

Oct. 17, 1961

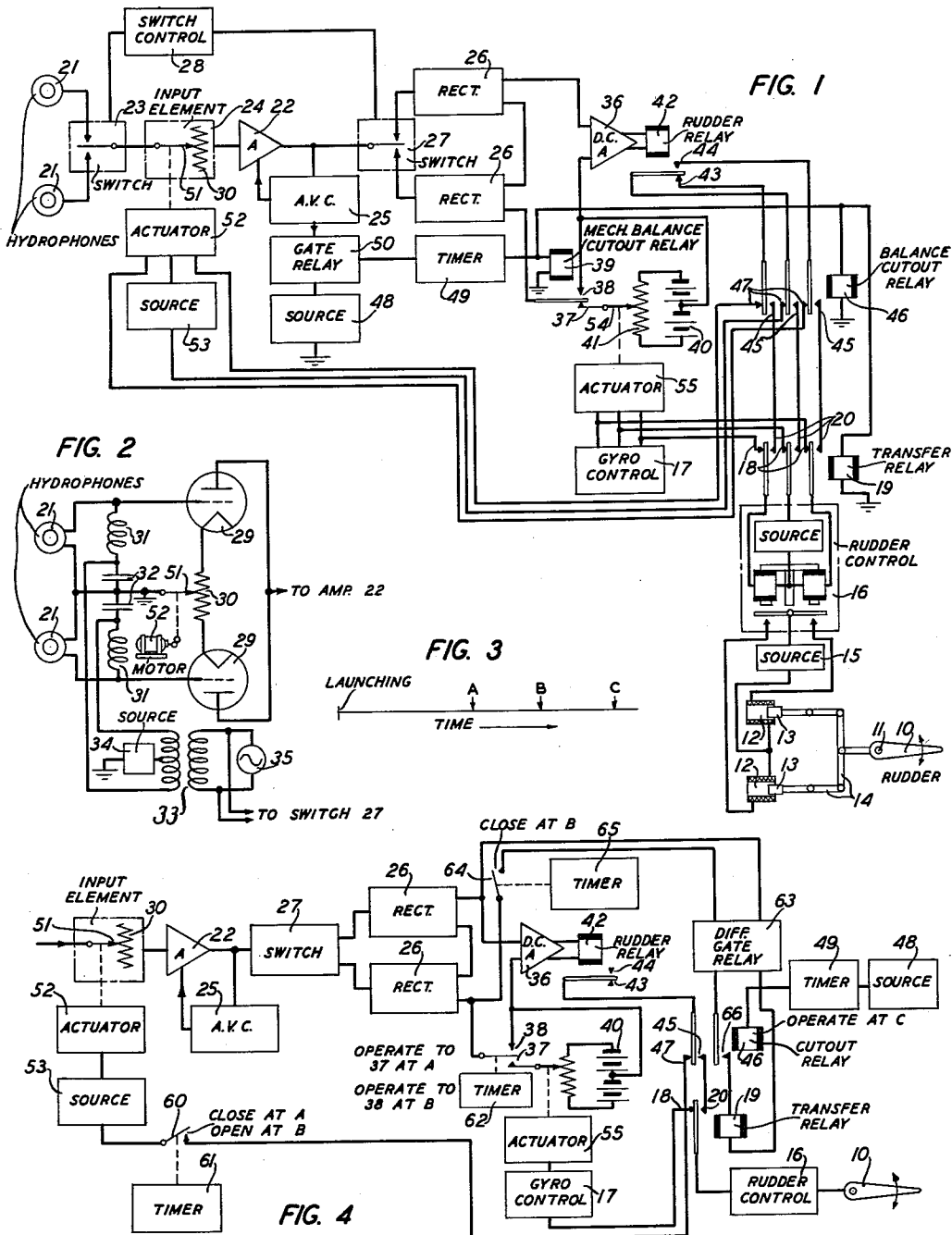
A. C. DICKIESON

3,004,508

CONTROL CIRCUIT

Filed July 20, 1944

3 Sheets-Sheet 1



INVENTOR
A. C. DICKIESON
BY

Walter C. Kiesel
ATTORNEY

Oct. 17, 1961

A. C. DICKIESON

3,004,508

CONTROL CIRCUIT

Filed July 20, 1944

3 Sheets-Sheet 2

FIG. 5

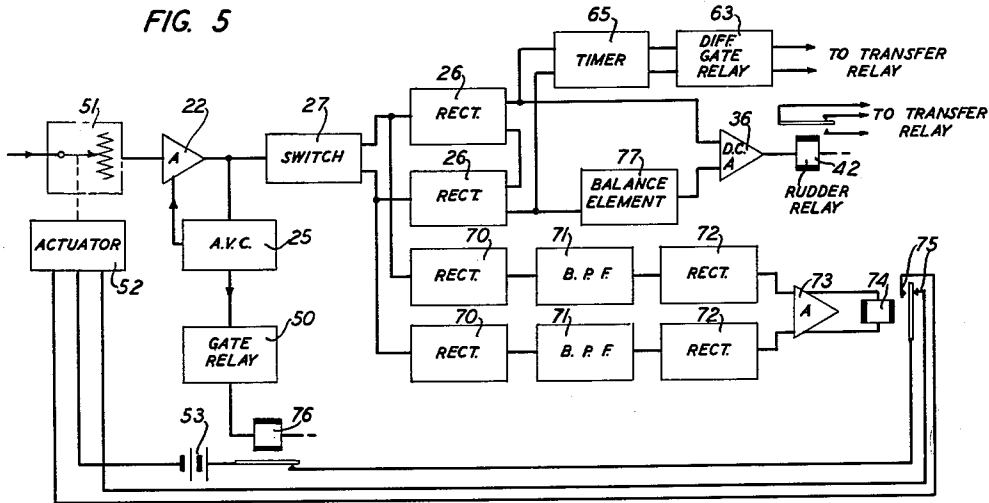
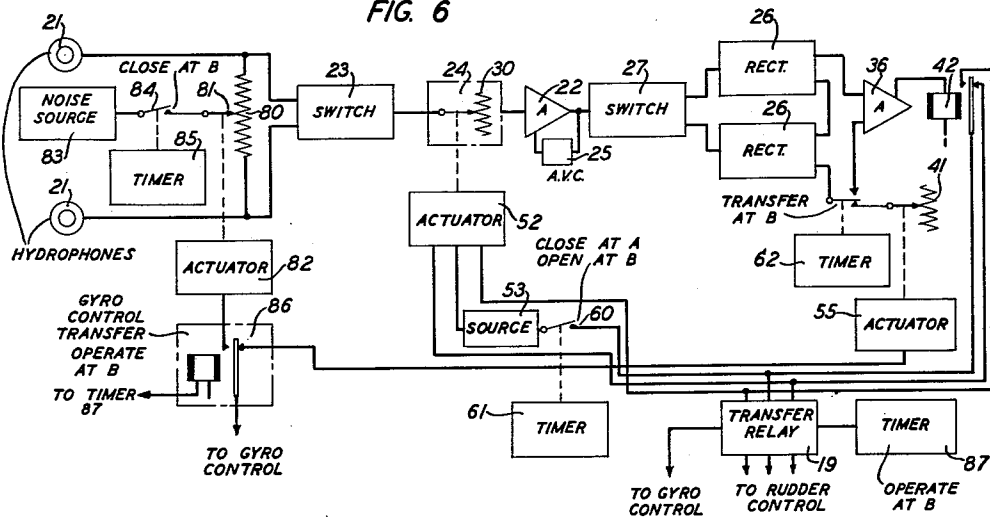


