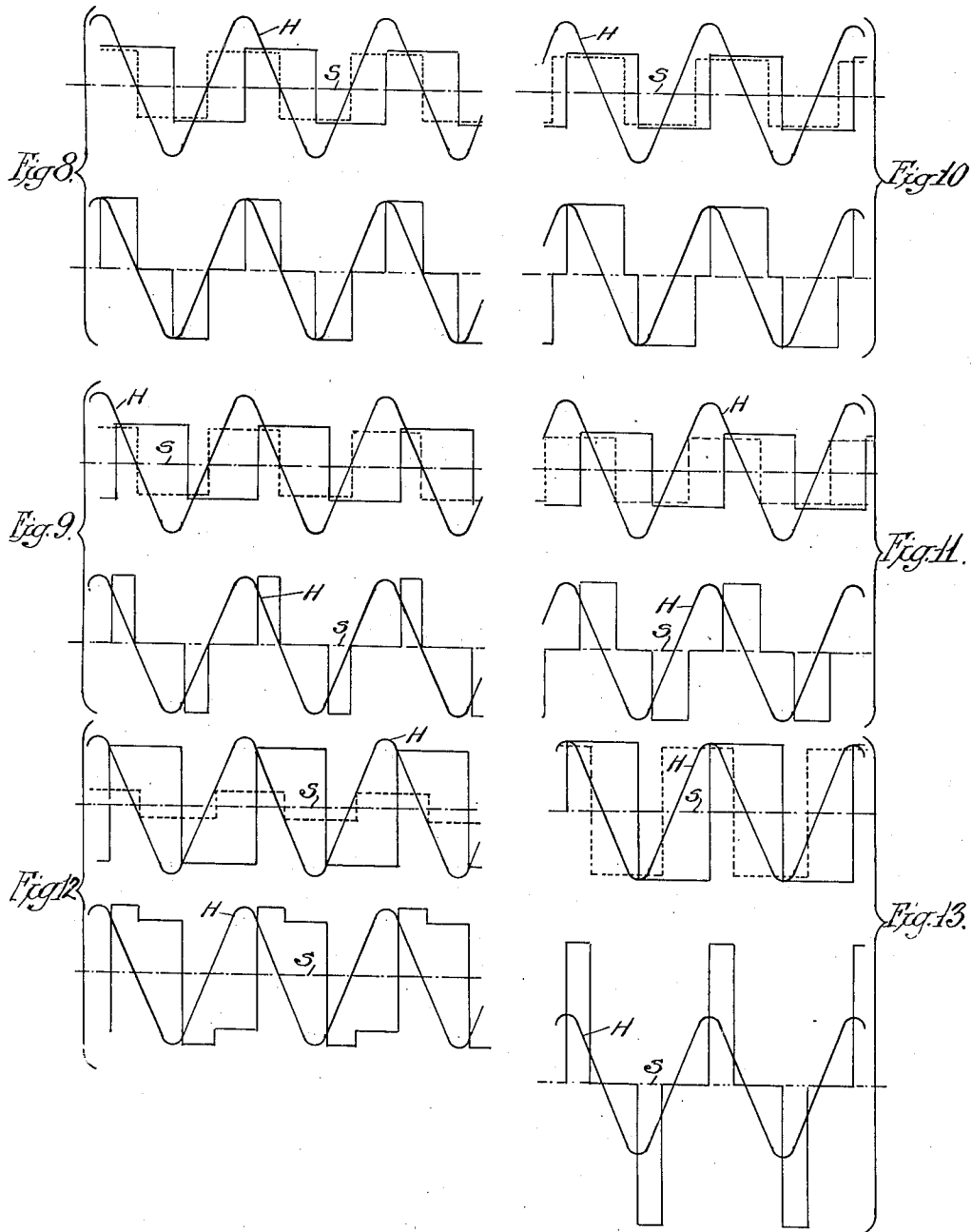
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AUTOMATIC STEERING SYSTEM

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,340,174

AUTOMATIC STEERING SYSTEM

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In Great Britain January 19, 1939

