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[54] TORPEDO CONTROL

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[52] **U.S. Cl.** .... **114/20 R;** 114/25
[51] **Int. Cl.** **F42b 19/00;** F42b 19/04
[58] **Field of Search**...... 114/25, 23, 20 R, 21, 21 W

[56] **References Cited**

UNITED STATES PATENTS

1,816,768	7/1931	Elia	114/23
2,341,287	2/1944	Pookhir et al.	114/23
2,363,363	11/1944	Rubissow	114/23
2,537,929	1/1951	Daley et al	114/25

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EXEMPLARY CLAIM

1. The method of effecting control and guidance of an anti-submarine torpedo of the type having a high yield warhead, said torpedo being launched from a hunter submarine against a submerged target submarine, said warhead when exploded beneath the surface of the water having explosive properties such that the maximum distance at which a predetermined damage inflicting effect occurs increases in a predetermined manner in accordance with the depth at which the warhead is exploded, said method comprising the steps:

a. placing the hunter submarine at a torpedo launching depth and launching the torpedo thereat and thereafter maintaining the hunter submarine at said depth or above until the warhead is exploded, said launching depth being above a predetermined depth from the surface of the water, said explosive properties defining a hunter submarine safety surface of revolution, said surface of revolution being generated by an upwardly convex curve, the upper end of which is rotated about the periphery of a circle on the surface of the water formed around a vertical axis passing through the hunter surmarine, the volume of water within and the volume of water surrounding the hunter submarine safety surface of revolution constituting an unsafe-to-detonate volume of water, and a safe-to-detonate volume of water, respectively,

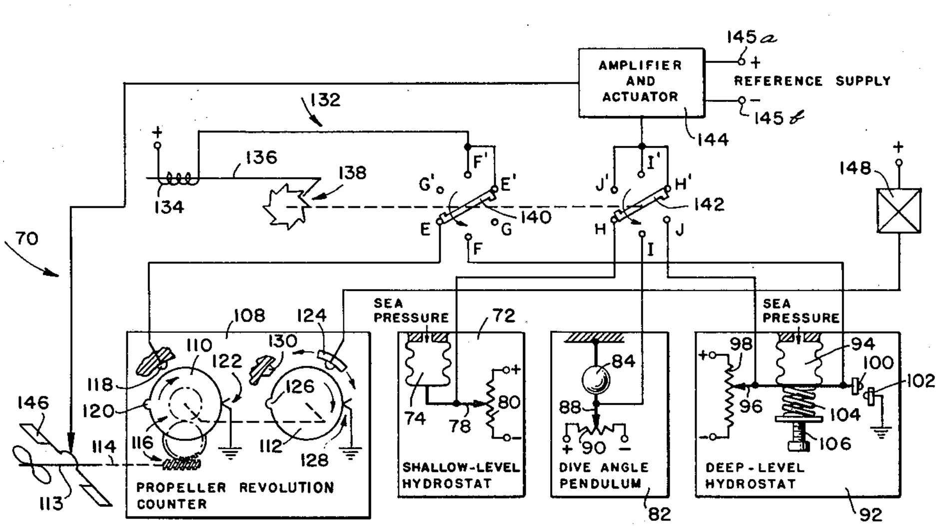
b. guiding the torpedo outwardly from the hunter submarine along a first substantially horizontal course,

