AZIMUTH STEERING AND CONTROL SYSTEM

Filed Dec. 9, 1953 3 Sheets-Sheet 1

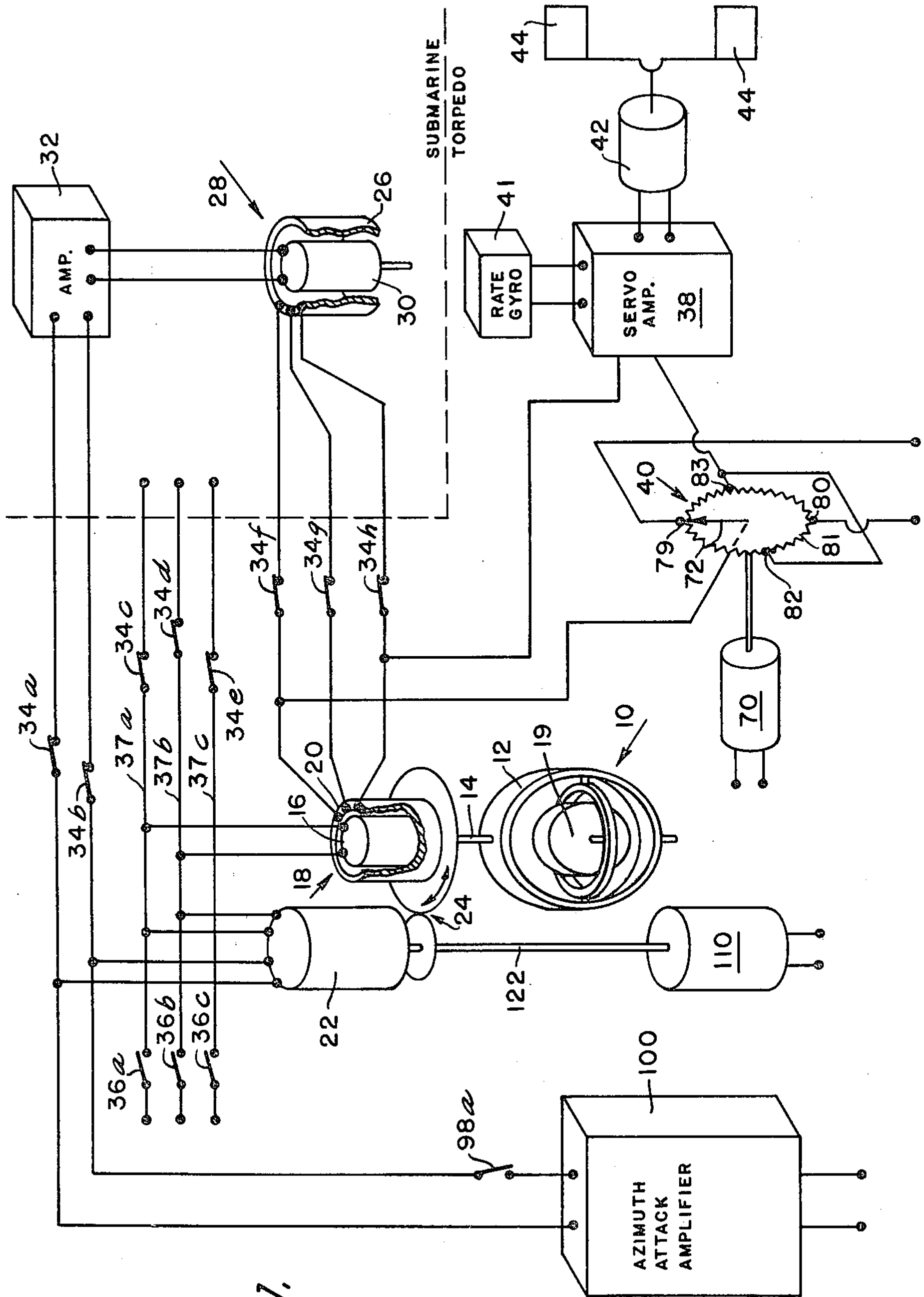

Fig. 1.