FIG. 6



INVENTOR
A. C. DICKIESON
BY

Walter C. Kiesel
ATTORNEY

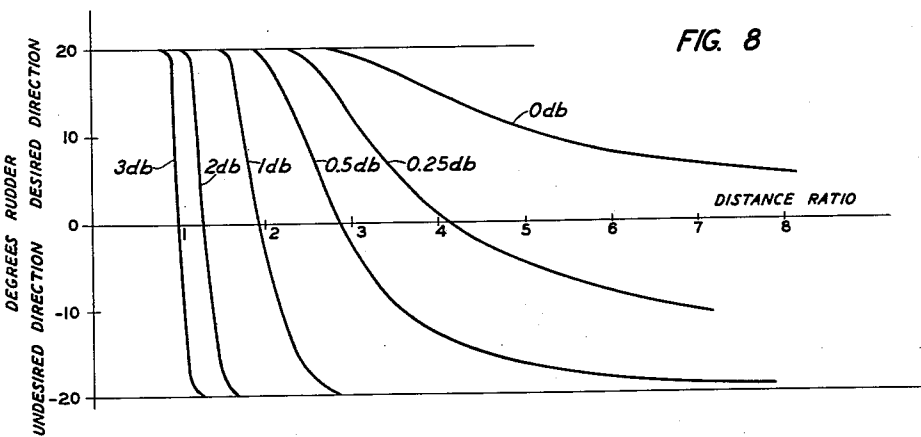
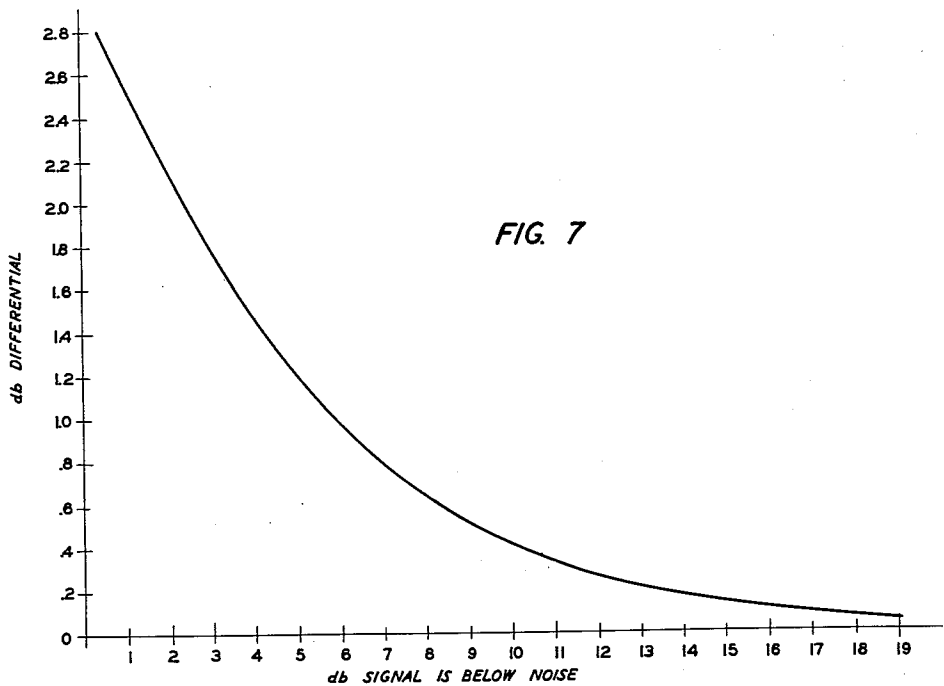
Oct. 17, 1961

A. C. DICKIESON
CONTROL CIRCUIT

3,004,508

Filed July 20, 1944

3 Sheets-Sheet 3



INVENTOR
A. C. DICKIESON
BY

Walter C. Kiesel
ATTORNEY

1

3,004,508

CONTROL CIRCUIT

Alton C. Dickieson, Mountain Lakes, N.J., assignor to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

Filed July 20, 1944, Ser. No. 545,835

30 Claims. (Cl. 114-23)

This invention relates to control circuits and more particularly to signal controlled steering systems for moving bodies, such as torpedoes.

One general object of this invention is to improve the performance characteristics of signal controlled steering systems for moving bodies, such as torpedoes. More specifically, objects of this invention are to increase the effective range of and to improve the accuracy of control by torpedo steering systems of the target signal actuated type.

In one illustrative embodiment of this invention, a torpedo steering system comprises a rudder, a gyroscope element normally operatively associated with the rudder to control the rudder for a period after the torpedo is launched, a signal actuated system normally dissociated from the rudder, for controlling it in accordance with signals emanating from a target, such as a ship, to guide the torpedo to the target, and transfer means for dissociating the gyroscope elements from the rudder and operatively associating the signal actuated system with the rudder. The latter system is of the type disclosed in the application Serial No. 491,795, filed June 22, 1943 of Donald D. Robertson, and comprises, generally, a pair of similar signal channels, a pair of hydrophones mounted on opposite sides of the longitudinal axis of the torpedo and each constituting the input element for a respective signal channel, and means for resolving the outputs of the two channels in difference relation into a control signal related in polarity and amplitude to the relative outputs of the two hydrophones and, hence, to the direction of the source of the signals received by the hydrophones.

Ideally, of course, the torpedo and the signal actuated system should be so constructed that in the absence of target signals at the hydrophones, and other controls, the steering system is in exact balance so that the torpedo remains on course. Practically these desiderata are difficult to obtain, at best, in manufacture and especially in manufacture of torpedoes in quantity for the reason that a multiplicity of factors, both electrical and mechanical, enter into the determination of the condition of the torpedo from the standpoint of balance of the steering system therefor. For example, dissymmetry of the signal actuated system may be caused by differences in the hydrophones and component parts of the two signal channels, by variations in the supply voltages and effects due to time and temperature. Further, such dissymmetry may be caused by noise in the vicinity of the torpedo when it is operating, that is, noise due to such items, for example, as the propulsion machinery, the propellers, the steering gear, the relays and the operating elements included in the circuits and water noises both ambient and due to motion of the torpedo. Such noise obviously, when detected by the hydrophones may create an unbalance in the steering system.

Among the mechanical factors which may create an unbalance in the steering system are dissymmetries of the body surfaces, fins and components of the torpedo, the effect of which is to subject the torpedo to turning forces even when the rudder is in its center or on course position.

One of the principal effects of unbalance of the character above mentioned, in the steering system is to decrease the range of the signal actuated system. This effect will be clear from the following considerations. The average amplitude of rudder deflections over a period of time is a

2

function of the difference in signal intensities at the two hydrophones. The signal inputs to the two hydrophones comprise two main components, namely, a component due to signals emanating from the target and a component due to the self-noise of the torpedo. It can be shown readily that the amplitude of the differential output of the two signal channels is a function of the relative levels of the target signal and self-noise components and that this differential decreases rapidly with decrease in target signal level in relation to self-noise signal level. The target signal level, of course, is a function of the distance between the target and the torpedo. Also, in general, at least a certain differential is requisite to produce a significant amplitude of rudder deflection.

