Aug. 9, 1960 T. A. DALY ET AL 2,948,248

STEERING SYSTEM FOR A HOMING TORPEDO

Filed Sept. 24, 1946 3 Sheets-Sheet 1

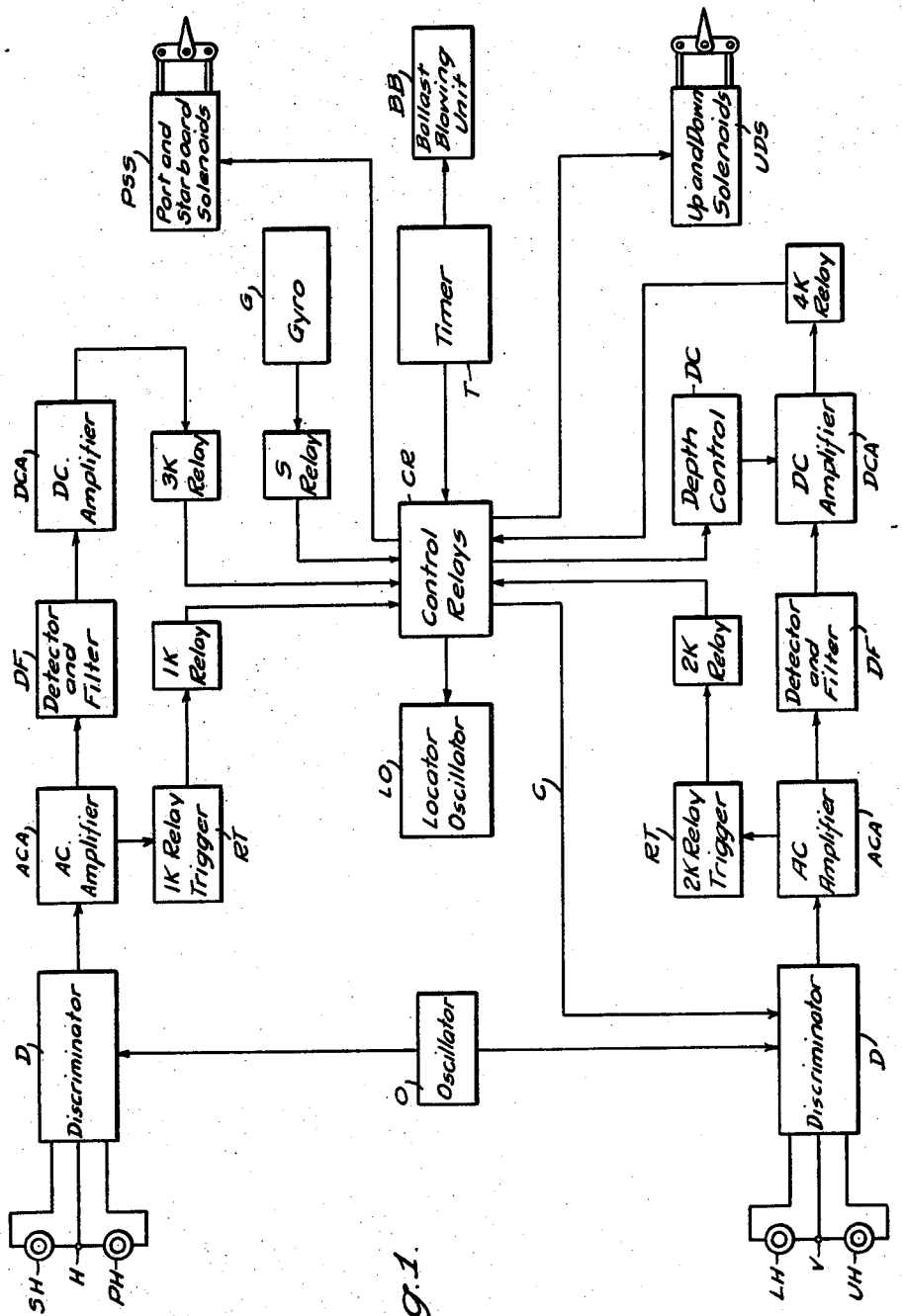


FIG. 1.

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Filed Sept. 24, 1946 3 Sheets-Sheet 2