7 Claims. (Cl. 114—144)

This invention relates to automatic steering gear for dirigible craft having rudders. In the conventional automatic steering system, it is necessary to apply follow-up or normal rudder which is proportional to the deviation of the craft from its course, and in order to steer accurately, especially in heavy weather, it is necessary to apply additional rudder at or near the peak of the craft's yaw, which is known as "initial rudder." The latter acts to oppose the following yaw and is applied in anticipation of the same. The object of this invention is to provide an improved steering system embodying a novel method and means for controlling rudder application by the utilization of what I choose to term "inverse rudder." At least a portion of the latter is negative with respect to initial rudder and subtracts from the same. This inverse or negative rudder is applied as the next yaw peak is approached to reduce the amount of initial rudder. For convenience, the terms "initial rudder" and "inverse rudder" will be used throughout this specification. It will be understood, however, that these terms do not refer to separate rudder movements, but to components which are combined, and the result-
ant of which is applied to the rudder.

It is well known that, for a variety of reasons, such as adverse weather conditions, size and shape of the craft, method of propulsion and quality of the steering gear, a craft constantly tends to deviate from its set course. This tendency may be counteracted by manual steering, the helmsman relying upon his experience to time the application of rudder; if the application of rudder is incorrectly timed for the existing conditions, then the deviation, or yaw, may become permanent. In countering the tendency to yaw by automatic steering gear, different considerations apply. It is found that the steering is most satisfactory if a large portion of the full rudder angle required is made at the peak of a yaw and in such a sense that it will act to oppose the following yaw of the craft; for on account of the large inertia, especially of a sizable craft, the craft will swing past the set course towards a peak on the other side of the set course. It has been usual in the past to change the application of the rudder abruptly when the peak of the yaw is reached by moving the rudder back to or beyond its central position in anticipation that the craft will swing beyond its course.

I have found that a far better control is obtained by applying a very large amount of rudder at or near the peak of a yaw in a sense to oppose the yaw of the craft to the other side of

the set course, as is customary, and then removing some of this initial rudder before the peak of the next yaw is reached. If the steering gear is of low sensitivity, the application of initial rudder may not take effect until a fraction of the yawing cycle after the peak of a yaw. In this manner, the rudder is held in a position such that a large torque is produced aiding the next yaw of the craft. If, however, this amount of rudder is reduced in the manner to be described, the effect of the torque in phase with the yaw is avoided.

According to the invention, the reduction of the amount of initial rudder is attained by use of "inverse rudder." The application of initial rudder is a known expedient and need not be elaborated here; if means are provided in automatic steering gear for applying initial rudder at the peak of a yaw, then according to the invention, a control will be provided to operate on the rudder, either directly or indirectly, this control being arranged to respond to displacement of the craft from its course and to give a predetermined amount of rudder depending upon the direction of deviation of the craft from its course. This control will be arranged to operate the rudder in such a sense as apparently to cause an increase of the yaw of the craft, thus applying what I have termed "inverse rudder."

The invention may be clearly understood by reference to the accompanying drawings, wherein

Fig. 1 is a schematic illustration of an apparatus embodying the invention;

Fig. 2 illustrates one form of inverse rudder device which may be employed;

Fig. 3 is a side elevational view of the same;

Fig. 4 is a detail sectional view along line 4—4 of Fig. 2;

Fig. 5 is a fragmentary sectional view along line 5—5 of Fig. 2;

Fig. 6 illustrates certain operating conditions of the device;

Fig. 7 illustrates the action obtained by such conditions; and

Figs. 8 to 13 illustrate graphically various results which may be obtained by the invention.

In the following consideration, the follow-up rudder effects are neglected. In any case, the follow-up will give but small amounts of rudder for a given deviation of the craft from its set course and this effect will be more or less to provide a high damping factor for unusual yaws and for the usual course changing motions, and would not alter the principles involved here.