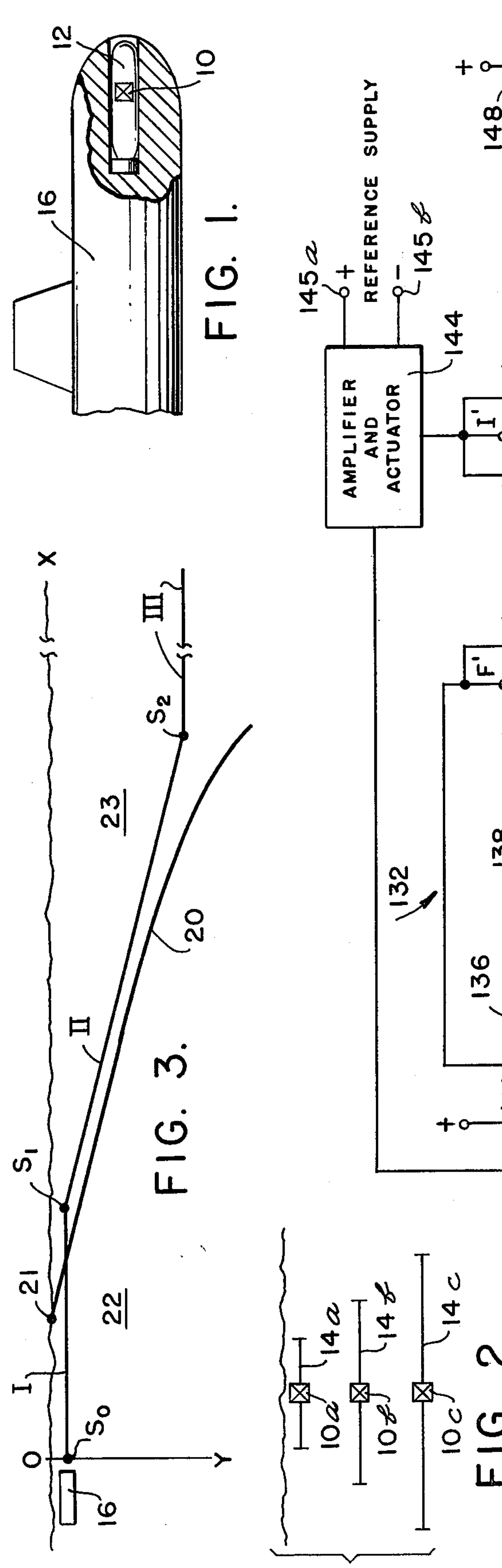
c. guiding said torpedo downwardly and outwardly through the safe-to-detonate volume along a second slant dive course at a fixed dive angle after the torpedo travels across said surface of revolution and into the safe-to-detonate volume,

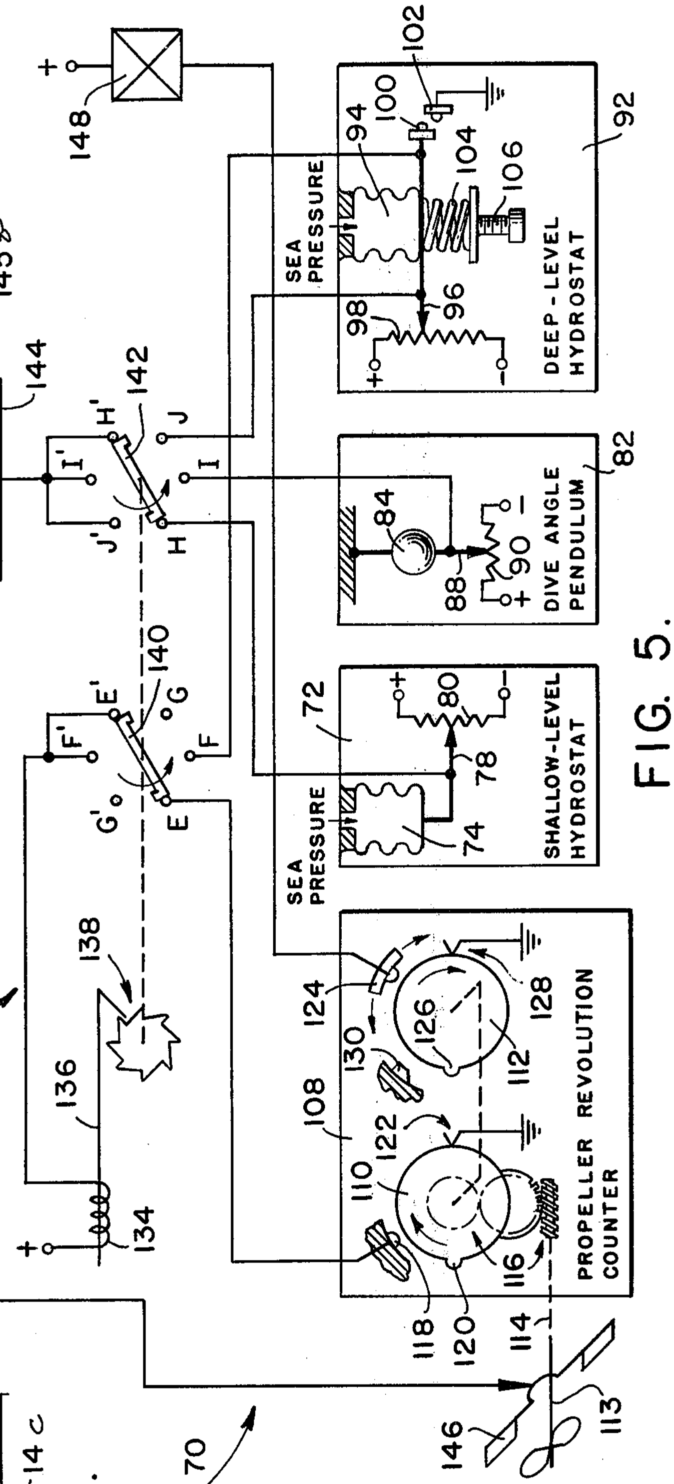
d. guiding the torpedo along a third horizontal course at a desired explosion depth after the torpedo dives to said explosion depth, said desired explosion depth being chosen to provide optimum damage inflicting effects upon the target submarine at various depths within said predetermined range of depths over which the target submarine may maneuver, and