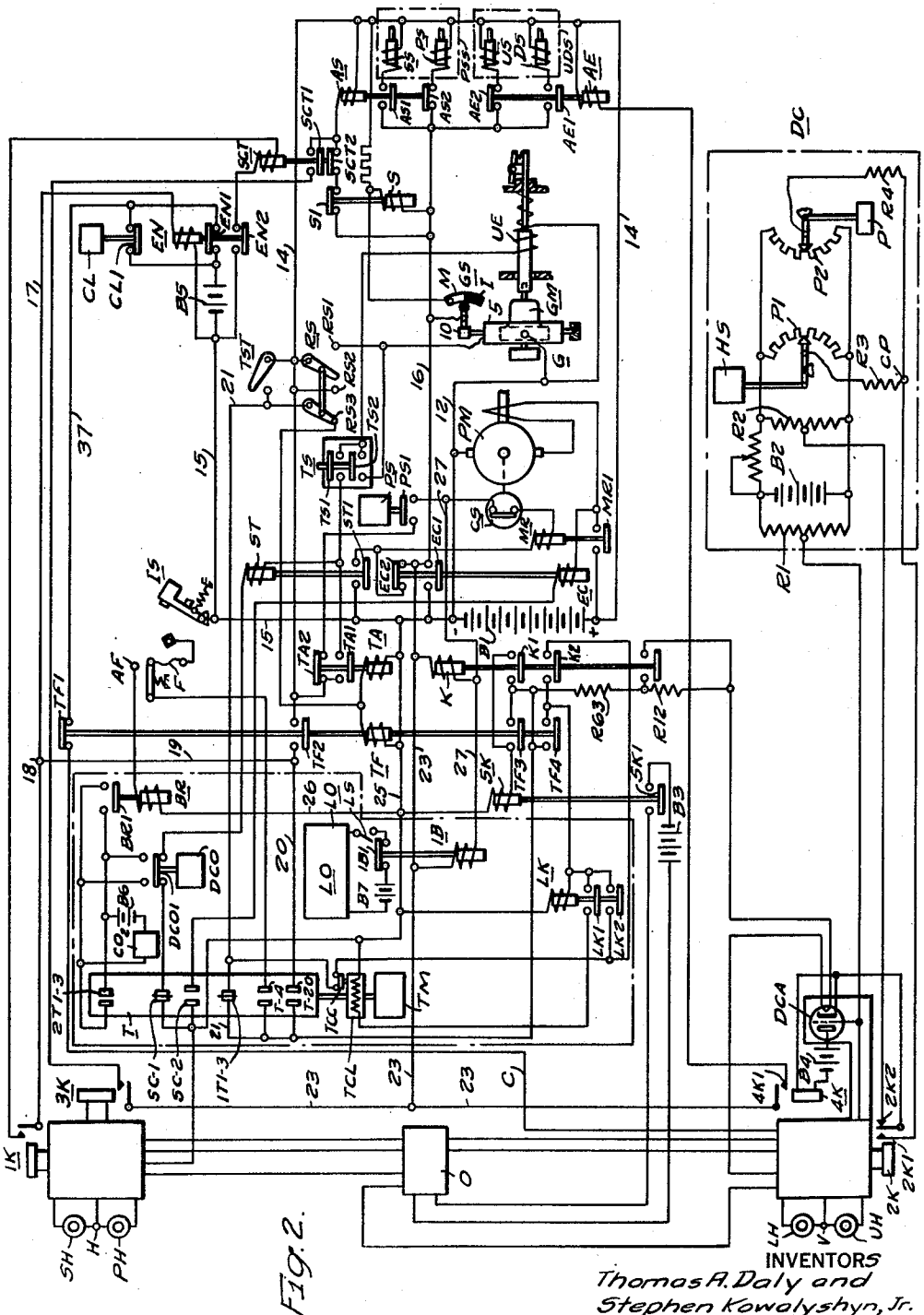


FIG. 2.

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Filed Sept. 24, 1946 3 Sheets-Sheet 3

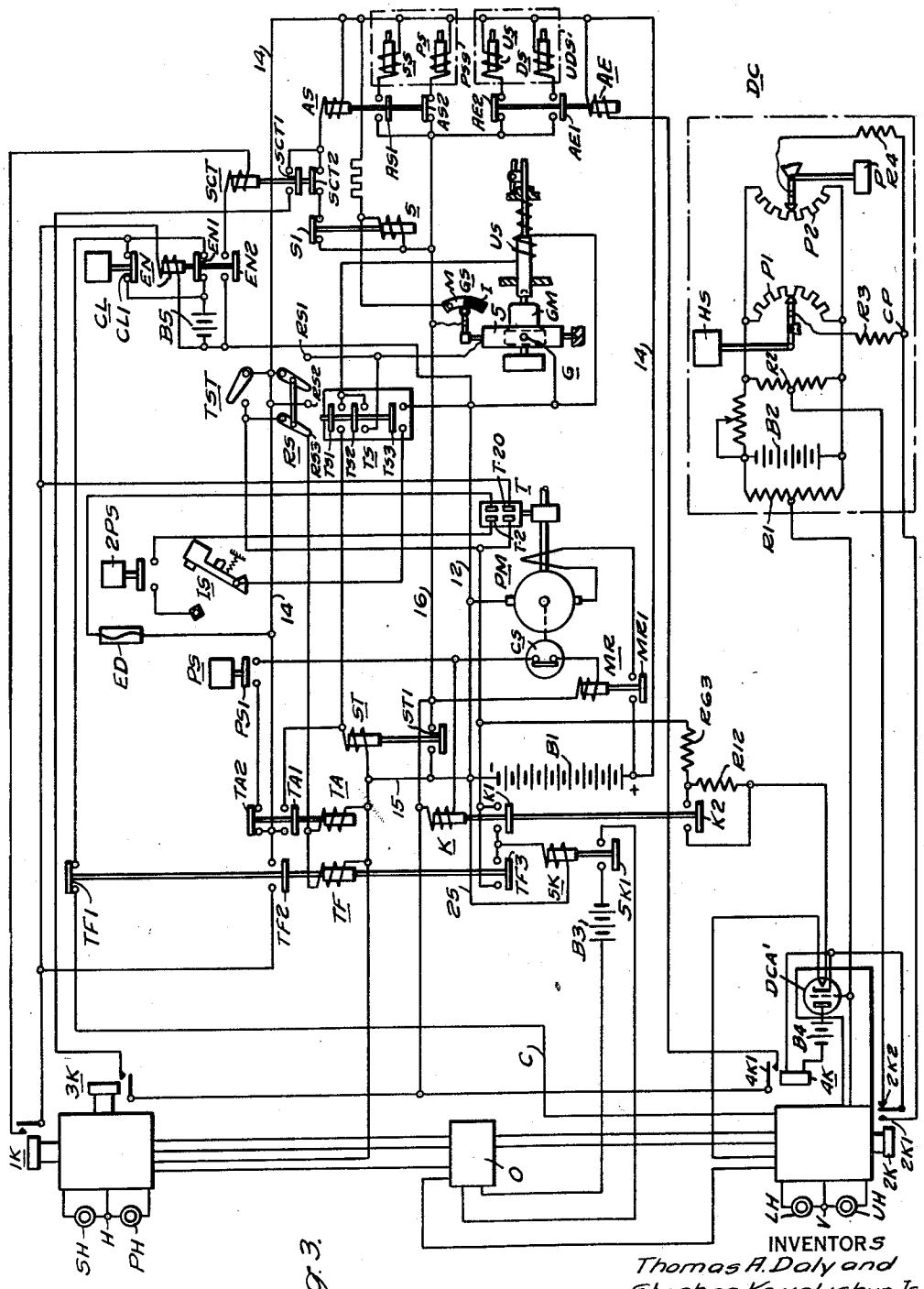


Fig. 3.

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2,948,248

STEERING SYSTEM FOR A HOMING TORPEDO

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Filed Sept. 24, 1946, Ser. No. 699,040

7 Claims. (Cl. 114—21)

This invention relates generally to electrically operated and controlled conveyances, and more particularly to conveyances of the type adapted for operation in a fluid medium.

More in particular, this invention is directed to an all-electric aircraft-launched torpedo having a new and novel system of control.

It has been recognized for some time that torpedoes in which compressed gases are utilized as the energy source either to drive turbines connected to propulsion screws or to be exhausted as a jet, are undesirable for war shot purposes, since the torpedo wake caused by the exhausted gas reveals the approximate location of the submarine from which the torpedo was fired as well as the course of the torpedo. Efforts directed to producing a torpedo leaving no wake have resulted in the development of torpedoes powered by electric motors. This, of course, required the inclusion of a large supply of electrical energy suitable for adequately supplying the electric motor for the duration of the torpedo's run. Usually the source of energy is of the form of a primary or secondary battery.

