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ACOUSTIC DEPTH TORPEDO

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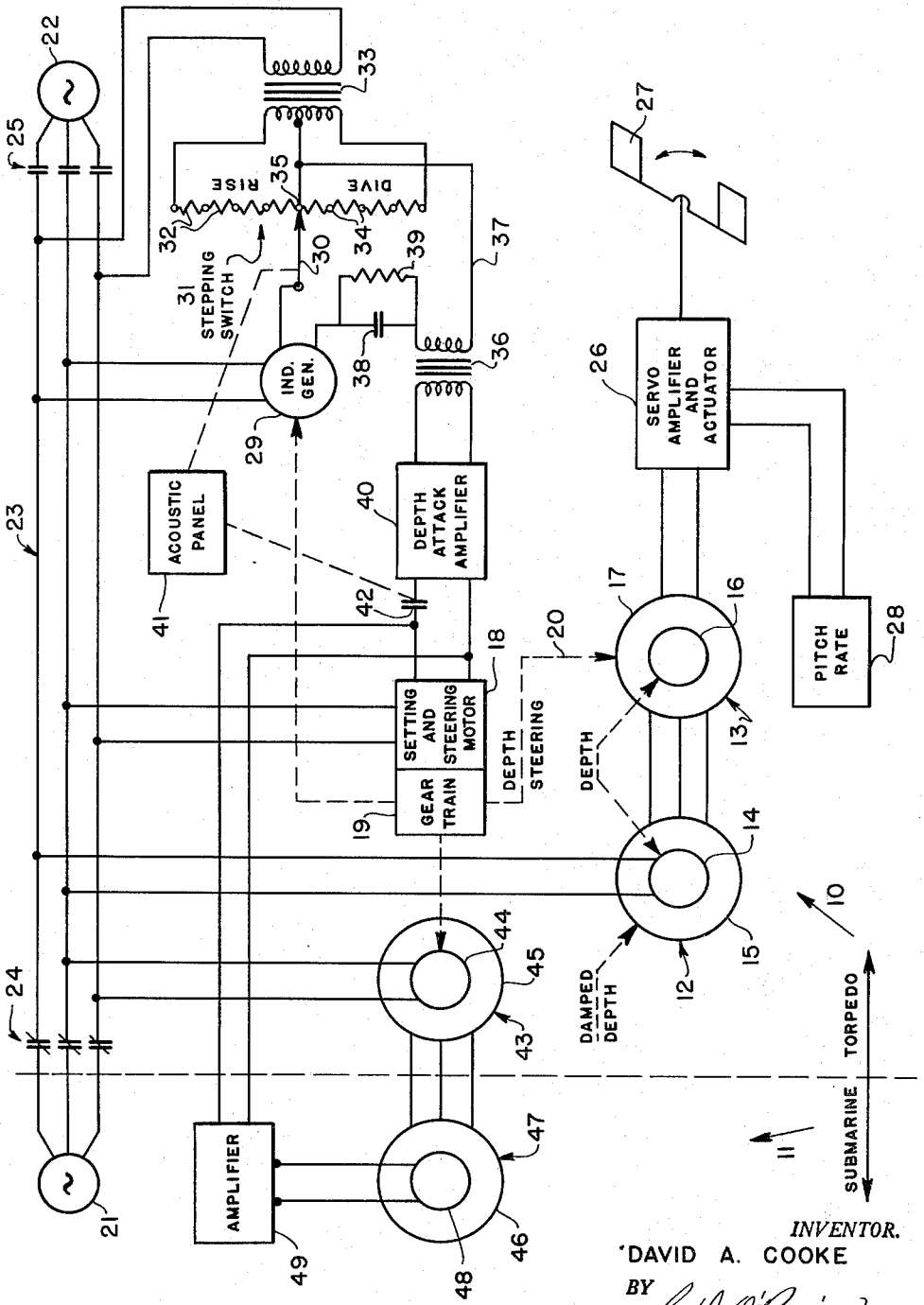

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ACOUSTIC DEPTH TORPEDO

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The present invention relates to improvements in acoustic torpedoes and has more particular reference to an improved depth steering system for echo ranging torpedoes.