e. detonating the warhead at a desired distance from the hunter submarine along said second or third courses within said safe-to-detonate volume.

3 Claims, 5 Drawing Figures







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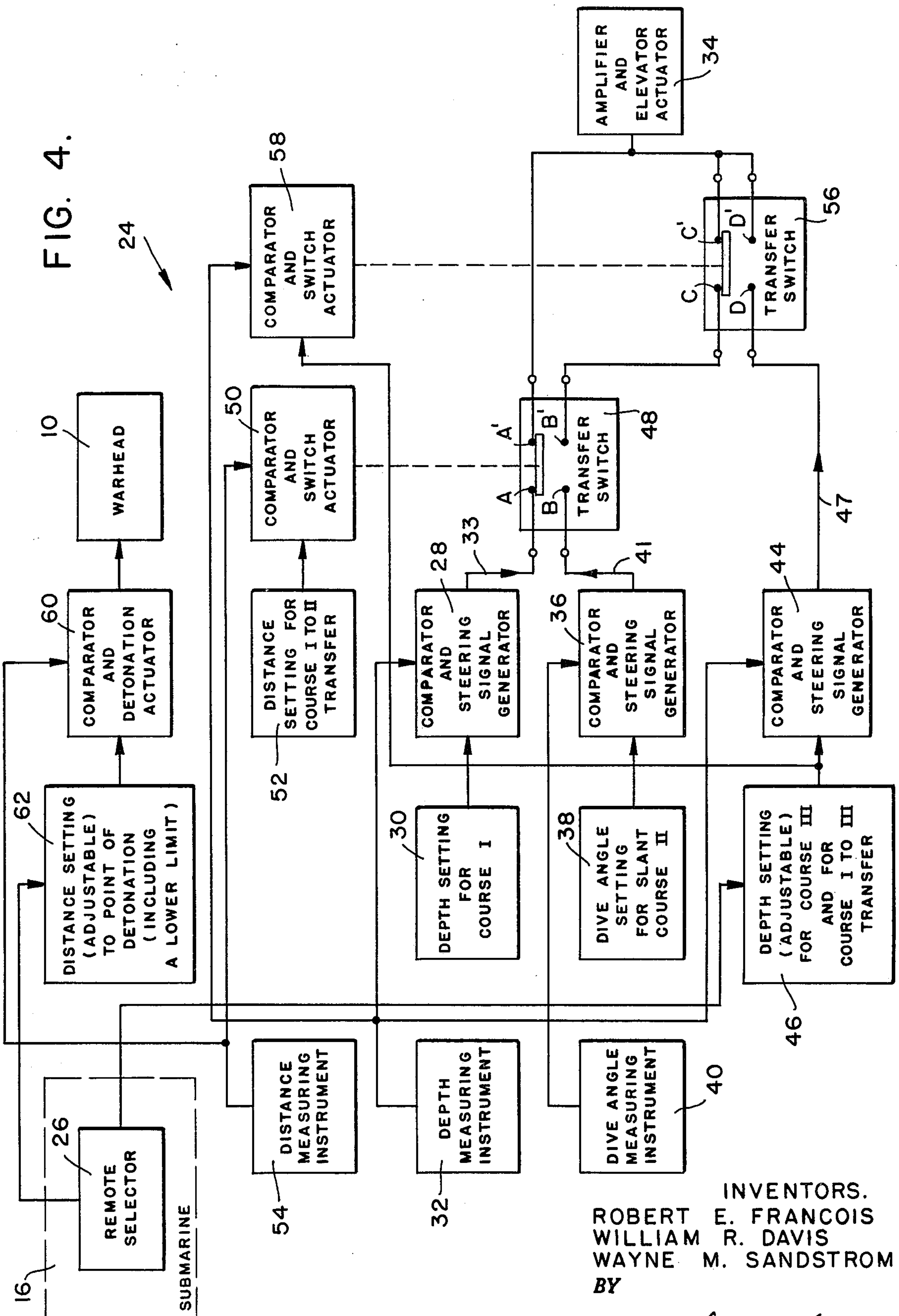

FIG. 4.