Bearing in mind that the signal actuated system controls the rudder in accordance with both the polarity and amplitude of the differential above noted, it will be appreciated that unbalance in the steering system, of the character noted above, deleteriously affects the performance of the steering system. For example, if the unbalance is such as to result in full rudder deflection, that is, maximum deflection as limited by stops associated with the rudder, in one direction, the torpedo must come relatively close to the target before the target signal components of the hydrophone inputs are of a sufficient level to overcome the differential due to the unbalance and cause deflection of the rudder in the requisite direction to bring the torpedo on course toward the target. Similarly, for unbalances less than that resulting in full rudder deflection, there is a loss in effective range of the signal actuated control system.

Further, it will be apparent that if the steering system is unbalanced and at the time the torpedo is transferred from gyroscope to target signal control the distance from the target is such that the target signal level is insufficient to overcome the effect of the unbalance, the torpedo may circle, due to the unbalance, and, thus, may never come sufficiently close to the target to enable steering of the torpedo in accordance with signals emanating from the target.

In accordance with one feature of this invention, means are provided for compensating for unbalance in the steering system, due to either electrical or mechanical factors or both, before the signal actuated control system is operatively associated with the rudder, whereby the steering system is effectively in balance when the signal actuated system is enabled to control the rudder.

In accordance with another feature of this invention, the transfer means is controlled in accordance with a parameter of the signals in the two signal channels so that the transfer means is operated to shift the torpedo from gyroscope to target signal control only when the torpedo is within such range of the target that the signal control system will be effective to guide the torpedo to the target.

The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

FIG. 1 is a circuit diagram, partly in functional schematic form, of a steering system for a torpedo, illustrative of one embodiment of this invention;

FIG. 2 is a circuit schematic showing details of the input circuit for the signal control circuit in the system illustrated in FIG. 1;

FIG. 3 is a time diagram which will be referred to hereinafter in the discussion of the sequence of operation of certain elements in the system illustrated in FIG. 4;

FIG. 4 is a functional schematic of a steering system illustrative of another embodiment of this invention;

FIGS. 5 and 6 are functional schematics of steering

systems illustrative of other embodiments of this invention;

FIG. 7 is a graph showing the relation between the differential signal and various ratios of target signal and noise levels; and

FIG. 8 is a graph illustrating the relation between rudder deflection and a distance ratio, defined hereinafter, for various degrees of unbalance in the steering system.

Referring now to the drawing, the torpedo steering system illustrated in FIG. 1 comprises a rudder 10 pivoted upon a shaft 11 and deflectable in opposite directions by a pair of solenoids 12 having cores 13 coupled to the rudder by a suitable linkage 14. The solenoids 12 are energized, as by a source 15, over a rudder control circuit 16. The control circuit 16 may be of any one of a number of forms, for example, of the transfer type including a relay as illustrated in FIG. 1, and is of such character that, in the absence of an input signal thereto, the solenoids are energized equally whereas, when an input signal is supplied to this circuit, the solenoids are energized unequally in accordance with the polarity of the control signal. Thus, the rudder is deflected in one direction or the other in accordance with the polarity of the input signal to the control circuit.

The polarity of the input signal to the control circuit 16 is determined by either a gyroscope control element 17 or a signal actuated control system. The gyroscope element normally is associated operatively with the rudder control circuit over the contacts 18 of a transfer relay 19. The signal control system is connected to the contacts 20 of this relay, which contacts normally are open so that this system is dissociated from the rudder control circuit 16. The gyroscope element 17 may be of known construction and, therefore, need not be described in detail here. Suffice it to say that this element functions to apply to the rudder control circuit 16 a signal related in polarity to the direction of the deviation of the torpedo from the course for which the gyroscope is set.

The signal actuated control system, which may be of the general form disclosed in detail in the application, identified hereinabove, of Donald D. Robertson, comprises a pair of hydrophones 21 mounted on opposite sides, i.e., port and starboard, of the torpedo body, symmetrically with respect to the longitudinal axis of the body. The hydrophones are connected in alternation to the input of a high frequency amplifier 22 by a switch 23 and by way of an input element or circuit 24, the amplifier being provided with automatic volume control 25. The amplifier output is connected in alternation to a pair of rectifiers 26 by a switch 27, which is operated in synchronism and at the same frequency as the switch 23 as by a switch control 28. Thus, it will be seen that the system comprises two channels each of which includes one of the hydrophones, the amplifier 22 and the respective rectifier 26, the corresponding hydrophone and rectifier being connected operatively to the amplifier in synchronism and the two channels being completed in alternation.

The input element 24, as shown clearly in FIG. 2, comprises a pair of similar electron discharge devices 29 having their anodes connected in common to the amplifier 22, and having their cathodes connected by a potentiometer resistance 30. The input circuit of each device 29 includes one of the hydrophones 21 and an associated inductance 31 and condenser 32. The condensers 32 are bridged across the secondary winding of a transformer 33, the mid-point of this winding being connected to ground, and thus to the potentiometer resistance 30, through a source 34, such as a battery, of such voltage as to bias both of the devices 29 beyond cut-off. The primary winding of the transformer 33 is connected in circuit with an alternating current source 35, such as an electronic oscillator, the output voltage of which is sufficient to effect overcoming of the blocking bias upon the

devices 29 whereby these devices are rendered conductive in alternation.

The output voltages of the two rectifiers 26 are resolved in difference relation to produce a control voltage related in polarity and proportional in amplitude to the difference between the outputs of the two hydrophones. The control voltage thus obtained is impressed upon the input circuit of a direct current amplifier 36 which is normally biased substantially at cut-off and the input circuit for which includes one or the other of the contacts 37 or 38 of a relay 39. The circuit, when closed over the normally closed contact 37 includes the source 40 and a potentiometer resistance 41. Included in the output circuit of the amplifier 36 is a relay 42 having a pair of contacts 43 and 44, these contacts and the relay armature being arranged for connection to the rudder control circuit 16 over the contacts 20 of the relay 19 and the contacts 45 of a relay 46. The contacts 47 of the relay 46 are connected in an auxiliary circuit described hereinafter. It will be seen that when the net voltage impressed upon the input circuit of the amplifier 36 is of the polarity to overcome the blocking bias, the amplifier is rendered conductive whereby the relay 42 operates to close its contact 44; when the voltage is of the opposite polarity, the amplifier is blocked and the contact 43 is closed. The relay 42, when its contacts are associated with the rudder control circuit 16 determines the polarity of the input signal to the circuit 16 and thus controls the rudder in accordance with the relative outputs of the hydrophones 21.

When the torpedo is launched, the several relays are in the condition shown in FIG. 1 so that the gyroscope control element 17 is associated with the rudder control circuit and the latter is dissociated from the signal control system. After an interval, determined as described hereinafter, the relay 19 operates so that, as will be seen, the gyroscope element is dissociated from the rudder control circuit and the signal control circuit is associated therewith.

The energizing circuit for the relay 19 includes a source 48 and a timer 49, or as is particularly advantageous, both the timer and a gate relay 50. In either case the timer 49 is set to operate only after the torpedo has traveled a preassigned distance from the launching vessel sufficient to prevent operation of the signal control circuit by noises emanating from the launching ship. The gate relay 50, when employed, may be connected to the automatic volume control circuit 25 so that it will operate only when the hydrophone inputs are of at least a preassigned level.