Heretofore, various systems have been proposed for steering an echo ranging torpedo or the like in depth toward a submerged or other target. Such prior depth steering systems, in general, functioned to actuate the depth steering surfaces during a period of target contact in a manner to direct the torpedo in increments or decrements of depth toward the target. Thus, upon the receipt of a target echo signal which indicated a target position above the torpedo plane, the depth steering surfaces were actuated to decrease torpedo operating depth by a predetermined decrement. Subsequent target echo signals caused the depth steering to operate in a manner to change torpedo operating depth, either up or down, by the predetermined depth increments or decrements until impact was had with the target.

The present invention provides a depth steering system wherein during attack, torpedo depth changes are accomplished by varying the rates of climb and dive of the torpedo rather than by changing depth in predetermined amounts.

In accordance with the foregoing, an object of the invention is the provision of an improved depth steering system for acoustic torpedoes.

Another object of the invention is the provision of a depth steering system for echo ranging torpedoes wherein changes in torpedo depth during periods of target contact are effected by varying the rates of climb and dive of the torpedo.

Still another object of the invention is the provision of a depth steering system, as in the foregoing, embodying an electrical synchro assembly for controlling the position of the torpedo depth control surfaces and wherein during an attack period a motor drive system drives an element of the synchro assembly at varied constant rates to provide for varying the rate of torpedo climb or dive.

Other objects and numerous advantages of the present invention will become apparent as the same becomes better understood from the following detailed description had in conjunction with the annexed drawings wherein the single figure schematically illustrates one form of the present depth steering system.

Referring now to the drawing, **10** denotes the present depth steering system and **11** denotes generally an electrical circuit within the launching vessel, for permitting presetting an initial running depth into the torpedo control circuit, as will be seen. The electrical conductors connecting circuit **10** to circuit **11** include separable connections (not shown) at the surface of the torpedo shell whereby to permit disconnection of the circuits prior to or at the time of firing.

Torpedo circuit **10** comprises an electrical synchro assembly including a depth rate synchro **12** and a depth steering synchro **13**. Depth rate synchro **12**, which may be an electrical synchro generator, comprises a rotor **14** which is angularly positioned as a function of torpedo depth, as indicated, as by being operatively connected to a hydrostat mechanism (not shown). Synchro **12** also comprises a stator **15** which is angularly positioned as a function of damped depth; that is, stator **15** is actuated by a hydrostat mechanism (not shown) which is damped, as by a dash pot arrangement. Synchro **13**, which may

be a synchro control transformer, comprises a rotor **16** which is angularly positioned as a function of torpedo depth, as was rotor **14** and a stator **17** which is adapted to be angularly driven by a depth setting and steering motor **18** through a gear train **19** and a driving connection **20**.

Mounted within the launching vessel is a first three phase power supply **21** and mounted within the torpedo is a second three phase power supply **22**. Power supplies **21** and **22** are adapted to be selectively coupled to a three phase electrical conductor system **23** within the torpedo through the operation of contacts **24** and **25** controlled by a relay (not shown). Prior to launching of the torpedo, contacts **24** are closed and contacts **25** are open whereby warmup power for the system is furnished by supply **21**. Upon launching of the torpedo, contacts **24** are opened and contacts **25** are closed whereby operating power for the system is furnished by supply **22**.

Energizing of the synchro system comprising synchros **12** and **13** is accomplished by connecting the leads of rotor **14** to the conductor system **23**, as shown. The output of rotor **16** of synchro **13**, which output will be a function of the angular displacements of the rotors **14** and **16** from their zero positions relative to their respective stators, is fed to a servo amplifier and control surface actuator **26** which operates to control the position of the torpedo depth steering surfaces **27**. A pitch rate signal from a pitch rate mechanism **28** may also be fed into amplifier **26**.

Setting and steering motor **18** comprises a two phase servo motor, one phase winding of which is energized by direct connection to the conductor system **23**, as shown. The other phase winding of motor **18** is energized in the manner now to be described.