With electrical power available in the torpedo, the problem of electric power for supplying equipment providing electrical control of the torpedo's movements is minimized. Accordingly, considerable development effort in the accomplishment of this end has been expended. Initially, controls of this type included depth and directional control devices for the torpedo which maintained a selected course and depth of operation once the torpedo was launched. In one control arrangement, a gyroscope which controlled directional rudder actuating solenoids and a pressure and longitudinal tilt responsive apparatus controlling depth rudder actuating solenoids were utilized as the movement controlling elements. Later refinements of this equipment permitted launching of the torpedo in any predetermined direction, by simple presetting of the gyroscope control, the control being such as to cause the torpedo to traverse a predetermined arc and then head towards the intended target.

While such electrical control systems for torpedoes offered measurable improvements over prior art schemes, both in respect to accuracy of control function and reliability, the possibilities of electrical control offered yet more desirable performances in the form of a control providing what may be generally termed automatic tracking of the target by the torpedo.

There are, of course, a number of ways in which electrical equipment may be utilized to detect and effect tracking a target, but probably the simplest, while yet effective, is the piezo-electric crystal generator which will produce pulses of electrical energy in dependence of the forces imposed thereon by vibrations of the fluid medium in which it is immersed, such vibrations being caused by the propulsion screws of conveyances operating in the fluid medium. By properly utilizing the piezo-electric crystal generators or hydrophones as the control elements

in control systems affording control, for example, of a torpedo in horizontal and vertical control planes, the torpedo can be made to follow a path tending always to terminate at the vibration or signal source constituting the target.

One object of this invention is to provide a highly effective and efficient torpedo.

Another object of this invention is to provide a torpedo which is as simple as operational requirements will permit.

A further object of this invention is to provide a torpedo which will automatically track a target.

Yet another object of this invention is to provide a torpedo characterized by the feature of automatic tracking of a target as hereinbefore described, in which, provision is had for preventing the torpedo from responding to the vibrations of its propulsion screw or screws.

Also another object of this invention is to provide an all-electric aircraft-launched torpedo.

Still another object of this invention is to provide a torpedo of the character described which is initially operated for a timed interval according to a predetermined control pattern providing a predetermined direction of movement and depth of operation thereof, which at the end of said timed interval is set for automatic tracking of a target but which yet is controlled according to the original control pattern, in the event the target signal is yet too weak because of target remoteness or other reason, to provide adequate automatic tracking control.

The foregoing statements are merely illustrative of the various aims and objects of this invention. Other objects and advantages will become apparent from a study of the following specification when considered in conjunction with the accompanying drawings, in which:

Figure 1 is a block diagram illustrating the elementary features of this invention;

Fig. 2 is a diagrammatic showing of a torpedo control system for test purposes, embodying the principles of this invention; and

Fig. 3 is a variation of the invention of Fig. 2 affording a control scheme whereby torpedo control for war shot purposes is had.

The science of aerial torpedo warfare as developed with prior types of torpedoes required the torpedo plane to traverse a flight path intercepting the path of the target ship, since, the heading of the torpedo was determined by the heading of the plane. Thus to assure accuracy it was necessary for the torpedo plane to approach the target ship quite closely. To avoid damaging the torpedo at water impact, the air speed at the time of launching is usually lowered to within 200 to 250 knots. This together with the close range of launching and low altitude made the torpedo plane quite vulnerable to enemy fire.

With the torpedo of this invention, this strategy may be changed and the torpedo launched at points from the target approaching the torpedo's maximum range and the torpedo set to follow a course having any desired angular relation with the flight path of the torpedo plane. The torpedo of this invention may thus be launched from safe ranges, caused to pursue a path directed towards the target and when a sufficiently strong target signal is received the torpedo automatically tracks the target along a path tending always to terminate at the target.

The elementary diagram of Fig. 1 illustrates the control arrangement whereby the foregoing desirable functions are accomplished. The control provides two distinct types of directional and depth control for the torpedo. The first type is that which directs the torpedo along a predetermined path at a relatively fixed depth and includes a gyroscope G and depth control unit

DC which are, respectively, the units at which the control stimuli originate for controlling the direction and depth of travel of the torpedo. The second type is the acoustic control which provides automatic tracking control of the torpedo. This control originates at the crystal type hydrophones SH and PH in the horizontal amplifier channel H and the hydrophones LH and UH in the vertical amplifier channel V, the output of the horizontal amplifier channel providing the directional control stimuli and the output of the vertical amplifier channel providing the depth control stimuli.

Solenoids are utilized to actuate the steering and depth control rudders SR and DR, the usual practice being to utilize two solenoids represented by the block PSS for steering, disposed in diametrically opposite relation to exert pulling forces on opposite sides of a steering rudder rocker ring and to utilize two solenoids designated by block UDS, for depth control in a similar manner.

A gyroscope G controls the port and starboard solenoids PSS through a circuit system including relay S controlled by the gyroscope and the control relays CR, whereby either the port or starboard solenoid is energized depending upon the direction of angular displacement of the longitudinal axis of the torpedo in a horizontal plane with respect to the gyroscope spin axis. The depth control DC through the intermediate control elements associated therewith energizes either of the up and down solenoids to provide operation at the proper depth. In accomplishing this the output of depth control unit DC drives the amplifier DCA in the vertical channel, which under the instant conditions when the depth control is active is not energized by the output of detector and filter DF. By way of example, the depth control unit controls the amplifier DCA to cause an output thereof if the torpedo is not sufficiently deep or if too deep to bias the amplifier to cutoff. Control relay 4K in response to this control actuates the up and down solenoids UDS through the control relay unit CR to effect operation at the proper depth. It will be seen from this that the path of the torpedo in both the horizontal and vertical control planes will be approximately sinusoidal because of the hard over to hard over nature of the control.

The electronic acoustic control includes the two amplifying channels H and V. Each channel is controlled by a pair of hydrophones which are physically arranged in diametrically opposite relation on a forward portion of the torpedo hull (not shown). The function of the horizontal and vertical channels insofar as the handling of the hydrophone signals is concerned is identical, hence, a discussion of the horizontal channel will suffice for both.