As has been pointed out above, mechanical and electrical dissymmetries may be present in the torpedo and the signal control system so that, as is apparent, when the torpedo is transferred from gyroscope to signal control the steering system may be unbalanced. The effect of unbalance in the system will be understood from the following consideration with particular reference to FIGS. 7 and 8.

In FIG. 7, the ordinates are in decibels differential and the abscissae are in terms of target signal, in decibels below noise, applied to one hydrophone with noise signals applied to both hydrophones. For low values of differential output of the hydrophones 21, for example for differentials below of the order of 0.5 decibel in a particular system, the average amplitude of rudder deflection over a period of time, considering both the amount and duration of deflection, varies directly with the differential input. For greater values of differential, the rudder deflection is the maximum, for example substantially 20 degrees, permitted by stops associated with the rudder. The differential input is a function of the target signal noise and other noise due to torpedo self-noise and random submarine noise. Considering the hydrophone inputs as the power addition of the target and other noises, the differential input, in the presence of such other noise, is dependent largely upon the ratio of target and other

noises. The general relation is shown by the graph in FIG. 7. For the particular case illustrated by the graph, when the target signal and other noises are equal, the differential input is 3 decibels.

For purposes of analysis, the distance from the torpedo to the target at which the target and other noises are equal may be taken as a base in illustrating the effect of unbalance upon the steering system. In FIG. 8, the abscissae are in terms of a distance ratio, namely the ratio of distance between the torpedo and the target to this distance for the condition of equality of target signal and other noises. The several curves in this figure correspond to different degrees of unbalance in the steering system expressed in terms of decibels, the unbalance for each curve being indicated by the appropriate legend therefor. It will be seen from FIG. 8 that if the steering system is balanced, maximum rudder deflection, 20 degrees in the particular case illustrated, is obtained for all values of distance ratio below about 2.9 and that for all values of this ratio up to about 8 significant rudder deflection, 5 degrees being taken as the significant minimum, is obtained and in the desired direction. As shown clearly by FIG. 8, when the system is unbalanced, rudder deflection in the direction opposite to that requisite to steer the torpedo to the target obtains for some values of distance ratio and, further, the range throughout which significant rudder deflection in the proper direction is obtained is reduced drastically. Thus, it is clear that the effect of unbalance is to decrease the effective range of the system. For example, the effect of an unbalance of 3 decibels is to reduce this range by a factor of about 8 from that obtained with a balanced system and by a factor of about 3.25 from that obtained for an unbalance of 0.25 decibel. Also, as will be apparent, if the system is unbalanced, and if the torpedo is transferred from gyroscope to signal control at a substantial distance from the target, for example at a distance corresponding to a distance ratio of about 2 for an unbalance of 2 decibels, the rudder will be deflected to the maximum in the wrong direction and the torpedo may be steered along such a course that it may never come sufficiently within the noise field of the target to enable the signal control system to guide the torpedo to the target.

In accordance with one feature of this invention, means are provided for balancing the signal control system automatically after the torpedo is launched and before it is committed to control by this system. Specifically, in the system illustrated in FIGS. 1 and 2, the balancing is effected by adjusting the relative sensitivities of the two signal channels so that the outputs of the two channels are substantially equalized while the torpedo is under gyroscope control.

When the torpedo is launched, it will be noted that the hydrophones 21 receive noise signals emanating from the launching ship as well as torpedo self-noise and random submarine noise signals. As the torpedo travels away from the launching ship, the level of ship noise signals decreases rapidly so that at some distance from this ship the major portion of the input to the hydrophones is due to self-noise and random submarine noise. As has been pointed out heretofore, the timer 49 serves to prevent operation of the transfer relay 19 until the torpedo is at such distance from the launching ship that the signal control system cannot be actuated in accordance with signals emanating from the ship. As will be appreciated, at the time the relay 19 operates, the torpedo may be either within the effective signal field of the target or be in such position that the only input to the hydrophones 21 is due to self and random submarine noise. In either case, it is highly desirable that the signal control system be in balance at this time.

The operation of the rudder relay 42 to close one or the other of its contacts is determined by the relative output voltages of the rectifiers in the two signal channels. The relation of these voltages is determined by the rela-

tive inputs to the amplifier 22 by the two devices 29 and the relation of these inputs, in turn, is dependent upon the relative proportions of the potentiometer resistance 30 included in the input circuits for the two devices.

In the system illustrated in FIG. 1, the contact arm 51 for the potentiometer resistance 30 is coupled to an actuator 52, such as a reversible motor as indicated in FIG. 2, which is energized from a source 53 over one of two circuits each including one of the contacts 47 of the relay 46 and one of the contacts, 43 or 44, of the rudder relay 42. When either of the circuits for the actuator is closed, the actuator moves the contact arm 51 in the direction tending to establish equality between the output voltages of the two rectifiers 26. The relay 42 controls the two circuits and operates in response to any unbalance between the two channels. Thus, before operation of the timer 49, the signal control system is substantially balanced on self and random noise and such electrical dissymmetry as may be present in the system, due for example to differences between the two hydrophones 21, the devices 29 or the rectifiers 26 or to other factors, is compensated for before the steering system is conditioned for control in accordance with target signals.

When the torpedo is beyond the effective point of the signal field of the launching ship, the timer 49 closes the energizing circuit from the source 53 for the relay 46, or if the system includes a gate relay 50 as shown, the circuit is closed when the torpedo enters to a preassigned extent, determined by the signal level for which the relay is set, into the sound field of the target. When the relay 46 operates, the energizing circuits for the actuator 52 are opened at the contacts 47 and the contact arm 51 remains thereafter at the point for balance of the signal control system in the absence of target signals.

Although in the specific system illustrated in FIG. 1, the transfer relay 19 and cut-out relay 46 are operated simultaneously, it will be understood that they may be operated separately. For example, the relay 19 may be timer controlled and the relay 46 may be controlled by a timer and gate relay so that the automatic balancing circuit will continue operating after the torpedo has been transferred from gyroscope to signal control until the torpedo comes within a range of the target set by the operating level of the gate relay.

In any case, the gate relay is set with due consideration for a number of factors to minimize the possibility of false operation. For example, in the case of an amplitude controlled gate relay, the relay should be set so that it will not operate on approximately the maximum level of self and random noise likely to be encountered in use of the torpedo.

The balancing adjustment described above compensates for electrical dissymmetries in the signal control system as well as unbalance due to self-noise. Means may be provided also for compensating for mechanical dissymmetries in the torpedo. As pointed out heretofore, the effect of mechanical dissymmetry is to subject the torpedo to a turning force. Now, while the torpedo is under gyroscope control, this control deflects the rudder in order to maintain the torpedo on its course despite the turning force. This action of the gyroscope control may be utilized to compensate for mechanical dissymmetries.

As shown in FIG. 1, the contact arm 54 for the potentiometer resistance 41 is coupled to an actuator 55, which may be, for example, a reversible motor similar to the motor 52. The actuator is controlled by the gyroscope element so that when the latter operates to cause deflection of the rudder to counteract in turning force due to mechanical dissymmetry, the contact arm 54 is moved in the direction to introduce in the input circuit for the direct current amplifier 36 a component of voltage corresponding in polarity and amplitude to the direction and degree of the rudder deflection. This component of voltage, representing an unbalance, will be compensated for

by operation of the actuator 52 and consequent displacement of the contact arm 51.