Motor **18** drives an induction generator **29** through the gear train **19**, which generator is energized from the conductor system **23**, as shown, the generator being energized from a different phase of the conductor system **23** than is the first mentioned winding of motor **18**. One output terminal of generator **29** is connected to a movable contact **30** forming a part of stepping switch **31**. Stepping switch **31** further comprises a plurality of series connected resistance elements **32** which are connected across the secondary of a transformer **33**, the primary of which is energized from the conductor system **23**, as shown. Opposed ends of adjacent resistance elements **32** are connected to contact buttons **34** with which the movable contact **30** may be selectively engaged. The center contact button **35** is electrically connected to a center tap on the secondary of transformer **33** and to one terminal of the primary winding of a transformer **36** through conductor **37**. Induction generator **29** has its other terminal connected to the other primary terminal of transformer **36** through a set of contacts **38** operated by a relay in the torpedo propulsion motor control system, not shown, which contacts are open, to insert a resistance **39** into the generator output circuit, when the propulsion motor, not shown, is operating at high speed, and closed, whereby to short out the resistance **39** when the motor is operating at low speed. The secondary of transformer **36** is coupled to a depth attack amplifier **40**, the output of which is fed to the second phase winding of depth setting and steering motor **18**.

Movable contact **30** of stepping switch **31** is operatively controlled, in a manner hereinafter more fully described, from the torpedo acoustic panel illustrated generally at **41**. As will be seen, panel **41** acts, upon the establishment of target contact, to step contact **30** in one direction or the other, depending on the bearing of the target, in the vertical plane relative to the torpedo heading, at predetermined intervals whereby to insert into the output circuit of generator **29** the voltage developed across one or more of the resistance elements **32**. If no target contact is had

for a predetermined period of time, panel 41 acts to open a pair of normally closed contacts 42 in the circuit from amplifier 40 to motor 18 and to reset movable contact 30 to its neutral position in contact with button 35.

To provide for setting of an initial running depth, there is provided within the torpedo a synchro generator 43, having a rotor 44 energized from the conductor system 23, and a stator 45. The stator leads of synchro 43 are connected, through separable connectors (not shown) at the torpedo hull, to the leads of the stator 46 of a synchro control transformer 47 in the launching vessel. Rotor 48 of synchro 47 has its leads coupled to an amplifier 49, the output of which is fed, through separable connectors, not shown, at the torpedo hull, to the aforesaid second phase winding of the depth steering and setting motor 18. Rotor 44 of synchro 43 is drivably connected to gear train 19 of motor 18 as shown.

Operation of the present depth steering system is as follows. Prior to launching of the torpedo, contacts 24 will be closed and contacts 25 open whereby the conductor system 23 will be energized from the three phase power source 21 in the launching vessel. The electrical synchro assembly, comprising the synchro generator 43 in the torpedo and the synchro control transformer 47 in the launching vessel, operates to produce an output voltage, to amplifier 49, which is a function of the angular displacements of the rotors 44 and 48 from their zero positions relative to their respective stators. To introduce into the torpedo depth steering system a desired initial running depth, the relative angular displacement of the rotor and stator of control transformer 47 in the launching vessel is so adjusted that the input to the second phase winding of depth setting motor 18 from amplifier 49 will cause rotation of motor 18 in a direction to drive the stator 17 of synchro control transformer 13 in the torpedo to an angular position relative to its rotor 16 corresponding to the desired initial running depth. Motor 18 is operatively connected through gear train 19 to the rotor 44 of synchro 43 in the torpedo whereby operation of motor 18 to drive stator 17 of synchro 13 to preset in initial running depth will cause rotation of rotor 44 until it has been driven to a position whereat the combined output of the synchros 43 and 47 becomes zero, at which point stator 17 will have been driven to the initial depth position. Upon launching of the torpedo, contacts 24 will be opened and contacts 25 will be closed by operation of a relay in the firing circuit, not shown, whereby conductor system 23 will be energized from the power supply 22 in the torpedo. Owing to the initial angular positioning of stator 17 to preset a running depth, the synchro assembly comprising synchros 12 and 13 will produce an initial output voltage which is a function of the initial relative angular displacement of stator 17 and rotor 16 from their zero position. This initial output voltage is fed to the servo amplifier 26 and causes the depth steering surfaces 27 to be actuated to either a climb or dive angle as required to steer the torpedo toward the initial running depth. Operation of the depth hydrostat elements, not shown, to drive the rotors 14 and 16 and the damped hydrostat element, not shown, to drive stator 15 during movement of the torpedo toward set depth results in an output voltage from the synchro assembly 12 and 13 which is a combined function of displacement of torpedo depth from the initial set depth and rate of change in torpedo depth. The arrangement is such that the torpedo seeks and then levels off at the initial set depth, synchro 13 functioning to direct the torpedo to the set depth and synchro 12 functioning as a rate mechanism to prevent hunting of the torpedo about the set depth.