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TORPEDO CONTROL

This invention relates to naval torpedoes of the type that produce a high yield explosion, and more particularly to control apparatus for use with same when intended to be fired from a "hunter-killer" submarine.

An important tactical application of a high yield torpedo is in connection with hunter-killer submarine attacks against a submerged enemy submarine. As is well known, a submarine is of relatively frail structure, and with the enormity of the explosive effect of a high yield underwater explosion, the safety of the hunter-killer submarine which launches the high yield torpedo is a major consideration.

An object of the present invention is to provide control apparatus for a torpedo, of the type referred to, which permits warhead detonation at minimum ranges and at depths providing maximum explosive effect.

Another object is to provide control apparatus in accordance with the preceding objective which may be constructed with existing control system components and is simple and reliable in operation.

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

FIG. 1 is a side elevation of a submarine, with portions cut away to show a high yield warhead type torpedo in a launching tube ready to be fired;

FIG. 2 diagrammatically compares the effects of explosions of the high yield torpedo warhead in the torpedo of FIG. 1, at various depths;

FIG. 3 diagrammatically illustrates attack trajectories obtainable with the apparatus of FIGS. 4 and 5 and shows a graphical relationship between minimum standoff distance and depth of explosion, with the ordinate of the graph, OY, in an exaggerated scale;

FIG. 4 is a block diagram of torpedo control apparatus forming the subject of the invention; and FIG. 5 is a schematic diagram of another embodiment of control apparatus.

Referring now to FIGS. 1 and 2, it has been found that the effects from an underwater explosion of a high yield warhead **10** of a torpedo **12** increase as the depth at which the explosion takes place is increased. Thus a series of independent high yield explosions from warheads **10***a*, **10***b*, and **10***c* FIG. 2, detonated at progressively greater depths would produce progressively longer "lethal ranges" **14***a*. **14***b*, and **14***c*. This variation of explosive effect with variation of depth must also be considered from the standpoint of the safety of the submarine **16** that launches the torpedo **12.** In considering such safety of the launching vessel, however, the lethal range **14** is not the factor to employ, since the launching vessel could receive substantial damage even though at ranges greater than the lethal range. Instead, the factor to be employed is the "minimum standoff distance" at which there is no reasonable likelihood of causing undesired damage. Through test findings and analytical techniques it has been determined that curve **20,** FIG. 3 is a representative plot of minimum standoff distance for a submarine **16** that launches a high yield torpedo at point S_o, where the launching submarine remains substantially disposed in the vicinity of point S_o and in a relatively shallow layer of water adjacent the surface until the warhead explodes. Curve **20** is derived from a plot of points with their abscissal values along axis OX representing minimum standoff distance and their ordinal values along axis OY representing depth of explosion. Certain relationships are observable. Curve **20** originates at the surface of the water at a predetermined point **21** and extends outwardly and downwardly therefrom and it has an upwardly convex shape. In three dimensional terms, point **21** defines a circle formed around a vertical axis OY passing through submarine **16,** and curve **20** defines a surface of revolution generated by rotating the curve about the periphery of the circle. This surface of revolution divides the body of water surrounding the submarine into an unsafe-to-detonate zone **22** and a safe-to-detonate zone **23.** As mentioned, curve **20** is a plot for the conditions where submarine **16** lies within a depth layer adjacent the surface. A nominal range of depths for such depth layer is from the surface extending down to a depth of 100 feet. The advantage of remaining in shallow water is that the hull and other equipment of the submarine are less vulnerable to damage from an underwater explosion when at a shallow depth.

Referring now to FIG. 4, disposed in torpedo **12** is apparatus **24** for controlling the torpedo in depth and for detonating warhead **10.** Disposed in launching submarine **16** is remote selector **26** comprising control circuits for presetting certain adjustable elements of apparatus **24,** remote selector **26** being connected to the elements of apparatus **24** through conventional separable connections which become separated after the torpedo leaves the launching tube.