The relay 39 in the specific system illustrated in FIG. 1 operates concurrently with the relays 19 and 46, although, as will be apparent, it may be controlled to operate simultaneously only with the relay 46. In any case, when the relay 39 operates to transfer its armature from the contact 37 to the contact 38, the resistance 41 and battery 40 are cut out of the input circuit for the direct current amplifier 36.

Thus, when the torpedo is committed to steering by the signal control system, both mechanical and electrical dissymmetries have been compensated for and this control system is substantially balanced, whereby a large effective range for this system is obtained and possibilities of the torpedo remaining outside of the effective sound field of the target are minimized.

The system illustrated in FIG. 4 is similar generally to that shown in FIGS. 1 and 2 and described hereinabove, differing therefrom in that the compensating means are time controlled and that a differential gate relay is utilized for effecting operation of the transfer relay. Specifically, the energizing circuit for the actuator 52 includes a switch 60 controlled by a timer 61 and the armature associated with the contacts 37 and 38 is controlled by a second timer 62. The differential gate relay 63 is energized in accordance with the difference between the outputs of the rectifiers 26 over a circuit including a switch 64 controlled by a timer 65. The energizing circuit for the transfer relay 19 includes the contact of the differential relay and an auxiliary contact 66 of the relay 46.

The several timers are set to produce a sequence of operations at preassigned times after launching of the torpedo, the times being indicated graphically at points A, B and C in FIG. 3. At the time of launching of the torpedo, the circuit is in the condition shown in FIG. 4 and the torpedo is steered by the gyroscope element. At a time A, advantageously sufficient after the launching so that the torpedo is removed from the effective sound field of the launching vessel, the timer 61 operates to close the switch 60 and the timer 62 operates to close the input circuit for the direct current amplifier at contact 37. Thus, the actuators 52 and 55 are enabled and the signal control system is balanced, for self and random noise, to compensate for electrical and mechanical dissymmetries. At a time B, sufficiently after time A to allow balance in the system to be obtained, the timers 61 and 62 operate so that the switch 60 is opened and the direct current amplifier input circuit is closed over contact 38. The system is then in balance. Also at the time B, the timer 65 operates to close switch 64 whereby the differential gate relay 63 is enabled. At a subsequent time C, sufficiently after time B to allow transients in the differential gate relay system to die away, the timer 49 operates to close the energizing circuit for the relay 46, whereby the contact 66 is closed and the transfer relay 19 is placed under control of the relay 63. Up until this time and thereafter until the relay 63 operates, the torpedo remains under gyroscope control. If at any instant after the time C, the torpedo comes into such position relative to the target that the differential input to the two hydrophones 21 is of a preassigned magnitude, determined by the setting of the gate relay 63, the relay 66 operates to transfer the torpedo from gyroscope control to control by the signal control system in accordance with noise emanating from the target.

It will be appreciated that inasmuch as the differential gate relay is not enabled until the time B, by which time the signal control system has been balanced automatically, this relay may be made very sensitive and thus effective to transfer the torpedo from gyroscope to signal controlled steering for small off-course angles of the torpedo with respect to the target after, of course, the torpedo comes within the effective signal field of the target.

The system illustrated in FIG. 5 is generally similar to that disclosed in FIGS. 1 and 4 and described hereinabove, differing therefrom principally in the manner of controlling the actuator 52 to balance the signal control system. The self-noise of a torpedo may have at least one attribute, for example an envelope frequency component such as the torpedo propeller frequency, whereby such self-noise may be distinguished from target signal noise. Such attribute is utilized in the system shown in FIG. 5 for effecting balance of the signal control system on self-noise.

Specifically, the control circuit for the actuator 52 in the system shown in FIG. 5 comprises two substantially identical auxiliary channels connected to respective sides of the switch 27 and each including a rectifier 70, a filter 71 and an output rectifier 72. The two filters 71 are designed to pass only a frequency or frequencies characteristic of the torpedo self-noise, such as the propeller blade frequency. Each channel, as is apparent, is energized in accordance with the signals in a respective main channel of the control system and the outputs of the two auxiliary channels are combined in difference relation to produce a control voltage which is impressed upon the input circuit of a direct current amplifier 73. The amplifier 73 is biased at cut-off and has a relay 74 in its output circuit. The relay 74 operates to close one or the other of its contacts 75 in accordance with the polarity of the control voltage supplied to the amplifier 73, and thus causes energization of the actuator 52 to establish balance between the main channels of the signal control system.

The energizing circuits for the actuator may be enabled permanently or, alternatively, may be disabled, as by operation of the gate relay 50 to operate the auxiliary relay 76, when the torpedo comes within a preassigned range, set by the gate relay 50, of the target.

The timer 65 is set to enable the differential gate relay 63 after the torpedo has passed beyond the effective noise field of the launching vessel. Also, as in the embodiments described previously, the operating levels of the gate relays 50 and 63 are set to prevent false operation on self-noise of the torpedo.

It will be understood that the system illustrated in FIG. 5 may include means similar to that included in the systems shown in FIGS. 1 and 4 for compensating for mechanical dissymmetry. For simplicity, such means has been indicated functionally at 77 in FIG. 5.

The system illustrated in FIG. 6 is generally the same as that shown in FIG. 4 and described heretofore, differing therefrom in the manner of gate control utilized to transfer steering of the torpedo from gyroscope to target signal control. The times, A, B, and C, indicated in FIG. 6 are in the sequence shown in FIG. 3.

As shown in FIG. 6, a potentiometer resistance 80 is bridged across the hydrophones 21 and the contact arm 81 thereof is coupled to an actuator 82. Electrically, this contact arm 81 is connected to a source 83 of random noise by way of a switch 84 controlled by a timer 85. The actuator 82 is adapted to be connected to the gyroscope control by way of a gyroscope transfer control 86, which, as indicated, may be a transfer relay operated in parallel with the transfer relay 19 or may comprise additional transfer contacts of the latter relay. Initially, that is at the time of launching of the torpedo, the contact arm 81 is at the mid-point of the resistance 80.

When the torpedo is launched, the circuit is in the condition shown in FIG. 6 and the torpedo travels under gyroscope control. The mechanical dissymmetry compensating element is operative. At the time A, sufficiently after the launching to allow the torpedo to travel to a point beyond the effective signal field of the launching vessel, the timer 61 operates to close the switch 60 whereby the balancing system including the actuator 52 is enabled. Up to a time B, the actuators 52 and 55 are effective to compensate for dissymmetries in the torpedo and control system. At the time B, the compensating

controls are disabled by operation of the timers 61 and 62 and the relay 46 operates to dissociate the rudder relay 42 from the compensating circuits and associate it with the rudder control 16. Also, at this time B, the timer 85 closes the switch 84, the transfer control 86 shifts the gyroscope control from the actuator 55 to the actuator 82, and the transfer relay operated by a timer 87 disconnects the gyroscope control from the rudder control 16 and operatively associates the rudder relay 42 with the rudder control.