The signals generated by the hydrophones in the horizontal channel are fed to a discriminator D. The output of the discriminator circuit under the control of oscillator O alternately includes a signal from the respective hydrophones PH and SH. The discriminator output is next passed to the alternating current amplifier ACA where the signals are amplified. From the amplifier ACA the signals are next passed to the detector and filter circuit DF which is constructed and arranged, for example, to pass only the positive portions of the signals of hydrophone PH and only the negative portions of the signals of hydrophone SH. The opposed quantities thus produced are mixed and filtered in circuit DF and the resulting signal or quantity, which is the differential of the rectified and filtered hydrophone signals, is applied to the direct current amplifier DCA. Amplifier DCA is responsive to the magnitude and/or polarity of the quantities applied thereto, and by way of illustration, will pass current only when the polarity of the detector and filter circuit DF is positive. If the detector output is negative, the amplifier DCA is biased to cutoff and its output is zero. Thus, further, by way of illustration, if the output of hydrophone SH predominates,

the amplifier DCA will pass current which is utilized to energize control relay 3K. If the signal from hydrophone PH predominates, the output of amplifier DCA is zero and relay 3K remains deenergized. Relay 3K is utilized in each of its two positions, through the control relays CR, to energize alternately the port and starboard solenoids designated by block PSS to operate the steering rudders between their two extremes of movement. Analogous considerations apply to the vertical channel V containing the upper and lower hydrophones respectively designated UH and LH.

A ballast blowing unit BB is utilized in test torpedoes and is set off by a timer T at the end of the test run. Its function is to exhaust the liquid ballast substituted in test torpedoes for the torpex-loaded war head, to render the torpedo buoyant, thus facilitating recovery. Similarly, a locator oscillator LO is energized by the timer through control relay circuits when the test run is completed. This unit by means of a diaphragm in the torpedo hull transmits vibrations to the fluid medium which may be picked up with suitable direction finding equipment.

The foregoing discussion covers the control of the torpedo afforded by the acoustic and gyro control devices in the horizontal plane and the acoustic and depth control devices in the vertical plane. These two controls do not operate together, that is, either the depth control unit DC together with the gyro control the torpedo, or the acoustic system controls the torpedo. The operating sequence of these two controls is established by the timer T, which through the medium of certain of the relays in the control relay unit CR connects the gyro G along with its companion depth control unit DC to the respective rudder solenoids and, at the same time, prevents the acoustic system from exerting its influence on the rudder solenoids. After a certain timed interval, circuits are established by the timer through the control relays CR to enable transfer to acoustic control but only if the acoustic signals are sufficiently strong to properly control the torpedo.

With the control afforded by this invention, the torpedo may be launched at any point from the target up to its maximum range. During the first timed interval, the torpedo will follow a course determined by the flight path of the launching plane and maintained by the gyro steering control while the depth control device regulates operation at the proper depth. The range at which launching occurs may be considerably beyond the effective range of the acoustic control. When the first time interval has elapsed, circuits are established by which a switch-over of torpedo control to the acoustic system may occur. If the acoustic signal produced by the target is sufficiently strong, the torpedo under the influence of the acoustic control immediately begins tracking the source of the signal, the average position of the torpedo being repeatedly corrected in dependence of changes in position of the source of the acoustic signal or of the torpedo with respect to the signal source until contact with that source is had. If the acoustic signal, once the switch-over connections from the initial control to acoustic control are set up, is yet too weak to adequately control the torpedo, the torpedo proceeds under the influence of the gyro and depth control until the acoustic signal reaches the required level. Thereafter, acoustic tracking occurs as explained above.

This function is achieved as follows: The discriminator circuit D in the vertical channel is biased to cutoff by a control potential supplied through the control relays CR over conductor C. Hence, the output of the detector and filter circuit DF in the vertical channel is zero and no control of the associated direct current amplifier DCA from the vertical acoustic control source occurs. In the horizontal channel, the control effect of port and starboard solenoid control relay 3K is rendered inactive by open circuits through the control relays CR, the control relays being initially set up to complete circuits for the

control of the rudder solenoids from the gyro G and the depth control unit DC. At launching the gyro and depth control units G and DC, respectively, direct the torpedo along the selected path and maintain the proper operating depth. After a timed interval timer T establishes connections to cause the control relays CR to set up the switch-over circuits. Assuming a sufficiently strong acoustic signal, the outputs of the alternating current amplifiers in the respective channels are sufficiently high to effect operation of the associated relay trigger RT, causing the relays 1K and 2K to operate and complete the switch-over connections. Relay 1K causes the setup of final circuits for relay 3K to control the port and starboard solenoids at PSS while relay 2K, in effect, disconnects the depth control unit DC from the direct current amplifier in the vertical channel and permits the control of that amplifier from the vertical acoustic signals. It will be noted that the relay triggers RT are ineffective until required acoustic signal levels are reached. Hence, acoustic control after the mentioned initial timed interval does not occur if the acoustic signal level is not sufficiently high. Thus, at no time is the torpedo under the influence of inadequate control.

The discussion hereinbefore presented has been made primarily to set forth the requirements, and considerations involved in the design and operation of aerial torpedoes and to set forth in a general way the manner in which this problem is solved by the control scheme of this invention. Further, while the discussion has been directed to the entire control scheme, it has been the intention to cover the acoustic control portion thereof in sufficient detail that other elements of the control may be treated specifically and their place in the system readily understood from the previous comments concerning Fig. 1. None of the acoustic control circuits as the discriminators D, the alternating current amplifiers ACA, etc., have been detailed, since, it is felt that the design of such elements, which may be conventional, is well within the scope of one skilled in the art.

A detailed showing of the control system for a test model torpedo appears in Fig. 2. In this embodiment, the horizontal and vertical acoustic circuits have been lumped together each in a single block to simplify the illustration. The propulsion motor which drives the torpedo propellers (not shown) is of the series type and is connected in a series loop including the battery B1, by the contacts MR1 of the motor relay MR. This motor is protected against overspeeding by a centrifugal switch CS having normally closed contacts arranged in series with the coil of relay MR.

The gyroscope G which controls the port and starboard solenoids PS nad SS is provided with a small motor GM carrying a gyro wheel on the overhanging end of the armature shaft. This assembly of motor and wheel is pivotally carried at its center of gravity in gimbal rings 5 providing freedom of movement about the torque and precession axes and is supplied with energizing current through conductors passing through the gimbal axes. A protruding rod on the aft end of the gyro motor housing engages a mating hole or other suitable attachment in the end of a plunger forming part of the unlocking electromagnet UE. In this position, the gyroscope is caged with the spin axis thereof paralleling the longitudinal axis of the torpedo. An arm 10 secured with respect to the torque axis of the gyroscope carries a small roller at the extremity thereof which is in contact with and sweeps an arcuate segment comprised of an insulating portion I and a conducting portion of metal M, the assembly forming the gyro compass switch GS. The arcuate segment is secured with respect to the torpedo body and, hence, moves therewith, while the contact arm 10 being secured to the gyroscope tends to maintain a fixed angular position in space. As a consequence, angular displacement of the torpedo in the horizontal plane effects relative movement between the arcuate segment and the arm 10, indicating a departure of the torpedo from the preselected course. While not specifically illustrated, it is obvious that any predetermined angular relation between the arcuate segment and the contact arm 10 may be established prior to launching, in which case, the torpedo will circle until the desired heading is achieved. Gyroscope G is energized in a circuit across battery B1 including conductor 12, the gyroscope motor GM, contact RS1 of the ready switch RS and conductor 14 to the opposite side of battery B1. Unlocking electromagnet UE is energized in a circuit branching from conductor 12, extending through contacts TS2 of trigger switch TS and returning to the battery B1 through contact RS1 and conductor 14.