In Fig. 1 there is represented schematically a

conventional automatic steering system 1 adapted to give initial rudder action. This device may take any known form, for example, it may be a device such as shown in my prior Patent No. 2,182,717, granted December 5, 1939. There is also represented schematically an inverse rudder device 2 provided according to the present invention. A specific form of this device is illustrated in Fig. 2 and will be described presently. The effects of the two devices 1 and 2 are combined in a conventional differential gear 3 and applied to the rudder to give various rudder actions as described hereinafter.

In Figs. 2 to 5 there is illustrated one form of apparatus which may be employed as the device 2 in Fig. 1 to provide inverse rudder according to the invention. A support 4 carries a rotatable shaft 5 (see Fig. 5) on which is mounted an arm 6. The supporting structure 4 also provides bearings 7 and 8 which support rotatably adjustable arms 9 and 10, at the upper ends of which are mounted arcuate contact members 11 and 12. The arms 9 and 10 are formed of insulating material for a reason which will presently appear.

The contact members 11 and 12 embrace an insulating gear sector 13 (see Fig. 4), and are adjustable therealong by means of set screws 14 and 15. The gear sector meshes with pinion 16 whose shaft 17 is journaled in support 4 and is rotatable manually, by means of a control knob or the like, to shift the gear sector and associated contact members in either direction.

The arm 6 is rotatable, through a variable arc according to the yaw of the craft, by a compass repeater of known form represented schematically at 18. The drive for arm 6 is such as to permit a slipping action when the arm engages either of the adjustable stops 19 and 20 carried by arms 9 and 10. In the specific illustration, the drive for arm 6 comprises pulleys 21 and 22 and belt 23.

The arm 6 is bifurcated at its end and carries resiliently a contact roller 24 whose trunnions 25 are disposed in slots 26 in cooperative relation with springs 27. The roller 24 rides over the contact members 11 and 12 and thus selectively energizes windings 28 and 29 of a double acting relay 30 whose pivoted armature 31 selectively controls the circuits of the multi-field reversible motor 32. Thus, the relay contacts 33 and 34 are arranged to control selectively the circuits of the motor field windings 35 and 36. Limit switches 37 and 38 control the extent of motor operation in either direction, thereby controlling the magnitude of the inverse rudder action as explained later. The limit switches may be operated by a cam 39 driven through gearing 40 from the motor shaft. In order that the action of the limit switches shall be adjustable, gears 40 are preferably of the speed change type. The motor 32 is connected, as indicated, to the differential gear of Fig. 1.

The operation of the inverse rudder device may be understood by considering a complete yawing cycle of the craft, as represented in Fig. 7, by the sinusoidal curve. The peak yaws in opposite directions are designated A and B respectively. The set course of the craft is represented by the axial line S. Now by means of the device of Fig. 2, inverse rudder may be applied at different points in the yawing cycle and may be caused to assume various phase relations with respect to the craft's yaw and the initial rudder. To explain this more clearly, there are represented in Fig. 6 various operating conditions of the inverse rudder device with respect to the yaw peaks A and

B. In these representations, A and B again represent the yaw peaks, while CD represents the insulating section between the contact members 11 and 12.

In operation, the trolley arm 6 is operated back and forth through an arc by the gyro compass 18 in correspondence to the craft's yaw, as will be well understood. It will be seen that by means of the pinion 16, the operating cycle of the device may be shifted with respect to the yawing cycle.

Assuming a given setting of the pinion 16, let us suppose first the case of Fig. 6 (a), where the insulating section CD is substantially a minimum in width, and the stops 19 and 20 are outside the range of movement AB. With reference to Fig. 7, during the motion of the craft from yaw peak A to yaw peak B, the roller 24 reaches point D, thereby energizing the inverse rudder motor, as shown in Fig. 2, and applying inverse rudder at a certain point in the yawing cycle as indicated at D₁ in Fig. 7. The arrow indicates the direction of the inverse rudder. When the limit switch 38 opens, the motor is deenergized. The craft's yaw proceeds to the peak B, the roller 24 moving over contact 11. During the motion of the craft from yaw peak B to the next yaw peak A, the roller reaches point C, thereby energizing the motor to apply inverse rudder in the opposite direction at a point C₁ (Fig. 7).