A comparator and steering signal generator **28,** for steering the torpedo at a fixed shallow depth level, has an associated reference unit **30** providing a predetermined reference depth or depth setting. The depth of torpedo **12** during its run is measured by a depth measuring instrument **32,** and comparator **28** compares such depth with the reference depth and produces an error or shallow-level steering signal **33,** in accordance with departures of the depth of torpedo **12** from the depth setting. When steering signal **33,** through switching arrangements to be hereinafter described, is coupled into an amplifier and elevator actuator **34,** it is there amplified and converted into appropriate mechanical motion of the torpedo elevators (not shown) to provide required corrections in depth to bring the depth of the torpedo into correspondence with the depth setting of reference unit **30.** The depth setting of reference unit **30** is a fixed value, nominally within the range of 50 to 100 feet.

In a similar mode of operation, a second comparator and steering signal generator **36,** for steering the torpedo along a slant course, has a reference unit **38** providing a fixed reference dive angle. Comparator **36** compares the dive angle of the torpedo, supplied by a dive angle measuring instrument **40,** with the predetermined reference to produce a slant course steering signal **41** to steer the torpedo along a dive course having a fixed dive angle when comparator **36** is connected to amplifier and elevator actuator **34.** The part that slant course signal **41** plays in the overall scheme of control will become apparent as the description proceeds. For the moment it is sufficient to state that a slant-course II, FIG. 3, is initiated at a predetermined point S_1 somewhat beyond the horozontal distance from launch point S_o to curve **20** and that the dive angle of reference unit **38** is so chosen that the torpedo trajectory will always be beyond the upwardly convex curve **20**. In a preferred form the angle of dive is 5½°.

Also in a similar mode of operation, the third comparator and signal generator **44**, for steering the torpedo at a fixed deep level, has an associated preselectively adjustable reference unit **46** providing a predetermined depth setting. Comparator **44** compares the depth indicated by instrument **32** with the reference depth and produces a deep-level steering signal **47**. The depth setting of reference unit **46** is chosen to optimize explosive effectiveness of the warhead charge **10** in consideration of various factors including: (1) the aforementioned variation of lethal range in accordance with depth of explosion, (2) the depth limit of the torpedo due to its hull and equipment limitations, and (3) the range of depths within which an enemy submarine is believed to be constrained by reason of limits in its hull structure. Normally the setting of reference unit **46** remains fixed at such optimum value. However, to accommodate depths of the ocean floor which may be less than such optimum value, reference unit **46** is made adjustable and may be preset to lesser depths from remote control **26**.

A transfer switch **48** has a first set of input and output contacts A,A′ and a second set of input and output contacts B,B′, with contacts A,A′ initially in an electrically closed condition and contacts B,B′ in an electrically open condition. Switch **48** is operatively controlled by a comparator and switch actuator **50** having an associated reference unit **52** which provides a predetermined distance setting at which comparator **50** is actuated. When the distance the torpedo has traveled from its point of launching S_o, FIG. **3**, reaches the value of predetermined setting of unit **52**, as measured by a distance measuring instrument **54**, comparator **50** actuates transfer switch **48** into a condition in which contacts A,A′ are open and contacts B,B′ are closed. The distance setting of reference unit **52** is the distance from the launching point S_o to a point S_1 that is somewhat beyond a horizontal distance from the launching point to curve **20**.

A similar transfer switch **56** has a set of contacts C,C′ in initially closed condition and a set of contacts D,D′ in an initially open condition and is controlled by a comparator and switch actuator **58**. Reference unit **46** which is the same unit that provides the depth setting for steering signal **41** provides the reference depth at which actuator **58** is actuated. When depth measuring instrument **32**, indicates that the torpedo has reached a point S_2, FIG. **3**, at the depth setting of reference unit **46**, comparator **58** actuates transfer switch **56** into a condition in which contacts C,C′ are open and contacts D,D′ are closed.

To complete the circuits for connecting the various steering signals to amplifier and elevator actuator **34**, the output of unit **28** is connected to contact A, the output of unit **36** is connected to contact B, contact B′ is connected to contact C, the output of unit **44** is connected to contact D, and contacts A′, C′ and D′ are connected to the input of unit **34**.