As previously generally described, the gyroscope G controls the port and starboard solenoids PS and SS through the relay S and certain of the control relays. Power for operating the solenoids is supplied over conductor 16 which connects with the negative side of battery B1 through a set of normally closed contacts EC2 of extended control relay EC and contacts ST1 of starting relay ST. The other end of conductor 16 branches through the contact assembly including contacts AS1 and AS2 of auxiliary steering relay AS. Contacts AS1 and AS2 are respectively disposed in series with the coils of the starboard and port solenoids SS and PS which, in turn, connect to conductor 14 extending to the positive terminal of the battery B1. As illustrated, the auxiliary steering relay AS is deenergized and the contacts AS2 thereof closed which, assuming contacts ST1 of the starting relay ST are closed, completes a circuit energizing the port solenoid and initially applying port rudder. Energization of relay AS closes contacts AS1 and opens contacts AS2 transferring energization from solenoid PS to solenoid SS and applying starboard rudder.

Auxiliary steering relay AS is selectively controlled by the contacts S1 of the gyro actuated relay S or the relay 3K of the horizontal acoustic circuit depending upon the position of the steering control transfer relay SCT. In the deenergized position of this relay shown, contacts SCT2 are closed connecting the coil of auxiliary steering relay AS between power conductors 16 and 14 through contacts S1 of relay S controlled by the gyro compass switch GS, the coil of relay S being connected between conductors 16 and 14 and periodically shunted by movement of contact arm 10 over the metal conducting segment M of the gyro switch to effect deenergization thereof.

Steering control transfer relay SCT is controlled by the enabler relay EN, the operation of relay EN determining the minimum time at which switch-over from gyro and depth control to acoustic control may occur. To this end, the coil of enabler relay EN is connected in a circuit with the time T including the power supply conductor 15 extending from the negative terminal of the battery B1, the coil of relay EN, conductor 17 to junction 18, conductors 19 and 20, contact T–20 of timer T, conductor 21 and thence through either the test switch TST or contact RS2 of the ready switch RS to conductor 14 and the positive side of the battery. Still further in the prevention of premature switch-over to acoustic control, contacts EN1 of the enabler relay which are normally closed, complete the biasing circuit applying the biasing potential to the discriminator section of the vertical acoustic channel biasing this circuit to cut-off as previously explained. This circuit may be traced from the battery B5, through the contacts EN1, the conductor 37, the normally closed contacts TF1 of test relay TF to conductor C and the vertical acoustic control V. Ceiling switch CL is provided to prevent switchover to acoustic control in the event the torpedo is not running at proper depth. This switch is bellows actuated and the contacts CL1 thereof shunt enabler relay contacts EN1. These contacts remain closed if the torpedo is not sufficiently deep and maintain the vertical hydrostat and pendulum control.

The depth control DC, which during the first interval of time controls the depth rudders, incorporates a potentiometer system including potentiometers P1 and P2 supplied by battery B2. Potentiometer P1 is controlled by the pressure responsive hydrostat HS, which may be a Sylphon bellows, and potentiometer P2 is controlled by a pendulum P arranged about a pivot disposed transversely of the torpedo hull (not shown). In general, the pendulum introduces a control into the potentiometer system of a nature to modify the function or effect of the hydrostat in the system tending always to prevent too rapid rates of diving or rising of the torpedo, it being assumed that in operation the degree of angular tilt of the torpedo longitudinally is an indication of the rate of climbing or diving. Each of the variable taps of the potentiometers P1 and P2 are connected in circuit with a stiffness adjusting resistor R3 and R4, respectively, and the movable tap circuits are connected to a common junction herein referred to as the control point CP. This control point during the initial timed interval of torpedo operation is connected to the cathode of the direct current amplifier tube DCA through the contacts 2K1 of relay 2K, the relay being energized during the said initial timed interval. When relay 2K is deenergized, the contacts 2K2 connect the cathode of tube DCA to a tap of the resistor R2. The grid of the direct current amplifier is connected to a tap of resistor R1 also supplied by the battery B2 in the depth control circuit, while the plate of this tube is connected to supply battery B4 and the tube circuit is completed through the coil of relay 4K controlled by the tube. It will be apparent that the voltage of control point CP is determined by the setting of the variable taps on the potentiometers P1 and P2. Assuming the stiffness adjusting resistors R3 and R4 to be of equal values, the voltage at point CP will be roughly the midpoint of the voltage across the variable potentiometer taps. As a consequence, the control potential applied to the cathode of the direct current amplifier DCA is varied from zero voltage at equilibrium to higher voltages depending upon the setting of the potentiometer taps. Thus, it will be seen that a variable voltage is provided by the depth control unit DC and that by properly setting the amplifier DCA to respond to this control voltage, the relay 4K may be alternately energized and deenergized.

As described in connection with Fig. 1, relay 4K through the control relays CR controls the depth rudders of the torpedo. To this end, the coil of auxiliary elevation relay AE is connected in circuit with the contacts 4K1 of relay 4K. This circuit is supplied with power from the battery B1 over conductors 14 and 23, conductor 23 connecting with the negative side of the battery through contacts EC2 and ST1 and thence through conductor 15. The up and down solenoids US and DS, respectively, which actuate the depth rudders are connected in a parallel circuit across conductors 14 and 16 and the contacts AE1 and AE2 of the auxiliary elevation relay are respectively disposed in circuit with the solenoids US and DS. In its deenergized position, relay AE closes the contacts AE2 thereof and when energized, contacts AE1 are closed. Thus, the control quantities produced at the depth control unit are utilized through the amplifier DCA and relay 4K responsive thereto, to control the auxiliary elevation relay AE in a manner to actuate the up and down solenoids and depth rudders attached thereto to maintain the torpedo at the desired depth. The control in the vertical plane as afforded by the operation of the depth rudders, like that in the horizontal plane, is hard over to hard over.