INVENTORS
DAVID A. COOKE
SETH G. FISHER
BY G. D. O'Brien
E. C. Walsh
ATTORNEYS

Nov. 20, 1962 D. A. COOKE ET AL 3,064,609

AZIMUTH STEERING AND CONTROL SYSTEM

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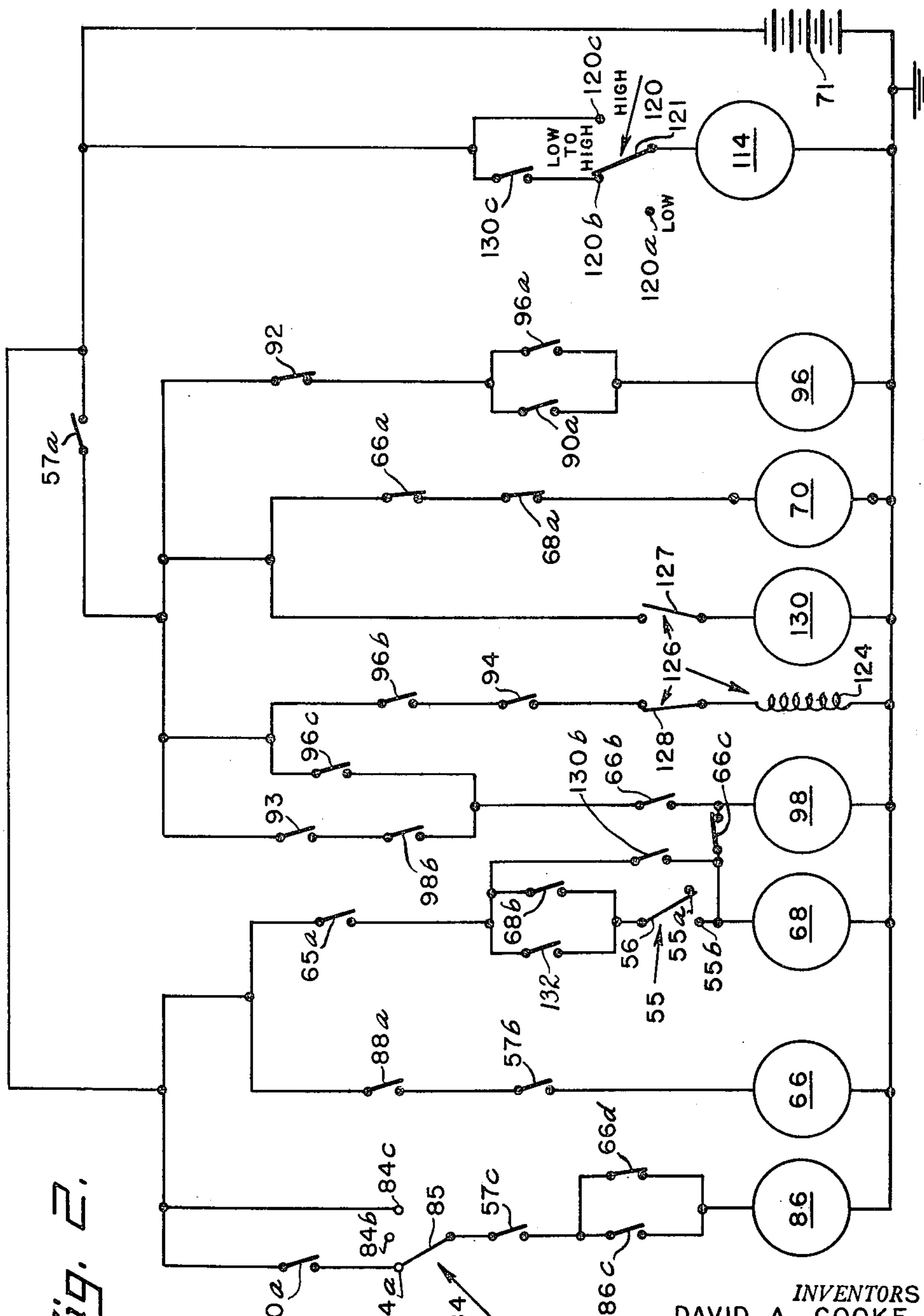

Fig. 2

INVENTORS
DAVID A. COOKE
SETH G. FISHER
BY *G. D. O'Brien*
E. C. Walsh
ATTORNEYS

AZIMUTH STEERING AND CONTROL SYSTEM

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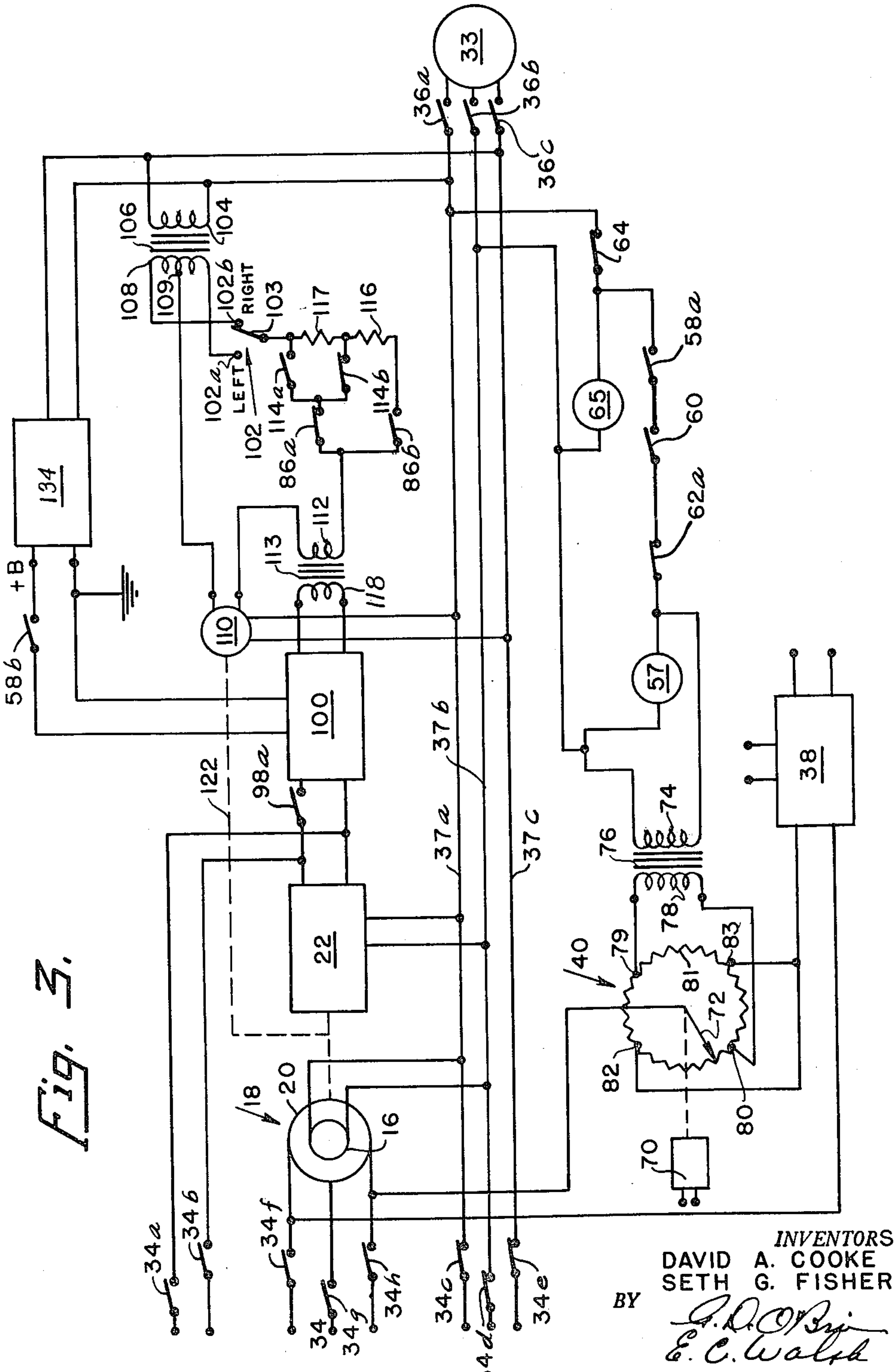