Operation of the portion of apparatus **24** thus described is such that shallow-level steering signal **33** from comparator **28** is initially connected to amplifier and actuator **34** through closed contacts A,A′, and upon launch of torpedo **12** at point S_o, FIG. 3, the torpedo follows at the depth setting of unit **30**. After the torpedo has traveled to point S_1, switch actuator **50**

opens contacts A,A′ which disconnects steering signal **31**, and closes contact B,B′ which connects slant dive steering signal **41** to amplifier and actuator **34** through initially closed contacts C,C′ of switch **56**. Thereupon the torpedo is steered along slant course II with the fixed dive angle called for by unit **38**. After the torpedo has dived along slant course II to a point S_2, having a depth equal to the present depth of reference unit **46**, switch actuator **58** opens contacts C,C′, which disconnects signal **41**, and closes contacts D,D′ which connects deep-level signal **47** to unit **34**. Thereafter the torpedo remains at a fixed depth course III under control of the signal from unit **44**.

Warhead **10** may be detonated at any preselectable point along slant course II or deep level III by means of a comparator and detonation actuator **60** and an associated preselectively adjustable reference unit **62** which provides a predetermined distance setting at which detonation of the warhead takes place. When the distance measuring instrument indicates that the torpedo has traveled a distance equal to the setting of reference unit **62**, the comparator **60** fires the warhead. It is to be understood that the slope of slant course II of the torpedo trajectory is so slight the distance traveled may be considered the range for purpose of fire control without need to compensate for the slope. Reference unit **62** is adjusted from remote selector **26** prior to launching of torpedo **12**. However, the adjustment has a lower limit equal to the distance from launch point S_o to point S_1, to prevent possible detonation in the unsafe-to-detonate zone **22**. If desired, however, the warhead could if necessary be detonated at any point beyond the horozontal distance from point S_o to curve **20**.

It will be understood that conventional torpedo control apparatus for steering the torpedo in azimuth is employed concurrently with the depth steering controls described. Also, to avoid any possibility of damage to submarine **16** through a circular run of the torpedo, conventional anticircular run cutout circuits are employed to disarm the torpedo if it deviates from its predetermined azimuth course by an undesired amount.

It will be apparent that at short ranges control apparatus **24** maintains the torpedo in shallow water, thereby permitting the torpedo to be used at minimum standoff distances; at intermediate ranges slant course II provides maximum lethal range of the torpedo consistent with safety of the launching submarine; and at long ranges the torpedo runs at a relative deep level giving optimum lethal range to its warhead. Also, the maneuverability and accuracy requirements of the trajectory scheme of the present invention are well within the capability of existing torpedo control components, and the inherent simplicity of the system provides manneverability high reliability and safety to the launching submarine.

Referring now to FIG. **5**, another embodiment further illustrative of the invention comprises mechanism **70** carried by a torpedo. A shallow-level hydrostat unit **72** comprises a hydrostatic bellows **74** which expands and contracts under changes in sea pressure and an associated potentiometer type voltage pick-off including a wiper arm **78** affixed to the movable end of the bellows **74** and a stationary potentiometer winding **80**. Potentiometer winding **80** is so placed that wiper **78** is at its electrical center or reference position when the sea pressure corresponds to the predetermined depth of course I, FIG. 3. A dive angle pendulum unit **82** comprises a pendulum **84** and an associated voltage pick-off including a wiper arm **88** affixed to the pendulum for movement therewith and a stationary potentiometer winding **90.** Winding **90** is so placed that wiper arm **88** engages its electrical center when the torpedo is at the predetermined angle of slant course II. A preselectably adjustable deep-level hydrostat unit **92** comprises an adjustable spring loaded bellows **94,** a potentiometer type voltage pick-off having a wiper **96** and a stationary winding **98,** and a set of contacts comprising a contact **100** carried by the bellows and a stationary contact **102.** Bellows **94** is of the adjustable type which act against the force of a compressed spring **104,** and is so calibrated that a sea pressure corresponding to the depth of deep level course III causes potentiometer arm **96** to engage the center of the winding **98** and contact **100** to engage contact **102** when adjustment screw **106** is in its full tight position. By slacking off screw **106,** unit **92** may be preselectably adjusted to decrease the depth of deep-level course III in order to accommodate shallow ocean floors.