Assuming for this discussion that the contacts 2K1 are closed and that the torpedo is in a horizontal position above its pre-established ceiling, the hydrostat HS will have expanded and the movable tap on potentiometer P1 moved to some position along the upper half of P1, the potential appearing at control point CP is then applied

to the cathode of direct current amplifier tube DCA. Relay 4K1 is energized picking up relay AE and energizing the down solenoid DS. The torpedo tilts downwardly to correct its position and the pendulum P tending to remain vertical moves in a direction to balance the tap voltage on P2 against that of P1. Similarly the hydrostat now being compressed with increasing depth moves in a direction on P1 to balance the P1 tap voltage against the P2 tap voltage. At a point approaching zero voltage differential between the tap voltages, tube DCA ceases to conduct and auxiliary elevation relay AE drops out. Contacts AE2 energize the up solenoid US and the torpedo axis tilts upwardly to correct its elevation. The pendulum now moves in an opposite direction and as previously, the tap on P2 again moves in a direction tending to balance the tap voltage on P2 against that of P1. Similarly, as the depth decreases and the pressure decreases, the hydrostat expands and the tap on P1 moves in a direction to balance the tap voltage on P1 against that of P2. Thus, as is the case in the horizontal plane, the path of the torpedo in the vertical plane is approximately sinusoidal about the predetermined operating depth.

As a general rule, in devices which depend for detonation upon contact with the target, an inertia mechanism is employed to establish circuits or to effect impact with a detonator, to ignite the explosive charge. In the present test torpedo such a mechanism designated IS is employed but for the purpose of blowing the liquid ballast and rendering the torpedo buoyant. To this end, the inertia switch IS is connected in a circuit from the negative side of battery B1 over conductor 15 including the fuse F, alarm fuse switch AF, which switch is spring biased to closed position but held open by the fuse F, contacts T–4 of timer T, thence through the normally closed contacts 1T1–3 of the timer over conductor 21 and switch RS, to conductor 14 and the positive side of battery B1. When inertia switch IS operates, the fuse F is blown and the alarm fuse switch AF closes, establishing an energizing circuit for the ballast control relay BR. This circuit begins at the negative side of battery B1 and conductor 15 and extends over conductors 25 and 26 to the coil of relay BR, thence through alarm fuse switch AF to the timer contacts T–4, 1T1–3 and then along conductor 21 through the switch RS to conductor 14 and the positive side of battery B1.

When the ballast relay BR is energized, the contacts BR1 thereof close and complete the battery circuit for opening the valve of the carbon dioxide bottle designated CO_2. Physically, the CO_2 bottle communicates with the liquid ballast chamber of the torpedo. When the gas is admitted to that chamber, the ballast is exhausted through one-way pressure valves and the torpedo is made buoyant.

There are two other ways in which the CO_2 bottle may be discharged. The first of these involves a depth cutout switch DCO, which may be of the bellows type. If the torpedo should function improperly and proceed to a depth where damage due to fluid pressure is eminent, the depth cutout moves sufficiently that its contacts DCO1 close the battery circuit and the valve on the CO_2 bottle is opened causing the torpedo to surface. The second of these two mentioned methods involves the normally open contact 2T1–3 of the timer T which closes at the end of the torpedo's run. Like the contacts DCO1 and BR1, this contact closes the battery circuit for the valve on the CO_2 bottle.

The locator oscillator LO which, as previously explained, transmits pulses to the surrounding fluid medium to aid in location, is supplied by its battery B7 arranged in circuit with the contacts 1B1 of relay 1B. Relay 1B is energized in a circuit extending from the positive side of the battery B1 over conductor 14 through contacts TA2 of test relay TA, through the contacts PS1 of pressure switch PS, thence over conductor 27 to the coil of relay 1B. From the coil of relay 1B this circuit con-

tinues over conductor 23 through contacts EC2 of extended control relay EC to contacts ST1 of the start relay and the circuit is completed over conductor 15 to the negative terminal of battery B1. The oscilaltor circuit includes a switch LS which must be thrown prior to launching to complete the circuit. Thus prior to launching, the relay 1B is deenergized and assuming switch LS closed, the oscillator is operating. When the torpedo enters the water, pressure switch PS closes its contacts PS1 and assuming contacts ST1 closed at the moment the relay 1B is energized and the oscillator circuit is opened. After the operation cycle of the torpedo is completed, relay ST drops out opening contacts ST1 and deenergizing relay 1B, the oscillator is again set in operation and the locating signals transmitted at the termination of the torpedo's run.

For the test torpedo the operating sequence is controlled by the timer T. This is a device having a plurality of cam-actuated or drum type contacts driven by a spring motor TM. Intermediate the timer motor and contact assembly is disposed an electrically actuated clutch TCL which engages the timer motor drive shaft with the contact assembly. Energization of the timer clutch is controlled by the timer auxiliary relay LK which, in turn, is controlled by auxiliary relay K, the relay K also controlling the heater circuits for the various tubes in the system. Relay K is energized in a circuit beginning at the positive side of battery B1 and conductor 14 extending through contacts TA2, pressure switch contacts PS1, conductor 27, through the coil of relay K to conductor 23, thence through contacts EC2 and ST1 to conductor 15 and the negative side of the battery. When relay K picks up, relay LK is energized in a circuit extending from the positive side of battery B1 over conductor 14, through either of the ready or test switches RS and TST, respectively, conductor 21, timer clutch contact TCC, contacts K2, the coil of relay LK and conductor 25 to the negative side of battery B1. Closure of contacts LK1 and LK2, of which contacts LK2 parallel contacts K2 tending to maintain the circuit for the coil of LK, while contacts LK1 are in series with the coils of the timer clutch, completes the energizing circuit for the coil of the timer clutch. This circuit is traceable from positive conductor 14 through the test or ready switches TST and RS, conductor 21, timer clutch contacts TCC, contacts LK2 and LK1, the coil of the timer clutch TCL, conductor 25 and negative conductor 15. After the adjustable preset time has run off and the torpedo has completed its test run, the clutch contacts TCC open deenergizing the clutch coil and the relay LK, in order to prevent the timer from recycling.

Relay K also controls the relay 5K which is utilized to connect the plate and grid supply battery B3 to the acoustic control system.

Extended control relay EC is provided primarily as a precautionary measure to obviate uncontrolled operation of the torpedo in the event the motor contactor MR should weld or for other reason remain closed after deenergization. This relay is energized by the normally open timer contacts SC–2 at the end of the timing cycle, should motor contactor MR remain closed, and the contacts EC1 thereof directly connect the power supply conductor 16, forming part of the supply circuit for the gyro G, the steering and depth solenoids associated therewith, to the battery B1. The acoustic system is deenergized when normally closed timer contact 1T1–3 drops out and deenergizes relays K and 5K, opening the plate, grid and heater supplies.