Fig. 3

INVENTORS
DAVID A. COOKE
SETH G. FISHER
BY
ATTORNEYS

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AZIMUTH STEERING AND CONTROL SYSTEM

David A. Cooke, Wallingford, and Seth G. Fisher, Sharon, Pa., assignors, by mesne assignments, to the United States of America as represented by the Secretary of the Navy

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6 Claims. (Cl. 114—23)

This invention relates to acoustic torpedoes and in particular to an azimuth steering and control system for such torpedoes which may be used with either active or passive acoustic guidance systems.

The run of an azimuth torpedo has three phases; the first, or initial, phase during which the torpedo leaves the launching vessel and proceeds to a given general area in which the target is located; the second, or search, phase during which the torpedo searches for the target; and the third, or attack, phase during which the torepdo attacks the target.

It is an object of this invention to provide an azimuth steering and control system for a torpedo which can be remotely set to cause the torpedo during its initial phase to make a straight gyroscopically controlled run, or, alternatively, a circular run.

It is another object of this invention to provide an azimuth steering and control system for a torpedo which can be remotely set to cause the torpedo during the search phase of its run to snake along the gyroscopically controlled course, or to make a circular run.

It is another object of this invention to provide an azimuth steering and control system for a torpedo in which the azimuth steering means is adapted to be controlled by acoustic guidance means to steer the torpedo toward a target detected by the guidance means during the attack phase of the torpedo's run.

It is another further object of this invention to provide an azimuth steering and control system for a torpedo which is adapted, if a target is detected by the guidance means of the torpedo and then lost, to cause the torpedo to return to the searching phase.

It is another object of this invention to provide an azimuth steering and control system which will cause the torpedo to follow a prescribed gyroscopic course during the initial phase, to follow an oscillating, or snaking, course about the prescribed gyroscopic course during the search phase, to attack the target under the control of the acoustic guidance system carried by the torpedo when a target is detected by the acoustic guidance system, and to return to the search phase if the target is subsequently lost.

It is another object of this invention to provide an acoustic steering and control system which permits remote setting of the gyroscopic course which the torpedo is to follow during its initial phase.

It is another object of this invention to provide an azimuth steering and control system which permits the torpedo to circle to search for a target located above the launching vessel.

It is another object of this invention to provide an azimuth steering and control system which permits the torpedo to circle during the first and second phases of its run, to be controlled by the acoustic guidance system carried by the torpedo during the attack phase, and to return to the circular search phase if the target is subsequently lost.

It is a further object of this invention to provide an acoustic guidance systeh which permits the torpedo to follow a given course for a prescribed distance, to search for a target by following a snaking course about the prescribed gyroscopic course, to attack the target under the control of the guidance system carried by the torpedo,

to return to the snaking search type course if the target is lost after being detected for less than a predetermined period of time, and to pursue a circular search type of course if the target has been detected for more than a predetermined minimum period of time.

Still further objects and many of the attendant advantages of this invention will be readily appreciated as the same become better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is a schematic illustration of the major components of the azimuth steering and control system;

FIG. 2 is a direct current wiring diagram of the control system, and

FIG. 3 is an A.C. wiring diagram of the steering and control system.

Referring in detail to the drawing, and particularly FIGS. 1 and 3, two degrees of freedom course gyroscope **10** has its outer gimbal **12** connected by means of shaft **14** to the rotor **16** of synchro generator **18**. Course gyroscope **10** is adapted to be energized and caged by conventional means, which are not illustrated, so that the axis of rotation of gyroscope rotor **19** has a predetermined orientation relative to the torpedo before the torpedo is launched from a conventional torpedo tube, which is not illustrated. The stator **20** of synchro generator **18** can be oriented to any position by means of setting and steering servo motor **22** which is connected to stator **20** by means of gears **24**, which are shown symbolically. The stator **20** of synchro generator **18** is electrically connected to the stator **26** of synchro control transformer **28**. The error voltage induced in rotor **30** of transformer **28** is amplified by amplifier **32** and applied to one of the windings of two phase A.C. servo motor **22**. Synchro control transformer **28** and amplifier **32** are located in a submarine, for example, from which the torpedo is to be fired. The second phase of servo motor **22** is supplied with a single phase 115 volt 400 cycle current from the submarine prior to launching, and from generator **33** (FIG. 3) located within the torpedo after the torpedo is fired, or launched. The servo loop including synchro generator **18**, synchro control transformer **28**, amplifier **32** and servo motor **22** permits the stator **20** of generator **18** to be given any desired orientation relative to rotor **16** prior to the firing of the torpedo.