At this time, the signal control system may still have some unbalance. If this is the case and the torpedo is not yet within the effective signal field of the target, the gyroscope element controls the rudder by operation of the actuator 82 to balance the system on the noise from the source 83. When, after the time B, the target signals received by the hydrophones 21 are of a preassigned amplitude, the signal control system takes over control of the rudder and thereafter the torpedo is guided to the target in accordance with the target signals.

In order that this may be effected, certain relationships must be observed particularly with reference to the level of self-noise and the degree of unbalance of the system which might be present at time B. Specifically, the output of the noise source 83 is made such that the gyroscope control by control of the actuator 82 can effect control of the rudder only up to unbalances of a prescribed maximum. For example, if the maximum probable unbalance between the two channels of the signal control system remaining at the time B is 0.5 decibel, the noise source 83 must be such as to be capable of adding to the input to one of the channels a noise component 9 decibels below the self-noise, as is seen from FIG. 7. Thus, the maximum output of the noise source must be set with relation to the level of self-noise and the maximum unbalance at the time B probable in any particular system. Both the self-noise level and this maximum probable unbalance can be determined, of course, for any system.

When, after the time B, the torpedo enters the signal field of the target and if the torpedo is not directly on course toward the target, the target signals will produce a differential in the inputs to the two channels of the signal control system and the latter will tend to steer the torpedo by operation of the relay 42. The gyroscope control by way of the actuator 82 will oppose this differential up to the limit of the gyroscope control range. As the torpedo approaches the target, the target signal amplitude increases and will become increasingly greater than the signal from the noise source 83. Hence, in effect, the target signals overcome the gyroscope control and throughout the latter part of its run to the target, the torpedo is steered by the signal control system in accordance with the target signals.

It will be appreciated, then, that in the systems illustrated and described, by virtue of the gate control of the transfer from gyroscope to target signal control of the rudder, in accordance with the amplitude of the target signals, or the difference in signal amplitude in the two channels due to target signals, the rudder is not placed under target signal control until the torpedo is within such range of the target that the target signals will be effective to cause guiding of the torpedo in accordance therewith and that, further, by virtue of the compensation for electrical and mechanical dissymmetries at the time the torpedo is conditioned for target signal control the signal control system is in a high degree of balance whereby a large range for the control system is assured. Further, as has been noted hereinabove, it will be appreciated that because of the balancing obtained, sensitive gate controls may be employed and the torpedo thus conditioned solely for target signal control at relatively large distances from the target.

Although specific embodiments of the invention have been shown and described, it will be understood that they

are but illustrative and that various modifications may be made therein without departing from the scope and spirit of the invention as defined in the appended claims.

What is claimed is:

1. A steering system for a torpedo, comprising a rudder, a control element for deflecting said rudder in one direction or the other, gyroscope means normally associated with said element for controlling it to maintain the torpedo on course, signal control means normally dissociated from said element and actuable in accordance with signals emanating from a target to control said element to guide the torpedo to the target, transfer means for associating said signal control means with said element and dissociating said gyroscope means therefrom, means for operating said transfer means at a time after the torpedo is launched, and means operable for at least a portion of the period between the launching of the torpedo and operation of said transfer means for adjusting said signal control means to compensate for unbalance in the steering system.

2. A steering system for a torpedo, comprising a rudder, a control element for deflecting said rudder in one direction or the other, gyroscope means normally associated with said element for controlling it to maintain the torpedo on course, signal control means normally dissociated from said element and actuable in accordance with signals emanating from a target to control said element to guide the torpedo to the target, transfer means for associating said signal control means with said element and dissociating said gyroscope means therefrom, means for operating said transfer means at a time after the torpedo is launched, and means actuated by said gyroscope means for a period preceding operation of said transfer means for adjusting said signal control means to compensate for mechanical dissymmetry in the torpedo affecting the steering thereof.

3. A steering system for a torpedo, comprising a rudder, a control element for deflecting said rudder in one direction or the other, gyroscope means normally associated with said element for controlling it to maintain the torpedo on course, signal control means normally dissociated from said element and actuable in accordance with signals emanating from a target to control said element to guide the torpedo to the target, transfer means for associating said signal control means with said element and dissociating said gyroscope means therefrom, means for operating said transfer means at a time after the torpedo is launched, and means controlled by said signal control means for at least a part of the period between launching of the torpedo and operation of said transfer means for adjusting said signal control means to compensate for electrical dissymmetries therein affecting the steering of the torpedo.

4. A steering system for a torpedo, comprising a rudder, a control element for deflecting said rudder in one direction or the other in accordance with the polarity of a control signal applied to the element, gyroscope means normally associated with said element for controlling the polarity of said control signal to maintain the torpedo on course, electrosonic means normally dissociated from said control element for controlling the polarity of said control signal in accordance with signals emanating from a target to steer the torpedo toward the target, transfer means for associating said electrosonic means with said control element and dissociating said gyroscope means therefrom, gate control means for operating said transfer means, normally enabled adjusting means associated with said electrosonic means for adjusting the electrosonic means to compensate for unbalance in the torpedo affecting the steering thereof, and means for disabling said adjusting means at a time in the period after launching of the torpedo up to operation of said transfer means.

5. A steering system in accordance with claim 4 wherein said adjusting means comprises means actuated by said gyroscope means for compensating for mechanical dissymmetries of the torpedo affecting the steering thereof.

6. A steering system for a moving body, comprising a rudder, a control element for deflecting said rudder in one direction or the other in accordance with the polarity of a control signal applied to the element, signal control means normally dissociated from said control element for determining the polarity of said control signal in accordance with signals emanating from a target to steer the body to the target, said signal control means comprising a pair of similar signal translating devices positioned symmetrically on opposite sides of the longitudinal axis of the body, a pair of similar signal channels each including a respective one of said devices at the input end thereof, means for combining the outputs of said signal channels in difference relation to produce a resultant signal, means operable in accordance with the polarity of said resultant signal for determining the polarity of said control signal, gate means for associating said signal control means with said control element, and means controlled in accordance with said resultant signal for substantially balancing the steering system before operation of said gate means.

7. A steering system in accordance with claim 6 wherein said balancing means comprises gyroscope controlled means for adjusting said channels to compensate for mechanical dissymmetry in said body affecting the steering thereof.

8. A steering system for a moving body, comprising a rudder, a control element for deflecting said rudder in one direction or the other in accordance with the polarity of a control signal applied to the element, signal control means normally dissociated from said control element for determining the polarity of said control signal in accordance with signals emanating from a target to steer the body to the target, said signal control means comprising a pair of similar signal translating devices positioned symmetrically on opposite sides of the longitudinal axis of the body, a pair of similar signal channels each including a respective one of said devices and an impedance at the input end thereof, means for resolving the outputs of said channels in combination into a difference signal, operating means actuated in accordance with said difference signal for determining the polarity of said control signal, gate means for associating said signal control means with said control element, and means operatively associated with said operating means and controlled thereby for a period preceding operation of said gate means for adjusting said impedances to substantially balance said signal control means.