Let us assume now the case of Fig. 6 (b), where the insulating section CD is of considerable width. In this instance, inverse rudder is applied in one direction at point D₂ and in the other direction at C₂ (see Fig. 7).

In the case of Fig. 6 (c), the insulating section is substantially a minimum in width and the stops 19 and 20 are within the yaw peaks, as indicated. In this instance, the arm 6 will be against stop 20 at the time of yaw peak A, and when the yaw reverses the arm will start back immediately and the roller 24 will reach point D at a point D₃ in the yawing cycle (see Fig. 7). Consequently, inverse rudder will be applied at that point, as indicated. The arm 6 will strike stop 19 at point S_b in the cycle and the belt 23 will slip while the yaw proceeds to peak B. Immediately upon reversal of the yaw, the arm 6 will move toward A and roller 24 will reach point C at point C₃ in the cycle, thereby applying inverse rudder in the opposite direction. At point S_a the arm 6 will strike stop 20 and remain there while the yaw proceeds to peak A.

Thus, it will be seen that inverse rudder may be variously applied by various adjustments of the apparatus. While only three conditions of the apparatus have been illustrated, it is possible by various combinations of the adjustments to obtain a large number of inverse rudder applications in relation to various initial rudder applications as depicted in Figs. 8 to 13 now to be described. These figures show both initial rudder effects and inverse rudder effects obtainable in the complete apparatus shown schematically in Fig. 1. They also show the resultant or useful rudder effects.

In Figs. 8 to 13, the craft's set course is indicated by the line S, and the craft's heading, as interpreted by the automatic steering system, is indicated by the line H in the form of a sinusoid. In the upper part of each figure, the solid line in the form of a square "wave" represents the application of initial rudder, while the dotted line represents the application of inverse rudder. The lower part of each figure shows the form of the resultant rudder application. For simplicity, it is

assumed that the craft yaws at constant amplitude.

In Fig. 8, the initial rudder is shown to be applied at the peak of a yaw and in a sense to oppose the motion of the craft on the following yaw. The inverse rudder is applied at the moment the craft swings across the set course. The amount of inverse rudder applied is substantially the same as the amount of initial rudder. The lower part of Fig. 8 shows that the rudder is brought to a central position as the craft swings over the set course in anticipation of the craft's swinging on to the other side of the set course.

In Fig. 9, the apparatus for applying initial rudder is represented as being of low sensitivity, the application lagging behind the peak yaw. The inverse rudder application is, however, timed as in the case of Fig. 8 to take effect as the craft swings over the set course. The result is that the useful rudder is effective for a shorter period.

This principle is especially useful when the accuracy of the steering gear does not permit of the application of initial rudder until after the peak of a yaw has been reached; or there may be a time lag in the operation of the rudder motor. Under these conditions the initial rudder is maintained past the peak of the yaw, in which case the craft's heading and the rudder torque are in the same sense—a condition to be avoided if possible. It may be avoided, as shown, by the application of inverse rudder which diminishes the initial rudder at any desired time before the next peak is reached.

It will be noted that the application of inverse rudder in Figs. 8 and 9 corresponds substantially to that illustrated in Fig. 6 (a) and described above.

If, as shown in Fig. 10, the initial rudder is sensitively applied, but the inverse rudder application lags behind the swinging of the craft over the set course, the useful rudder is effective for a longer period than in the cases of Figs. 8 and 9.

It will be noted that the application of inverse rudder in Fig. 10 corresponds substantially to that of Fig. 6 (b) as described above.

In Fig. 11, there is illustrated the effect of low sensitivity in the apparatus for applying inverse rudder as well as in the apparatus for applying initial rudder.

While I have illustrated in Figs. 8 to 11 the application of initial and inverse rudder in equal proportions, it may be found that better control can be obtained by applying inverse rudder which is a fraction of the amount of initial rudder. In Fig. 12 there is illustrated the case where there is low sensitivity throughout and the inverse rudder application is about one-quarter of the initial rudder application.

In Fig. 13, there is illustrated the case where the apparatus for applying initial rudder is highly sensitive and the inverse rudder is applied as illustrated in Fig. 6 (c) and described above.