Prior to launching, synchro generator **18** is a component of the servo loop adapted to orient stator **20** to a position which will determine the gyroscopic course the torpedo will follow after launching. After launching, synchro generator **18** becomes the electrical pick-off for gyroscope **10** of the azimuth steering system of the torpedo. When the torpedo is launched, the connections between the submarine and the torpedo are broken and relay contacts **34** *a, b, c, d, e, f, g, h* open while relay contacts **36** *a, b, c* are closed to permit 400 cycle 115 volt current from three phase A.C. generator **33** to be supplied to conductors **37** *a, b, c*. Single phase 115 volt 400 cycle current is then applied to one winding of setting and steering motor **22** and to rotor **16** of synchro generator **18**. The voltage induced across two of the three windings of stator **20** is applied to servo amplifier **38** through potentiometer **40** whose function will be explained later. In amplifier **38** the voltage from synchro generator **18** is amplified and combined with the electrical output of a conventional course rate gyroscope **41**. The amplified output voltage of amplifier **38** is applied to a conventional rudder actuator **42** which positions rudders **44** to steer the torpedo in azimuth. After launching, the actuator and rudders will cause the torpedo to turn in response to the voltage applied to servo amplifier **38** from synchro generator **18** until the voltage from synchro generator **18** is substantially zero. When this occurs, the torpedo is on the desired course in azimuth. The electrical output of rate gyroscope **41** is added to minimize oscillation as well as to damp oscillation of the torpedo in azimuth.

If horizontal circle switch **55** (FIG. 2) has its movable element **56** in engagement with terminal **55***a*, the torpedo will make a straight run during the initial phase. Switch **55** is adapted to be remotely positioned by conventional means, which are not illustrated. When so positioned, the torpedo will follow a gyroscopically controlled course in azimuth until the acoustic enabling relay **57** (FIG. 3) is energized by the closing of selected distance relay contacts **58***a*, if pressure switch contacts **60**, anti-circular run relay contacts **62***a* and fin switch **64** are closed. Relay contacts **58***a* and **58***b* are closed when the torpedo has traveled a preselected distance from the launching vessel as determined by a variable enabler such as is described in U.S. Patent application No. 390,268, filed November 4, 1953, by David A. Cooke and Robert H. Kittleman and entitled Variable Enabler and now Patent Number 3,004,506. Pressure switch contacts **60** are closed when the torpedo is above a predetermined minimum depth, say 150 feet. Anti-circular run relay contacts **62***a* are closed unless the anti-circular run device with which the torpedo is adapted to be supplied detects a malfunctioning of the azimuth stering system prior to the closing of contacts **58***a*. An anti-circular run device suitable for the foregoing purpose is described in U.S. Patent application No. 365,441, filed July 1, 1953, by Harry E. Ellerman, Jr. and entitled Anti-Circular Run Device, and now Patent Number 2,955,557. Fin switch **64**, such as is disclosed in the variable enabler application, supra, closes at the time the torpedo leaves the torpedo tube and energizes fin switch relay **65** to close relay contacts **65***a* in FIG. 2.

When the acoustic enabling relay **57** is energized, the second, or search phase, of the torpedo run begins. Energization of relay **57** closes contacts **57***a* in FIG. 2, as well as contacts **57***b* and **57***c*. Auxiliary hold in relay contacts **66***a* and circle search relay contacts **68***a* in the circuit of constant speed D.C. snaking search motor **70** are closed except when relays **66** and **68** are energized. Relay **66** is not energized until a target is detected by the acoustic guidance system, as will be explained later, and the circle search relay **68** is not energized when movable contact **56** of switch **55** engages terminal **55***a*, until after a target has been detected by the acoustic guidance system for a predetermined period of time and is then lost. Thus when contacts **57***a* close, D.C. motor **70** is energized by 24 volts D.C. from battery **71** carried by the torpedo.

Referring to FIGS. 1 and 3, motor **70** is adapted to rotate slider **72** of circular potentiometer **40** at a constant angular velocity. At the same time that acoustic enabling relay **57** is energized, 115 volt 400 cycle A.C. is applied across the primary windings **74** of stepdown transformer **76** seen in FIG. 3. The output of the secondary windings **78** of transformer **76** is applied to diagonally located terminals **79**, **80** of resistor element **81** of potentiometer **40**. The circuit between amplifier **38** and synchro generator **18** is completed through slider **72** and diagonally located terminals **82**, **83** which are spaced in an angle of 90° from terminals **79**, **80**.

When slider **72** is being rotated by motor **70**, an A.C. voltage which is either in phase or in phase opposition with the voltage across windings **78**, and whose amplitude varies sinusoidally, is added to the voltage from the synchro generator **18**. The sinusoidally modulated voltage from potentiometer **40** causes the torpedo to change its course in azimuth with the result that the torpedo will oscillate about the gyroscopically controlled course. This periodic oscillation, also called a snaking course, permits the acoustic system of the torpedo to scan a wider area of the water ahead of the torpedo for a target.

The acoustic guidance system with which this invention is adapted to be used can be active or passive after being enabled. When active, the guidance system periodically transmits pulses of acoustic energy and uses the reflected acoustic energy from a target to determine the bearing of the target relative to the torpedo. When passive, the guidance system continuously listens to noise created by a target and determines the bearing of the target relative to the torpedo from the sound generated by the target. Remotely positioned three position acoustic guidance switch **84** (FIG. 2) determines whether the acoustic guidance system will operate as an active system, a passive system, or as a combination of the two; i.e. passive until a target is detected for a sufficient period of time and then active if the target is subsequently lost. When movable element **85** of switch **84** is positioned to contact terminal **84***a* the guidance system will be passive and then changes to active as described above. When element **85** engages terminal **84***b*, the guidance system, after enabling, will be passive during the entire run of the torpedo. When element **85** engages terminal **84***c* the guidance system, after enabling, will be active during the entire run of the torpedo.