9. A steering system for a torpedo, comprising a rudder, a control element for effecting deflection of said rudder in one direction or the other in accordance with the polarity of a control signal applied to the element, a signal control system for determining the polarity of said control signal, said signal control system comprising a pair of hydrophones mounted symmetrically in opposite sides of the longitudinal axis of said torpedo, a pair of similar signal channels each including a respective hydrophone and potentiometer means at the input end thereof, means for converting the outputs of said channels in combination into a difference signal, and means actuated in accordance with the polarity of said difference signal for determining the polarity of said control signal, gate means for operatively associating said signal control system with said element at a time when said torpedo is substantially beyond the effective sound field of the launching vessel, and means controlled in accordance with said difference signal for adjusting said channels to substantially balance said signal control system on torpedo self-noise before operation of said gate means.

10. A steering system in accordance with claim 9 comprising gyroscope controlled means for adjusting said channels to compensate for mechanical dissymmetry of the torpedo affecting the steering thereof.

11. A steering system for a torpedo, comprising a rudder, a control element for effecting deflection of said

rudder in one direction or the other in accordance with the polarity of a control signal applied to said element, gyroscope means for maintaining the torpedo on course and normally associated with said element to control the polarity of said control signal, signal control means normally dissociated from said control element and actuable in accordance with signals emanating from a target to control said element to guide the torpedo to the target, transfer means for associating said signal control means with said element and dissociating said gyroscope means therefrom, energizing means for said transfer means, and means for enabling said energizing means including gate means operable only in response to the presence of a prescribed signal condition at the input to said signal control element.

12. A steering system for a torpedo, comprising a rudder, a control element for effecting deflection of said rudder in one direction or the other in accordance with the polarity of a control signal applied to the element, signal control means for controlling said element and normally dissociated therefrom, said signal control means comprising a pair of hydrophones mounted symmetrically on opposite sides of the longitudinal axis of the torpedo, a pair of similar signal channels each including a respective hydrophone at the input end thereof, and means for determining the polarity of said control signal in accordance with the relative outputs of said signal channels, operating means for associating said signal control means with said control element, gate means for enabling said operating means only when a preassigned submarine signal condition exists at said hydrophones, means normally associated with said signal control means for adjusting said channels to compensate for dissymmetries in the steering system, and means controlled by said gate means and responsive to operation thereof for dissociating said adjusting means from said signal control means.

13. A steering system in accordance with claim 12 wherein said gate means comprises an amplitude controlled relay and means for energizing said relay proportionately to the signal level at said hydrophones.

14. A steering system for a torpedo, comprising a rudder, a control element for effecting deflection of said rudder in one direction or the other in accordance with the polarity of a signal applied to the element, signal control means responsive to submarine signals in the vicinity of the torpedo for producing a control signal related in polarity to the effective direction of the source of such submarine signals with respect to the longitudinal axis of the torpedo, said signal control means comprising a pair of hydrophones mounted symmetrically on opposite sides of the longitudinal axis of the torpedo, a pair of similar signal channels each including a respective hydrophone as the input element therefor and means for resolving the outputs of said channels in difference relation to produce said control signal, operating means for determining the polarity of the signal applied to said element in accordance with the polarity of said control signal, said operating means being normally dissociated from said control element, gate means for associating said operating means with said element including a timer operable at a preassigned time after launching of the torpedo such that the torpedo is outside of the effective sound field of the launching vessel, means controlled by said operating means for adjusting said channels to compensate for dissymmetries in the steering system, and means operable in response to operation of said gate means for disabling said adjusting means.

15. A steering system for a torpedo, comprising a rudder, a control element for deflecting said rudder in one direction or the other in accordance with the polarity of a control signal applied to the element, a pair of similar hydrophones mounted symmetrically on opposite sides of the torpedo, a pair of similar signal channels each including a respective hydrophone at the input end thereof, means for combining the outputs of said channels to pro-

duce a difference signal, operating means actuated in accordance with said difference signal for determining the polarity of said control signal in accordance with said difference signal, control means for operatively associating said operating means with said control element, gate means for operating said control means including a timer element operable only at a time after launching of the torpedo sufficient to enable the torpedo to travel beyond the effective sound field of the launching vessel and a relay energized in accordance with the signal level at said hydrophones and operable only when the signal level is of at least a preassigned amplitude, said timer element and relay being associated so that operation of both is requisite for operation of said control means, means actuated in accordance with operation of said operating means for adjusting said channels to compensate for dissymmetry in the steering system, and means controlled by said gate means for disabling said adjusting means.

16. A steering system for a torpedo, comprising a rudder, a control element for effecting deflection of said rudder in one direction or the other in accordance with the polarity of a control signal applied to the element, gyroscope means normally associated with said element for determining the polarity of said signal, signal control means for determining the polarity of said signal and normally dissociated from said element, said signal control means comprising a pair of similar hydrophones mounted symmetrically on opposite sides of the torpedo, a pair of similar signal channels each including a respective hydrophone at the input end thereof, means for combining the outputs of said hydrophones to produce a difference signal and operating means actuated in accordance with the polarity of said difference signal and effective when said signal control means is associated with said element to determine the polarity of said control signal, a transfer relay for associating said signal control means with said element and dissociating said gyroscope means therefrom, an energizing circuit for said relay including a timer operable only at a time after launching of the torpedo sufficient to allow the torpedo to travel beyond the effective sound field of the launching vessel and a gate relay controlled in accordance with a parameter of the signals being passed by said channels, said timer and gate relay being associated so that operation of both is requisite for closing of said energizing circuit, means controlled in accordance with operation of said operating means for adjusting said channels to compensate for dissymmetry therebetween, and means controlled by said gate relay and timer for disabling said adjusting means concurrently with the energization of said transfer relay.

17. A steering system for a torpedo, comprising a rudder, submarine signal responsive means actuable in accordance with signals received thereby for producing a control signal related in polarity to the direction of said signals with respect to the longitudinal axis of the torpedo, said means comprising a pair of similar hydrophones, a pair of similar signal channels each including a respective hydrophone at the input end thereof and means for resolving the outputs of said channels in combination into said control signal, operating means for effecting deflection of said rudder in one direction or the other in accordance with the polarity of said control signal, said operating means being normally dissociated from said rudder, means actuated in accordance with said control signal for adjusting the relative sensitivities of said channels, and means including a timer element operable at a preassigned time after launching of the torpedo sufficient to allow the torpedo to travel beyond the effective sound field of the launching vessel for associating said operating means with said rudder and disabling said adjusting means.

18. A steering system for a torpedo, comprising a rudder, submarine signal responsive means actuable in accordance with signals received thereby for producing a control signal related in polarity to the direction of said

signals with respect to the longitudinal axis of the torpedo, said means comprising a pair of similar hydrophones, a pair of similar signal channels each including a respective hydrophone at the input end thereof and means for resolving the outputs of said channels in combination into said control signal, operating means for effecting deflection of said rudder in one direction or the other in accordance with the polarity of said control signal, said operating means being normally dissociated from said rudder, means actuated in accordance with said control signal for adjusting the relative sensitivities of said channels to compensate for dissymmetries in the steering system, means for operatively associating said adjusting means with said operating means for a period of predetermined duration sufficiently subsequent to the launching of the torpedo that the torpedo is outside the effective sound field of the launching vessel whereby said channels are substantially balanced for signals received by said hydrophones during said period, and transfer means for associating said operating means with said rudder after said period.

19. A steering system in accordance with claim 18 wherein said transfer means comprises a relay and a control circuit for said relay including a timer operable at the end of said period and a gate relay energized in accordance with said control signal and operable only when said signal is of at least a prescribed amplitude, said timer and gate relay being arranged so that operation of both is requisite for operation of said first relay.