The synchro assembly 12 and 13 will act to maintain the torpedo at the initial running depth whereat the torpedo will follow a horizontal search course the configuration of which will be determined by the characteristics of the particular azimuth steering control system, not shown, which is employed. The present depth steering control is intended to be controlled by an active or echo ranging type acoustic guidance system wherein pulses of high frequency energy are transmitted into the water from the torpedo. If a transmitted pulse impinges on a submerged object, such as a target, it is reflected back to the torpedo, the direction of such target reflected signal being detected by the torpedo acoustic system. Thus, while a torpedo, employing the present depth control system is traversing the aforementioned search course at the initial preset depth, its acoustic system is continuously transmitting pulses of high frequency energy into the water. Upon detection, by the acoustic system, of a target reflected signal, the acoustic panel 41 becomes operative to actuate contacts 42 to their closed position whereby to place the depth steering motor 18 in electrical circuit with the induction generator 29 and stepping switch 31. Panel 41 also becomes operative to step the movable contact 30, of stepping switch 31, to the first contact button 34 to one side or the other of the zero position button 35 depending on whether the target reflected signal indicates a target depth less than or greater than torpedo depth.

Depth steering during attack is accomplished, in the present invention, by causing steering motor 18 to drive stator 17 of synchro 13 at varied constant rates whereby to cause the torpedo to assume varied rates of climb or dive. To this end, the circuit including stepping switch 31 and induction generator 29 forms an A.C. speed control loop for controlling the speed of motor 18. To drive at varied constant rates, the output of generator 29, which output is a signal whose frequency is determined by the frequency of power supply 22, whose phase is determined by the direction of rotation of the generator rotor, and whose amplitude is determined by the speed of such rotation, is bucked by a variable voltage input to said speed control loop. The resultant of the generator output voltage and the input voltage is amplified by depth attack amplifier 40 and applied to the second phase winding of motor 18. The aforementioned variable input voltage to the speed control loop is determined by the position of movable contact 30 of stepping switch 31 which contact picks off a voltage from any of a given number of points on the resistance network 32 of the stepping switch to provide for a given number of varied rates of climb or dive. Thus, as shown in the drawing, the resistance network of the switch is provided with a plurality of pickoff points on either side of the electrically neutral point 35 of the network, the input voltages corresponding to the pickoff points on that portion of the resistance network labeled "rise" providing for increasing rates of climb and the input voltages corresponding to the pickoff points on that portion of the resistance network labeled "dive" providing for increasing rates of dive. Panel 41 operates to step contact 30 at predetermined intervals, as, for example, every 1¼ seconds. That is, as long as the target echo signal indicates that the torpedo is headed below the target, the system will step at 1¼ second intervals to gradually increase the rate of climb of the torpedo. Upon the target echo signal indicating a torpedo heading above the target, panel 41 operates to step contact 30 back toward the neutral point 35 and into the dive portion of the resistance network whereby to cause the torpedo to assume gradually increasing angles of dive. Thus, the rates of climb and dive of the torpedo are constantly changing, during attack, in a manner to guide the torpedo to the target. If contact with the target is lost for more than a given period of time, say four seconds, panel 41 operates to step contact 30 back to its neutral position, whereby the torpedo will resume search at a new running depth, and to open contacts 42 whereby to disconnect the motor 18 from the generator circuit. Contacts 38, controlled by a relay in the torpedo propulsion motor control circuit, not shown, act to insert resistance 39 into the speed control loop for motor 18 when the torpedo is being propelled at high speed and to short out resistance 39 from the speed control loop when the torpedo is being driven

at low speed whereby to the operating speed of depth steering motor 18 will be compensated for rate of torpedo movement through the motor to give the same angles of rise and dive at both torpedo speeds.