From the above description it will be seen that the invention enables the application of large amounts of useful rudder, since the inverse rudder is combined with the initial rudder, and the time of occurrence duration and magnitude of the useful rudder may be readily controlled by adjustment of the inverse rudder device. Thus, the system is extremely flexible and greatly enhances the steering of the craft.

It will be understood, of course, that the invention is capable of various modifications and is not limited to the specific apparatus illustrated.

I claim:

1. In an automatic steering system adapted to direct a dirigible craft along a substantially sinusoidal path, means for applying large movement to the craft's rudder substantially at the peak of each yaw in a direction to oppose the next yaw, and means for subtracting at least a portion of said movement within each interim between successive applications of said rudder movement.

2. In an automatic steering system adapted to direct a dirigible craft along a substantially sinusoidal path, means responsive to the craft's reaching substantially its peak yaw in either direction for throwing the craft's rudder in a direction to oppose the next yaw, and means responsive to the craft's yawing motion for subtracting at least a portion of the rudder throw within each interim between successive rudder throws.

3. In an automatic steering system adapted to direct a dirigible craft along a substantially sinusoidal path, means responsive to the craft's reaching substantially its peak yaw in either direction for throwing the craft's rudder in a direction to oppose the next yaw, means responsive to the craft's yawing motion for subtracting at least a portion of the rudder throw within each interim between successive rudder throws, and means for varying the operation of said last-named means so as to vary the time of occurrence and duration of its subtracting action.

4. In an automatic steering system adapted to direct a dirigible craft along a substantially sinusoidal path, means responsive to the craft's yawing motion for producing a mechanical movement which when applied to the craft's rudder imparts a relatively great throw thereto substantially at the peak of each yaw in a direction to oppose the next yaw, other means responsive to the craft's yawing motion for producing a mechanical movement having a predetermined relation to said first movement, and means for compounding said movements and for applying their resultant to the craft's rudder, the last-named movement serving to nullify at least a portion of the first-named movement to reduce the rudder throw between yaw peaks.

5. In an automatic steering system adapted to direct a dirigible craft along a substantially sinusoidal path, means responsive to the craft's yawing motion for producing a mechanical movement which when applied to the craft's rudder imparts a relatively great throw thereto substantially at the peak of each yaw in a direction to oppose the next yaw, other means responsive to the craft's yawing motion for producing a mechanical movement having a predetermined relation to said first movement, means for compounding said movements and for applying their resultant to the craft's rudder, the last-named movement adding to the first-named movement during a part of the yawing cycle and subtracting therefrom during another part of the cycle, and means for varying the operation of said second means so as to vary the action of said last-named movement.

6. In an automatic steering system adapted to direct a dirigible craft along a substantially sinusoidal path, a first device adapted to produce a mechanical movement which when applied to the craft's rudder imparts a relatively great throw thereto substantially at the peak of each yaw in a direction to oppose the next yaw, a second device adapted to produce a mechanical movement having a predetermined relation to said first movement, and means for compounding said

movements and for applying their resultant to

the craft's rudder, the last-named movement serving to nullify at least a portion of the first-named movement to reduce the rudder throw between yaw peaks, said second device comprising a reversible motor, switching means for controlling the energization of said motor, and means responsive to the craft's yawing motion for actuating said switching means.

7. In an automatic steering system adapted to direct a dirigible craft along a substantially sinusoidal path, a first device adapted to produce a mechanical movement which when applied to the craft's rudder imparts a relatively great throw thereto substantially at the peak of each yaw in a direction to oppose the next yaw, a second 15

device adapted to produce a mechanical movement having a predetermined relation to said first movement, and means for compounding said movements and for applying their resultant to the 5 craft's rudder, the last-named movement serving to nullify at least a portion of the first-named movement to reduce the rudder throw between yaw peaks, said second device comprising a reversible motor, switching means including spaced 10 contact elements and a movable contact element, adjustable stops for said movable element, compass means, and a slip drive means interconnecting said movable element and said compass means.

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