20. A steering system for a torpedo, comprising a rudder, means responsive to submarine signals emanating from a target for producing a signal related in polarity to the direction of the target with respect to the torpedo, said means comprising a pair of similar hydrophones mounted in opposite sides of the torpedo, a pair of similar signal channels each including a respective hydrophone and means for combining the outputs in difference relation to produce a control signal, operating means for effecting deflection of said rudder in accordance with said difference signal and adjusting means actuated in accordance with self-noise of the torpedo for varying the relative sensitivities of said channels to establish substantially equality between the self-noise signal components in the two channels.

21. A steering system in accordance with claim 20 wherein said adjusting means comprise a pair of similar auxiliary signal channels capable of transmitting only signals characteristic of torpedo self-noise, each of said auxiliary channels having its input end connected to a respective one of said first signal channels, means for combining the outputs of said auxiliary channels in difference relation and means for varying the relative sensitivities of said first channels in accordance with the polarity of the resultant of the combined outputs of said auxiliary channels.

22. A steering system for a moving body, comprising a rudder, signal responsive means for producing a control signal related in polarity to the direction of signals received thereby relative to the torpedo, said means comprising a pair of similar signal translating devices, a pair of similar signal channels each including a respective signal translating device at the input end thereof, means for resolving the outputs of said devices in difference relation to produce said control signal and means for effecting deflection of said rudder in one direction or the other in accordance with the polarity of said control signal, gyroscope means for producing a signal related in polarity to the direction of rudder deflection, an auxiliary signal source connected to the input ends of both said channels, and adjusting means actuated in accordance with the signal produced by said gyroscope means for varying the relative intensities of signals supplied to said channels by said auxiliary source for substantially balancing said channels for signals from said auxiliary source.

23. A steering system in accordance with claim 22 wherein said signal responsive means normally is dissociated from said rudder and said gyroscope means is normally associated with said rudder to maintain the torpedo on course, said system comprising also transfer means for associating said signal responsive means with said rudder and disassociating said gyroscope means therefrom at a preassigned time after launching of the torpedo, means for associating said gyroscope means with said adjusting means and for connecting said auxiliary source to said first channels at said preassigned time, and means associated with said signal responsive means for a period preceding operation of said transfer means for balancing the steering system for signals received by said hydrophones during said period.

24. A signal responsive system comprising a pair of similar signal translating devices, a pair of similar signal channels each including a respective one of said devices as an input element therefor, control means operable in accordance with the difference between the outputs of said channels, an operating element adapted to be controlled by said control means and normally dissociated therefrom, signal controlled means for associating said operating element with said control means, means actuated in accordance with operation of said control means for adjusting said channels to balance said channels for signals received by said devices, and means for disabling said adjusting means prior to operation of said signal controlled means.

25. A submarine signal responsive system comprising a pair of similar hydrophones, a pair of similar signal channels each including a respective hydrophone as an input element therefor, control means actuated in accordance with the difference between the outputs of said channels, operating means adapted to be controlled by said control means and normally dissociated therefrom, adjusting means normally associated with said control means and actuated in accordance with operation thereof for varying the relative sensitivities of said channels to balance said channels for signals received by said hydrophones, and means for substantially concurrently associating said operating means with said control means and disassociating said adjusting means therefrom.

26. A steering system for a torpedo, comprising a rudder, a signal actuated system including a pair of similar hydrophones mounted symmetrically on opposite sides of the torpedo, a pair of similar signal channels each including a respective hydrophone as an input element therefor and control means actuated in accordance with the difference between the outputs of said channels, a control element for said rudder adapted to be controlled by said control means to effect deflection of said rudder in one direction or the other in accordance with the polarity of the difference between the outputs of said channels, said control element being normally dissociated from said control means, gate means for associating said control element with said control means at a time subsequent to the launching of the torpedo, and means for substantially balancing said control system during a period preceding operation of said gate means, said balancing means comprising a potentiometer resistance connected to both of said channels, means for varying the relative proportions of said resistance included in said channels and reversible means controlled by said control means for actuating said varying means.

27. A steering system for a torpedo, comprising a rudder, a signal actuated system including a pair of similar hydrophones mounted symmetrically on opposite sides of the torpedo, a pair of similar signal channels each including a respective hydrophone as an input element therefor and control means actuated in accordance with the difference between the outputs of said channels, a control element for said rudder adapted to be controlled by said control means to effect deflection of said rudder in one direction or the other in accordance with the

polarity of the difference between the outputs of said channels, said control element being normally dissociated from said control means, gate means for associating said control element with said control means at a time subsequent to the launching of the torpedo, and means for substantially balancing said control system during a period preceding operation of said gate means, said balancing means comprising resistors in the input ends of said channels and means controlled by said control means for varying the relative magnitudes of the resistors in the two channels to establish substantial equality between the outputs of said channels.

28. A steering system in accordance with claim 27 wherein said control means comprises a direct current amplifier biased substantially at cut-off, said system comprising also means for converting the outputs of said channels in combination into a direct current difference signal applied to the input circuit of said amplifier, rudder control means for maintaining the torpedo upon a preset course before operation of said gate means, and means for compensating for mechanical dissymmetries in the torpedo including means actuated by said rudder control means for impressing upon said input circuit a direct current potential of polarity and amplitude determined by the direction of the force effective upon the torpedo due to said dissymmetries.

29. A steering system for a torpedo, comprising a rudder, actuating means for deflecting said rudder in one or the opposite direction, a control circuit for said actuating means effective to determine the direction of deflection of said rudder thereby in accordance with the polarity of the potential appearing across a portion of said circuit, means responsive to signals emanating from a target for establishing across said portion a first component of potential of amplitude and polarity determined by the bearing of the target relative to the torpedo, and gyroscope controlled means for establishing across said portion a second component of potential of polarity determined by the direction of departure of the torpedo from a preset course and of amplitude less than a preassigned value of said first component.

30. A steering system for a torpedo, comprising a rudder, actuating means for deflecting said rudder in one or the opposite direction, a first control circuit for said actuating means, a second control circuit for said actuating means and effective to determine the direction of deflection of said rudder thereby in accordance with the polarity of the potential appearing across a portion of said second control circuit, a first gyroscope controlled means for controlling said first control circuit to maintain the torpedo on a preset course, means responsive to signals emanating from a target for establishing across said portion of said second circuit a first component of potential of amplitude proportional to and polarity determined by the bearing of the target relative to the torpedo, a second gyroscope controlled means for establishing across said portion a second component of potential of polarity determined by the direction of departure of the torpedo from said preset course and of amplitude less than a preassigned value of said first component, said first control circuit normally being associated with said actuating means, and said second control circuit normally being dissociated from said actuating means, and means for dissociating said first control circuit from said actuating means and associating said second control circuit therewith at a prescribed time after launching of the torpedo.

References Cited in the file of this patent

UNITED STATES PATENTS

70	1,121,563	Leon	Dec. 15, 1914
	1,137,222	Leon	Apr. 27, 1915
	1,344,352	Parmelet al.	June 22, 1920
	1,473,149	Hammond	Nov. 6, 1923
	1,588,932	Blair	June 15, 1926
75	1,892,431	Hammond	Dec. 27, 1932