If element **85** of acoustic switch **84** is in the position illustrated in FIG. 2, the acoustic guidance system will be energized, or enabled, when relay **57** is energized. When the guidance system, which is now listening, or passive, hears, or detects, a target, relay contacts **88***a* of a relay controlled by the acoustic guidance system close and relay contacts **90***a* of a second relay controlled by the acoustic guidance system also close.

Since contacts **57***b* were closed at enabling, the closing of contacts **88***a* when a target is detected energizes auxiliary hold in relay **66** which opens contacts **66***a* to deenergize, or stop, motor **70**, closes contacts **66***b*, and opens contacts **66***c*. Transformer **76**, in FIG. 3 is still energized so that there is no sudden change in the voltage applied to servo amplifier **38** which could cause the torpedo to turn and possibly lose the target.

Contacts **92**, **93**, **94** (FIG. 2) are cam operated by a constant speed motor, which is not illustrated, to open and close in a desired sequence. The period of time for each of contacts **92**, **93**, **94** to complete a cycle equals the time between pulses of transmitted acoustic energy when the guidance system is active. In a preferred example this period is approximately one and one-fourth seconds. Contacts **92** are closed during the cycle except for approximately thirty milliseconds which corresponds with the time the acoustic transmitter of the guidance system is transmitting. Contacts **93** are closed except for approximately fifty milliseconds before the transmitter pulses, but close shortly before the pulse is transmitted. Contacts **94** close with the transmitting of the pulse and open approximately 405 milliseconds later. The sequence of the opening and closing of the contacts **92**, **93**, **94** is the same whether the guidance system is active or passive.

When contacts **92** are closed and relay contacts **90***a* are closed because the guidance system has detected a target, delayed gate relay **96** is energized and closes relay contacts **96***a*, **96***b*, **96***c*. The closing of contacts **96***a* seals in relay **96** during closed condition of cam-operated switch **92**. Contacts **66***b*, in the circuit of relay **98**, closed when relay **66** was energized so that the azimuth steering relay **98** is energized which closes contacts **98***a* (FIG. 1 and FIG. 3), **98***b* (FIG. 2). When contacts **98***a* close, the output voltage of the azimuth attack amplifier **100** is applied across one of the windings of setting and steering servo motor **22** and causes it to rotate.

In FIG. 3 there is illustrated the circuitry by which the speed and direction of rotation of setting and steering motor **22**, and the direction and rate of turning of the torpedo is determined. Two position azimuth steering switch **102** is adapated to be controlled by the acoustic guidance system. Movable element **103** of switch **102** engages either terminal **102***a* or terminal **102***b*. The primary winding **104** of transformer **106** has applied across it 115 volt, 400 cycle A.C. from generator **33**. The secondary winding **108** of transformer **106** has a center tap **109**. Terminal **102***a* of switch **102** is connected to one end of secondary winding 108 and terminal 102*b* is connected to the other end. Center tap 109 is connected to one of the output terminals of induction generator 110. The other output terminal of generator 110 is connected to one end of primary winding 112 of transformer 113. The other terminal of primary winding 112 is connected through echo ranging contacts 86*a* or 86*b*, high speed relay contacts 114*a* or 114*b* and resistors 116 and 117 to movable element 103 of switch 102. The voltage induced in the secondary winding 118 of transformer 113 is applied to azimuth attack amplifier 100.

Remotely positioned speed selection switch 120 (FIG. 2) determines the speed of the torpedo. The propulsion means of the torpedo, which are not illustrated, is designed to drive the torpedo at a high speed, or at a low speed. If movable element 121 of switch 120 engages terminal 120*a*, the torpedo will travel at a low speed during the entire run; if element 121 engages terminal 120*c*, the run will be made at high speed; and if element 121 engages terminal 120*b*, the torpedo will travel at low speed until the target is detected for a predetermined period of time and then the speed will be changed to the high speed.

The direction the torpedo is to turn is determined by the phase of the voltage applied to amplifier 100 as determined by the position of element 103 of switch 102, and the amplitude of the applied voltage determines the turning rate. The maximum turning rate is desired when the torpedo is making a high speed passive attack, at which time contacts 86*a* are closed, 86*b* open, contacts 114*a* are closed and contacts 114*b* are open. When a low speed passive attack is made, contacts 86*a* are closed, contacts 86*b* are open, contacts 114*b* are closed and contacts 114*a* are open. When an active acoustic attack is made, whether at high or low speed, the lowest turning rates are desired. This is achieved by closing contacts 86*b* and opening contacts 86*a* so that resistors 116 and 117 are in series with primary winding 112 of transformer 113.

Induction generator 110 is connected by shaft 122, which is shown schematically as a dashed line in FIG. 3, to setting and steering motor 22. The phase and amplitude of the output voltage of generator 110 are determined by the direction and rate of rotation of motor 22, and is such as to oppose in amplitude and phase the voltage being applied to the primary windings 112 of transformer 113 from the secondary windings 108 of transformer 106. The result is a conventional A.C. speed control which will cause the setting and steering motor 22 to rotate at a substantially constant speed, the magnitude of which is determined by which of relay contacts 86*a* or 86*b* and 114*a* or 114*b* are closed, as previously described.

The rotation of stator 20 of synchro generator 18 relative to rotor 16, which is held fixed in inertial space, induces a 400 cycle A.C. error voltage in the windings of stator 20 whose phase determines the direction in which rudders 44 turn and whose amplitude determines the magnitude of the deflection of rudders 44 to determine the turning rate of the torpedo. When the torpedo is heading substantially directly toward a target, azimuth steering switch 102 will be continuously changing so as to require alternately left and right steering with the result that the torpedo will follow a zig-zag course to the target.