Means are provided for testing the various control components of the torpedo without running the torpedo propulsion motor. The arrangement provides for the testing of the acoustic control operation, depth hydrostat and pendulum setting and for making a sequence test. To this end, ready switch RS is provided with a contact RS3 which is made in the off position of the switch (the position indicated in the drawing) and which is arranged in series with the test switch TST between power supply conductor 14 and the coils of relays TA and TF. The other side of each of the coils of relays TA and TF are connected to the negative side of battery B1. Thus, closure of the test switch TST picks up test relays TA and TF. Contacts TA2 open the circuit for the motor relay MR, while contacts TA1 connect the coil or start relay ST to the conductor 14 and complete its energizing circuit across the battery B1 through contacts DCO1, SC–1 and conductors 25 and 15. Relays K, 1B and MR remain deenergized since contacts TA2 are now open. With relay K deenergized, contacts K3 remain open, inserting a resistance R12 in series with all tube heaters to protect them against the higher voltage of batery B1 when the propulsion motor is not energized. Relay TF now assumes the function of relay K in certain respects. Contacts TF1 open and unblock the discriminator circuits of the vertical acousitc channel. Contacts TF2 close connecting conductors 14 and 20 supplying power through timer contacts T–4 and to conductor 19. Conductor 19 in turn supplies the enabler relay EN which picks up and at its contacts EN2 establishes a partial energizing circuit for the coil of steering control transfer relay SCT, which transfer relay is controlled through the contacts of relay 1K energized upon the application of sufficiently strong acoustic signals as previously described. Contacts TF3 replace contacts K1 in controlling relay 5K and contacts TF4 replace contacts K2 in controlling timer auxiliary relay LK. Sequence tests may, therefore, be made on the controlling circuits by closing the test switch TST and operating the trigger switch TS.

A better understanding of this embodiment of the present invention will probably be had by following the operating sequence of the test torpedo circuit during a test run. For such a test a suitable signal generator simulating the target is submerged in the water. When the target plane approaches within torpedo range of the target, the pilot throws the ready switch so that contacts RS1 and RS2 are engaged. This starts the gyro motor and energizes the tube heater circuit, approximately 30 seconds being required for proper gyro acceleration and adequate tube heating. When the launching point is reached, the torpedo is released and a lanyard attached to the aircraft closes the trigger switch TS. Contacts TS2 energize the unlocking electromagnet UE which uncages the gyro G while the starting relay ST is energized in the previously described circuit including contacts RS1, TS1, TS2, DCO1 and the normally closed timer contacts SC–1 supplying power through the extended control relay contacts EC2 to the rudder solenoids and associated control and completing partial circuits for relays MR, and 1B and K. Upon entering of the torpedo into the water, pressure switch PS closes and its contacts PS1 complete the final link in the previously traced circuits for the motor relay MR starting the propulsion motor and for energizing relays K and 1B. Relay K picks up relays 5K and LK, 5K supplying power to the electronic acoustic control and LK energizing the timer clutch TCL as hereinbefore described. The timer now begins to operate. Contacts T–4 which, for example, may be set for operation 4 seconds after timer operation begins are open at water entrance and render the inertia switch circuit insensitive to inertia switch operation should such operation occur upon entrance of the torpedo into the water. When closed these contacts set up the inertia switch circuit, rendering this circuit sensitive to target impact. Meanwhile, the torpedo proceeds under its own propulsion and is controlled by the gyroscope and depth control DC. At the end of say, about 20 seconds, contacts T–20 close energizing enabler relay EN. Contacts EN1 now unblock the vertical acoustic discriminator and contacts EN2 establish a partial energizing circuit for steering control transfer relay to be completed by relay IK. Meanwhile, the torpedo proceeds under the influence of gyro and hy-

drostat-pendulum control. As the torpedo approaches the target vicinity, the signals from the signal generator are sufficiently strong to operate the relay triggers RT (see Fig. 1) effecting a control of relays 1K and 2K such that the horizontal and vertical acoustic channels now control the torpedo rudders. Thereafter, the torpedo is directed along a path terminating at the signal source. Upon impact with the simulated target, the inertia switch closes blowing fuse F and closing alarm fuse switch AF. Ballast relay BR is then energized and the torpedo's liquid ballast chamber blown. At the end of, say, 1 to 3 minutes, contacts 1T1–3 and 2T1–3 may be set for operation. Normally open contacts 2T1–3 then close and if the torpedo's liquid ballast is not yet blown cause the CO_2 bottle to be discharged. Normally closed contacts 1T1–3 open, deenergizing relays BR, 5K, EN and SCT. About 10 seconds thereafter the normally open contacts SC–2 may be set to close and establish a circuit for extended control relay EC through motor relay contacts MR1. Normally closed contacts SC–1 open dropping out the starting relay ST which, in turn, deenergizes the power supply circuits for the various rudder controls and the motor relay MR to stop the propulsion motor. Should the motor relay MR fail to drop out and the propulsion motor remain energized, extended control relay EC at its contacts EC1 maintains the control power.

The embodiment of the invention illustrated in Fig. 3 for a war-shot torpedo is essentially the same as that of Fig. 2 except for the elimination of the test circuits including the spring-driven timer. The timer T utilized in the war-shot torpedo is more conveniently driven by the propulsion shaft and is provided with a pair of normally open contacts T–20 and T–2. Contacts T–20 like those of the test torpedo control may be set to close about 20 seconds after the propulsion motor starts. Contacts T–2 may be set to close after the torpedo has proceeded approximately 200 yards in the water. It will be understood that control system elements of this embodiment bearing reference characters like those of Fig. 2 are similar in construction and perform similar control functions to those of Fig. 2. Hence, a detailed discussion of these system elements is deemed unnecessary. The electrical detonator circuit in principle is similar to the ballast-blowing circuit of Fig. 2, additional precautions having been taken, however, to obviate premature detonation of the war head. This circuit extends from positive conductor 14 through the exploder or electrical detonator ED, timer contacts T–2, pressure switch 2PS, inertia switch IS, trigger switch contacts TS3 and, thence, over conductors 12 and 15 to the negative side of the battery B1. Switches T2, 2PS, IS and contacts TS3 are all open when the torpedo is being handled. Trigger switch TS is not actuated until the torpedo is released from the launching plane at which time a lanyard attached to the aircraft causes its operation. Pressure switch 2PS is open in air and does not close until submergence of the torpedo. Contacts T–2 are delayed in closing until 200 yards of water travel have occurred. Thus, at water impact should the inertia switch close due to the high rate of deceleration, the electric detonator is yet open circuited through the timer contacts T–2 and premature detonation prevented.

The foregoing disclosure and the showing made in the drawings are merely illustrative of this invention and are not to be interpreted in a limiting sense. The only limitations are to be determined from the scope of the appended claims.