Obviously, many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. In a depth steering system for an echo ranging torpedo launched from a launching vessel, depth steering surface control means including an electrical synchro having its rotor angularly positioned as a function of torpedo depth, reversible means for driving the stator of said synchro in either direction of rotation, the torpedo depth steering surfaces being positioned at a function of the angular displacement of the rotor from its zero position with respect to the stator, means for controlling the operation of said driving means and including intermittently actuated means operable during periods of target contact to periodically vary the speed, in predetermined increments, and direction of operation of said driving means in accordance with heading of the torpedo relative to the target whereby to cause the torpedo to steer in depth toward the target in predetermined increments of climb and dive angle, means partly in the vessel and partly in the torpedo including said driving means for effecting initial angular positioning of said stator whereby to preset into the system an initial running depth, and separable connections between the vessel and torpedo portions of said last mentioned means.

2. In a depth steering system for an echo ranging torpedo, depth steering surface control means including an electrical synchro having its rotor angularly positioned as a function of depth, reversible means for driving the stator of said synchro in either direction of rotation, the torpedo depth steering surfaces being positioned as a function of the angular displacement of the rotor from its zero position with respect to the stator, means for controlling the speed and direction of operation of said driving means and including switching means having a neutral position wherein said driving means is stationary and a plurality of positions on either side of said neutral position, said last mentioned positions on one side of said neutral position corresponding to predetermined operating speeds in one direction of operation of said driving means and the positions on the other side of said neutral position corresponding to predetermined operating speeds in the other direction of operation of said driving means, and means operative during periods of target contact and controlled by the torpedo echo ranging gear for sequentially stepping said switch means through said positions in a manner to cause the torpedo to steer toward the target in predetermined increments of climp and dive angle.

3. The arrangement according to claim 2 wherein said driving means comprises a reversible electric motor.

4. The arrangement according to claim 3 wherein the second mentioned control means further includes a generator driven by said motor, and said switching means comprises means for inserting predetermined incremental voltages in series with the output of said generator, the resultant of the generator output and switching means incremental voltages being applied to said motor for controlling the speed and direction of rotation of the latter.

5. In a depth steering system for an echo ranging torpedo, an electrical synchro assembly including a synchro having a rotor angularly positioned as a function of torpedo depth and a rotatably mounted stator, the torpedo depth steering surfaces being positioned as a function of the angular displacement of the rotor from its zero position relative to the stator, the angular position of the stator relative to a fixed reference determining the depth which the steering system will cause the torpedo to seek, reversible means comprising an electric motor for driving said stator in either direction of rotation, and control means for said driving means operable during target attack periods to cause said driving means to drive the stator in a manner to steer the torpedo toward the target in predetermined increments of rise and dive angle, said control means comprising a generator driven by said motor, means for inserting predetermined incremental voltages in series with the output of the generator, the resultant of the generator output and the incremental voltages being applied to said motor, some of said incremental voltages providing resultant voltages for causing said motor to drive at predetermined constant rates in one direction of rotation whereby to cause the depth steering surface to steer the torpedo in predetermined increments of rise angle and others of said incremental voltages providing resultant voltages for causing said motor to drive at predetermined constant rates in the other direction of rotation whereby to cause the depth steering surfaces to steer the torpedo in predetermined increments of dive angle, and means controlled by echo ranging apparatus of the storpedo for effecting stepped operation of incremental voltage inserting means whereby to cause the torpedo to steer in said incremental rise and dive angles toward the target.

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