During a passive acoustic attack relay contacts 90*a* in FIG. 2 are closed as long as the acoustic guidance system hears, or detects, a target. Contacts 92 open at the beginning of every one and one-fourth seconds period to deenergize relays 96 and open contacts 96*a*, 96*b*, 96*c*. Contacts 93 which open toward the latter part of a one and one-fourth period, close before contacts 92 open so that relay 98 is continuously energized and relay contacts 98*a* are closed to permit continuous steering of the torpedo under the control of the acoustic guidance system. Contacts 94 close at the beginning of the one and one-fourth second period and open approximately 405 milliseconds later so that contacts 94 are closed during part of the time cam contacts 92 are closed. If relay contacts 90*a* are closed during the period when cam contacts 92 and 94 are closed, coil 124 of stepping switch 126 will be energized. After being alternately energized and deenergized ten times, movable element 127 of stepping switch 126 closes the circuit to energize ten-step relay 130, and movable element 128 opens the circuit to coil 124. Energization of relay 130 closes contacts 130*a*, 130*b*, 130*c*. If speed selection switch 120 has its movable element 121 engaging terminal 102*b*, high speed relay 114 will be energized when contacts 130*c* close so that the speed of the torpedo will change from low to high.

Fin switch relay contacts 65*a* close when the torpedo leaves the launching tube so that the circle search relay 68 is energized to open contacts 68*a* to motor 70 when contacts 130*b* close. However, since contacts 66*c* are open when the acoustic guidance system is detecting a target, relay 98 will not be energized through contacts 66*c*. If movable element 56 of horizontal circle switch 55 engages terminal 55*a* and if the acoustic guidance system no longer detects a target, relay contacts 90*a* open and relay 96 will be deenergized when contacts 92 open. Steering relay 98 will be deenergized when cam contacts 93 open and will open contacts 98*a* to open the circuit between amplifier 100 and motor 22. Relay contacts 88*a* remain closed for approximately four seconds (three cam switch cycles) after the target is lost, and then open. This prevents shifting from the attack phase to the search phase if the target is lost momentarily. When contacts 88*a* open, relay 66 is deenergized and contacts 66*c* close to energize relay 98, through closed relay contacts 130*b*, which closes contacts 98*a* and completes the circuit between amplifier 100 and setting and steering motor 22. The torpedo will then steer in a circle, the direction of the circle being determined by the position of switch 102, and the rate of turning being determined by the speed of the torpedo and the manner in which the guidance system is operating. If the torpedo has detected a target for approximately thirteen seconds (ten cam switch cycles) and then loses the target, it can be assumed that the torpedo is relatively close to the target. A circular search course is then the best course the torpedo can follow to try to relocate the target.

If the acoustic guiding switch 84 in FIG. 2 has its movable element 85 engaging terminal 84*a*, echo ranging relay 86 will be energized to cause the guidance system to change from passive to active when contacts 66*d* close after the target has been lost for approximately four seconds (three cam switch cycles), since contacts 57*c* closed when the acoustic system was enabled and contacts 130*a* closed after the target had been detected by the guidance system for ten cam switch cycles. Contacts 86*c* then close to seal in relay 86. The torpedo will circle until the guidance system picks up the target. When a target is detected, the acoustic guidance system through switch 102 steers the torpedo to the target.

If movable element 85 of acoustic guidance switch 84 engages terminal 84*c*, echo ranging relay 86 will be energized when contacts 57*c* of the acoustic enabling relay 57 are energized since contacts 66*d* of auxiliary holding relay 66 are closed until the guidance system detects a target.

When a torpedo is making an active acoustic attack, contacts 90*a* close only during the period of time that the reflected pulse, or echo from the target, is detected by the guidance system. Since contacts 92 are open only when the guidance system is transmitting a pulse of acoustic energy, relav 96 will be energized when contacts 90*a* close and will seal itself in until contacts 92 open, by closing relay contacts 96*a*. Relay 66 is also energized when the guidance means detects a target, since contacts **88**a close and remain closed until the target has been lost for approximately four seconds (three cam switch cycles), so that relay **98** is energized through contacts **96**c and contacts **66**b, to close contacts **98**a. When relay **96** is deenergized by the opening of contacts **92**, relay **98** remains energized through contacts **93** and contacts **98**b. As each echo from the target is detected by the guidance system, switch **102** is positioned for left or right steering from information derived by the guidance system from the reflected pulse to steer the torpedo in azimuth toward the target.

Contacts **94** are closed for 405 milliseconds beginning with the time the pulse of the acoustic energy is transmitted by the guidance system. Contacts **96**b close when the echo from the target is received by the guidance system. Since a period of 405 milliseconds is required for acoustic energy to travel to a target and return to the torpedo if the target is substantially 1000 feet from the torpedo, stepping switch **126** will not be pulsed during an active attack unless the target is within 1000 feet of the torpedo. If the target is detected for ten periods within the 1000 foot range, ten step switch **126** will energize relay **130**. This will change the torpedo speed to high speed as described above if switch **120** has element **121** engaging contact **120**b. Since the guidance system is already active, closing of contacts **130**a has no effect on the guidance system. Circle search relay **68** is energized when contacts **130**b close, and the torpedo will go into a circle search if the target is lost long enough to deenergize relay **66** to open contacts **66**c and de-energize relay **98**.

If switch **55** has movable element **56** in engagement with terminal **55**a, and if the target is picked up and subsequently lost before relay **130** is energized, the torpedo will return to the snaking search course since motor **70** will be energized when contacts **66**a close since circle search relay **68** has not been energized to open contacts **68**a.