We claim as our invention:

1. In a conveyance adapted for operation in a fluid medium and having steering and elevating rudders for control thereof in the medium, the combination of, electroresponsive steering and elevating means, respectively, for controlling the steering and elevating rudders, gyroscope actuated control means for producing electrical quantities in dependence of a departure in angular relation from a prearranged angular relation of said gyroscope control means and conveyance, depth responsive control means for producing electrical quantities indicative of a departure in depth and change in angular position of operation of said conveyance from a prearranged depth, directional control means for producing electrical quantities in dependence of the directional disposition of a target with respect to said conveyance, elevational control means for producing electrical quantities in dependence of the elevational disposition of said target with respect to said conveyance, and timing means constructed and arranged to first apply the electrical quantities produced by said gyroscope actuated control means and said depth control means, respectively, to said steering and elevating control means, and thereafter to remove said electrical quantities of said gyroscope actuated control means and said depth control means and to apply the electrical quantities produced by said directional and elevational control means, respectively, to said steering and elevating control means.

2. In a conveyance adapted for operation in a fluid medium and having steering and elevating rudders for control thereof in the medium, the combination of, electroresponsive steering and elevating means, respectively, for controlling the steering and elevating rudders, gyroscope actuated control means for producing electrical quantities in dependence of a departure in angular relation from a prearranged angular relation of said gyroscope control means and conveyance, depth responsive control means for producing electrical quantities indicative of a departure in depth of operation or change in angular position of said conveyance from a prearranged depth, directional control means for producing electrical quantities in dependence of the directional disposition of a target with respect to said conveyance, elevational control means for producing electrical quantities in dependence of the elevational disposition of a target with respect to said conveyance, a steering relay for energizing and deenergizing said electroresponsive steering means, an elevation relay for energizing and deenergizing said electroresponsive elevating means, means for controlling said steering relay in dependence of the electrical quantities produced by said gyroscope actuated control means, means for controlling said elevating relay in dependence of the electrical quantities produced by said depth responsive control means, timing means, a transfer control relay for transferring the control of said steering relay from said gyroscope actuated control means to said directional control means, an enabler relay for controlling said transfer control relay, means responsive to a predetermined minimum value of the electrical quantities produced by said directional control means and operable in conjunction with said timing means for controlling said enabler relay, means responsive to the operation of said enabler relay for effecting operation of said elevational control means, and means responsive to a predetermined minimum value of the electrical quantities produced by said elevational control means for transferring the control of said elevation relay from said depth responsive control means to said elevational control means.

3. In a test torpedo having a liquid ballast chamber, the combination of, a source of electrical energy, an electric propulsion motor, circuit means including a pressure responsive switch and a centrifugal switch connecting said propulsion motor to said source, said pressure switch preventing connection of said motor to said source until said torpedo has entered the water, said centrifugal switch opening upon overspeeding of said motor to disconnect said motor from said source, electrical steering control means for said torpedo, gyroscope actuated control means for controlling the energization of said electrical steering control means, directional control means operable in dependence of the directional disposition of a target with respect to said torpedo for controlling the energization of said electrical steering means, electrical elevating con-

trol means for said torpedo, depth responsive control means for controlling the energization of said electrical elevating control means, elevational control means operable in dependence of the elevational disposition of said target with respect to said torpedo for controlling the energization of said electrical elevating control means, timing means for sequentially arranging first said gyroscope actuated control means and said depth responsive control means to control the energizations, respectively, of said electrical steering control means and said electrical elevating control means and second to arrange said directional control means and elevational control means, respectively, to control said electrical steering control means and said electrical elevating control means, means responsive to said timing means for evacuating the liquid ballast chamber of said torpedo, means responsive to said timing means for deenergizing said propulsion motor, and means for effecting vibrations in the water for aiding in the location of said torpedo.

4. In a conveyance adapted for operation in a fluid medium and having steering and elevating rudders for control thereof in the medium, the combination of, gyroscope means and depth responsive control means, respectively, for controlling said steering and elevating rudders, a pair of electrical systems, one for controlling the steering rudders and one for controlling the elevating rudders, each responsive to signals in said fluid medium indicative of a course said conveyance is to traverse, means for first utilizing the gyroscope means and the depth responsive control means to first control said conveyance, and secondly for utilizing said pair of electrical systems for controlling said conveyance, and means for transferring the control of said conveyance back from said electrical systems to said gyroscope and depth responsive control means when a prearranged operating level in said fluid medium is exceeded.

5. In a control for an aerial torpedo, the combination of electroresponsive steering means for the torpedo, electroresponsive elevating means for the torpedo, gyroscope controlled electrical means for producing electrical quantities for energizing the electroresponsive steering means, means responsive to fluid pressure and the elevation angle of the torpedo for producing electrical quantities for energizing the electroresponsive elevating means, first acoustic responsive means for producing electrical quantities for energizing the electroresponsive steering means, second acoustic responsive means for producing electrical quantities for energizing the electroresponsive elevating means, means for first utilizing the gyroscope controlled electrical means and the means responsive to fluid pressure and elevation angle of the torpedo for controlling, respectively, the electroresponsive steering means and electroresponsive elevating means, and thereafter utilizing said first and second acoustic responsive means, respectively, for controlling the electroresponsive steering means and the electroresponsive elevating means, an electric propulsion motor for said torpedo, means for supplying electrical energy to said propulsion motor, means for partially establishing energizing circuits for said propulsion motor upon launching of said torpedo, and means responsive to fluid pressure for completing said energizing circuits.

6. Apparatus as set forth in claim 5 and in addition means for establishing energizing circuits for the gyroscope controlled electrical means, the means responsive to fluid pressure and elevation angle of the torpedo and the first and second acoustic means, prior to launching of said torpedo.

7. In a system of elevation control for a conveyance operable in a fluid medium and having elevation control means, the combination of, electromagnetic means for operating said elevation control means, means for supplying electrical energy to said electromagnetic control means, pressure responsive control means for controlling the application of electrical energy to said electromagnetic means, an electrical elevation control system, responsive to signals in said fluid medium indicative of a position in elevation said conveyance is to seek, said electrical elevation control system controlling the application of electrical energy to said electromagnetic means independently of said pressure responsive control means, timing means, switching means normally rendering said electrical elevation control system inoperative and responsive to said timing means for rendering said electrical elevation control system operative, and second switching means normally connecting said pressure responsive means to control the application of electrical energy to said electromagnetic means and responsive to said electrical elevation control system for transferring the control of said electromagnetic means from said pressure responsive control means to said electrical elevation control system.

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