Under certain tactical situations it may be desirable to have the torpedo attack a target above the submarine from which the torpedo is launched. To accomplish this, movable element **56** of switch **55** in FIG. 2 is placed to engage terminal **55**b prior to launching. Contacts **65**a of fin switch relay **65** close as soon as the torpedo leaves the launching tube. Pressure switch contacts **132** are closed when the torpedo is at greater than a set depth, say **150** feet. Therefore, if the torpedo is launched at a depth equal to or greater than say 150 feet, relay **68** is energized and seals itself in by closing contacts **68**b. Relay **98** is energized at the same time since contacts **66**c are closed until a target is detected by the guidance system. Amplifier **100** is connected to setting and steering motor **22** through closed contacts **98**a but cannot energize motor **22** until +B potential from rectifier **134** is applied to amplifier **100**. This occurs when contacts **58**b (FIG. 3) close. Contacts **58**a, **58**b of FIG. 3 can be made to close after the torpedo has traveled as little as zero distance from the torpedo tube by the proper setting of the variable enabler and by means of contacts of the circle search relay **68** which permit the preselected distance relay of the variable enabler to be energized at less than the minimum enabling distance. As soon as contacts **58**b close, the torpedo will begin to circle in a direction corresponding to the position of azimuth steering switch **102**. Acustic enabling relay **57** is energized to enable the acoustic system when pressure switch contacts **60** close. Contacts **60** are adapted to be closed when the torpedo is less than 150 feet below the surface. If a target is detected, the acoustic system will guide the torpedo to the target by action of switch **102**, as described above both in the active and passive mode of torpedo operation. Subsequent loss of the target will cause the torpedo to return to the circle search since relay **68** cannot be deenergized after once being energized. Since contacts **68**a in the circuit to the snaking search motor are open, snaking search motor **70** cannot be energized.

If the torpedo is fired from a depth of less than 150 feet, circle search relay **68** will not be energized since pressure switch contacts **132** will be open. The torpedo will then proceed along a straight gyroscopically controlled course corresponding to the position of stator **20** of synchro control generator **16**. The acoustic system will be enabled when contacts **58**a are closed after the torpedo has traveled at least the minimum enabling distance. The torpedo will then follow a snaking search type of course as described above until a target is detected. The action after a target has been detected will be the same as described previously.

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 torpedo, azimuth steering means comprising a course gyroscope, means operatively connected to said gyroscope for producing an electrical signal which is a function of the direction and magnitude of the error between the actual course of said torpedo and a preselected course, means responsive to said signal to cause said torpedo to steer to eliminate said signal, and means for modulating said signal to cause said torpedo to oscillate periodically in azimuth about said preselected course.

2. In a torpedo having an acoustic guidance system, the improvements comprising, in combination, rudders, a rudder actuator adapted to position the rudders, gyroscopic means adapted to control the rudder actuator and cause the torpedo to steer a substantially straight preselected course in azimuth, snaking search means adapted to control the rudder actuator to cause the torpedo to steer an oscillating course, circle search means adapted to control the rudder actuator to cause the torpedo to steer in a circle, means adapted to be controlled by the guidance system to control the rudder actuator to steer the torpedo to a target detected by the guidance system, and control means adapted to cause said gyroscopic means to control the rudder actuator until the torpedo has traveled a predetermined distance, adapted to cause the snaking search means and the gyroscopic means to control said actuator to cause said torpedo to oscillate about the preselected gyroscopic course after said torpedo has traveled said predetermined distance, and adapted, when the guidance system detects a target, to cause said means controlled by said guidance means to solely control said rudder actuator to steer the torpedo to the target.

3. In a torpedo having an acoustic guidance system, the improvements comprising in combination, rudders adapted to steer said torpedo in azimuth, a rudder actuator adapted to position the rudders, gyroscopic means adapted to control the rudder actuator to steer the torpedo along a preselected substantially straight course, snaking search means adapted to control the rudder actuator to steer the torpedo so that the heading of the torpedo in azimuth is sinusoidally varied, circle search means adapted to control the rudder actuator to steer the torpedo in a circle, means controlled by the acoustic guidance system to control the rudder actuator to steer the torpedo to a target when the guidance system detects a target, and control means adapted to permit said gyroscopic means to solely control the rudder actuator until the torpedo has traveled a predetermined distance after being launched, to permit the gyroscopic means and the snaking search means to control the rudder actuator to sinusoidally vary the heading of the torpedo about the preselected course after the torpedo has traveled said predetermined distance, adapted to permit the means controlled by the acoustic guidance system to solely control the rudder actuator when the guidance system

detects a target, adapted to permit the gyroscopic means and the snaking search means to control the rudder actuator if the target is detected for less than a predetermined period of time and then lost, or to permit the circle search means to control the rudder actuator if the target is detected for more than said predetermined period of time and then lost, and adapted to permit the means controlled by the acoustic guidance system to control the rudder actuator when the guidance system subsequently detects the target.

4. In a torpedo having an active acoustic guidance systtem, azimuth steering means comprising, in combination, rudders adapted to steer said torpedo in azimuth, a rudder actuator adapted to position the rudders, gyroscopic means adapted to control the rudder actuator to steer the torpedo along a selected substantially straight course, snaking search means adapted to control the rudder actuator to steer the torpedo so that the heading of the torpedo in azimuth is sinusoidally varied, circle search means adapted to control the rudder actuator to steer the torpedo in a circle, switch means adapted to be controlled by the acoustic guidance system to control the rudder actuator to steer the torpedo to a target when the guidance system detects a target, and control means adapted to permit said gyroscopic means to solely control the rudder actuator until the torpedo has traveled a predetermined distance from the launching point, adapted to permit the gyroscopic means and the snaking search means to control the rudder actuator to sinusoidally vary the heading of the torpedo about the gyroscopically controlled course after the torpedo has traveled said predetermined distance, adapted to permit the switch means to solely control the rudder actuator when the guidance system detects a target, adapted to permit the gyroscopic means and the snaking search means to control the rudder actuator if the target is detected within a predetermined range for less than a predetermined period of time and then lost, or to permit the circle search means to control the rudder actuator if the target is detected within said predetermined range for more than said predetermined period of time and then lost, and adapted to permit the means controlled by the acoustic guidance system to control the rudder actuator when the guidance system again detects the target.

5. In a torpedo having an acoustic guidance system, the improvements comprising, in combination, rudders adapted to steer said torpedo in azimuth, a rudder actuator adapted to position the rudders, gyroscopic means adapted to control the rudder actuators to steer the torpedo on a preselected substantially straight course in azimuth, snaking search means adapted to control the rudder actuator to steer the torpedo so that the heading of the torpedo in azimuth oscillates periodically, circle search means adapted to control the rudder actuator to steer the torpedo in circles, switch means adapted to be controlled by the acoustic guidence system to control the rudder actuator to steer the torpedo toward a target detected by the guidance system, and control means adapted under a first condition to permit said gyroscopic means to control said rudder actuator until the torpedo has traveled a predetermined distance which may be substantially zero after having been launched, adapted to permit said circle search means to control said rudder actuator until the guidance system detects a target if the torpedo is launched from below a predetermined depth, or if the torpedo is launched from above said predetermined depth, adapted to permit said snaking search means and said gyroscopic means to control the rudder actuator until the guidance means detects a target, adapted to permit said switch means to control said rudder actuator when the guidance system detects a target, adapted to permit said circle search means to control said rudder actuator if the torpedo was launched from a depth greater than said predetermined depth and if the target is subsequently lost, or adapted to permit said gyroscopic means and the snaking search means to control the actuator if the torpedo was launched from a depth less than said predetermined depth, and if the guidance system has detected a target for less than a predetermined period of time when the target was lost, or if the guidance system has detected a target for more than said predetermined period of time when the target is lost, adapted to permit the circle search means to control the rudder actuators, or in a second condition adapted to permit said gyroscopic means to control the rudder actuator until the torpedo has traveled a predetermined distance, adapted to permit the snaking search means and the gyroscopic means to control the rudder actuator until the guidance system detects the target, adapted to permit the gyroscopic means and the snaking search means to control the rudder actuator if the target is lost after being detected by the guidance system for less than a predetermined period of time, and adapted to permit the circle search means to control the rudder actuator if the guidance system has detected a target for more than said predetermined period of time.

6. In a torpedo having a guidance system that can be either active or passive, and having propulsion means that are adapted to propel the torpedo at either a high or a low speed, the improvements comprising, in combination, rudders adapted to steer said torpedo in azimuth, a rudder actuator adapted to position the rudders, remotely positioned gyroscopic means adapted to control the rudder actuator to steer the torpedo along a preselected substantially straight course in azimuth, snaking search means adapted to control the rudder actuator to steer the torpedo so that the heading of the torpedo in azimuth oscillates periodically, circle search means adapted to control the rudder actuator to steer the torpedo in a circle, switch means controlled by the acoustic guidance system to control the rudder actuator to steer the torpedo toward a target detected by the guidance system, means for varying the turning rate of the torpedo responsive to the method of operating of the guidance system and the speed of the torpedo, and control means adapted, under a first condition, to permit said gyroscopic means to control said rudder actuator until the torpedo has traveled a preselected distance, which may be substantially zero, adapted to permit, if the torpedo is launched from below a predetermined depth, said circle search means to control said rudder actuator until the guidance system detects a target, or if the torpedo is launched from above said predetermined depth, and adapted to permit said snaking search means and said gyroscopic means to control the rudder actuator after the torpedo has traveled a minimum distance after being launched; said control means adapted when the guidance means detects a target to permit said switch means to control said rudder actuator, adapted to permit, when the torpedo is launched from a depth greater than said predetermined depth and if the guidance system loses the traget, the circle search means to control said rudder actuator, or adapted to permit, when the torpedo is launched from a depth less than said predetermined depth, and if the guidance system loses the target, the gyroscopic means and the snaking search means to control the actuator if the guidance system is passive and has detected the target for less than a predetermined period of time, or if the guidance system is active and has detected the target within a predetermined range for less than a predetermined period of time, or adapted to permit, when the torpedo is launched from less than said minimum depth, and if the guidance system loses the target, the circle search means to control said rudder actuator if the guidance system is passive and has detected the target for more than said predetermined period of time; or if the guidance system is active and has detected the target within said predetermined range for more than said predetermined period of time, or in a second condition, adapted to permit said gyroscopic means to control the actuator until the torpedo has

traveled a preselected distance after launching, adapted to permit the snaking search means and the gyroscopic means to control the rudder actuator after the torpedo has traveled said preselected distance and until the guidance system detects a target, adapted to permit the switch means to control the rudder actuator after the guidance means detects a target, and adapted to permit the gyroscopic means and the snaking search means to control the rudder actuator if the target is subsequently lost after being detected, when the guidance system is passive, for less than a predetermined period of time, or after being detected, when the guidance system is active, for less than said predetermined period of time within a predetermined minimum range, or to permit the circle search means to control the rudder actuator if the target is

subsequently lost after being detected, when the guidance system is passive, for more than a predetermined period of time, or after being detected, when the guidance system is active, for more than said predetermined period of time within said predetermined minimum range.

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