A propeller revolution counting unit **108** comprises first timing wheel **110** and second preselectively adjustable timing wheel **112,** both wheels being coupled to torpedo propeller shaft **113** through a coupling, symbolically shown by dashed line **114,** and reduction gears **116.** Since a torpedo moves a substantially constant distance for each revolution of its propeller, the number of turns of the propeller is a measure of the distance the torpedo has traveled from its point of launching. A stationary contact **118** is disposed adjacent the periphery of wheel **110** where it may be engaged by a contact **120** on the periphery of wheel **110** after the wheel has turned a predetermined angular distance corresponding to travel by the torpedo from launch point S_0 to point S_1, FIG. **3.** Engagement of contacts **118** and **120** returns contact **118** to ground potential through a wiper contact **122.**

Similarly, a selectively positionable contact **124** is disposed adjacent the periphery of timing wheel **112** in position where it may be engaged by a contact **126** on the periphery of the wheel to return contact **124** to ground through a wiping contact **128.** Contact **124** is movable between angular positions corresponding to various distances along slant course II and deep-level course III. A limit stop **130** provides a lower limit of adjustment corresponding to the distance from launch point S_0 to point S_1.

A solenoid operated selector switch **132** is controlled by action of a solenoid **134.** Each time solenoid **134** is energized, an armature **136** is attracted operating a pawl and ratchet **138,** which causes a first and second switching arm **140, 142** to each "step" or rotate one-sixth of a revolution in a counter-clockwise direction. Three sets of diametrically opposed contacts E,E', F,F', G,G', are equiangularly placed around the circle described by arm **140** in positions engageable with corresponding stepping positions of arm **140,** and in similar manner, three sets of contacts H,H', I,I', J,J', are placed about the circle of revolution of arm **142.** Stationary contact **118** of timing wheel **110** is connected to contact E, and contact **100** of the deep-level hydrostat **92** is connected to contact F. Contacts E' and F' are connected, via a common conductor, to solenoid **134,** and thence to a positive power source. Potentiometer wiper **78** of the shallow-level hydrostat **72** is connected to contact H, potentiometer wiper **88** of the pendulum unit **82** is connected to contact I, and potentiometer wiper **96** of the deep-level hydrostat **92** is connected to contact J. Contacts H', I' and J' are connected, via a common conductor, to the input of an amplifier and actuator device **144.** Device **144** has a reference input comprising input terminals **145***a*, **145***b* and a reference voltage source applies equal positive and negative potentials, relative to ground, to terminals **145***a*, **145***b*, respectively. The reference voltage source is also connected across potentiometer windings **80, 90** and **98,** so that the center point of these windings are essentially at a zero potential. Thus any deviation or departure of the torpedo from the predetermined depth or dive angle setting of units **72, 82** and **92** causes their respective wiper arms to be at a potential having a polarity and magnitude representing the magnitude and direction of deviation. Amplifier actuator **144** amplifies such voltage and converts it into appropriate mechanical movement of depth control surfaces **146** to bring about a correction in depth steering to cause the torpedo to return to the predetermined depth or dive angle called for by the one of units **72, 82** or **92** connected to the actuator at the time.

Contact **124** adjacent timing wheel **112** is series connected with a warhead detonations circuit **148** and a positive source of potential, forming a firing circuit to detonate the warhead upon engagement of contacts **124** and **126.**

The operation of control mechanism **70** is such that contacts H,H' of selector switch **132** initially apply the potential at wiper arm **78** of unit **72** of the amplifier actuator **144,** causing the torpedo to steer along a shallow-level course I upon being launched. Upon the propeller having turned through a number of revolutions corresponding to the distance of travel to point S_1, contact **120** on timing wheel **110** engages contact **118.** This causes solenoid **134** of selector switch **132** to be energized through contacts E,E' and steps arms **140** and **142** to their next position. Thereupon the potential at wiper arm **88** is applied to amplifier and actuator **144** through contacts I,I' causing the torpedo to follow slant course II. When, in the course of the dive of the torpedo along slant course II, the hydrostatic sea pressure becomes sufficient to cause bellows **94** to move contact **100** into engagement with contact **102,** solenoid **134** is again energized and arms **140, 142** are stepped. Thereafter the potential at wiper arm **96** is applied to amplifier and actuator **144** through contacts J,J' steering the torpedo along deep-level course III. When at some point along slant course II or deep level course III, depending on the position of adjustable contact **124,** the latter engages contact **126** the warhead detonator **148** is actuated and the warhead explodes.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. For example, a wire guided type of torpedo such as disclosed in copending application, Ser. No. 66,366, filed by Julian H. Ray, 31 October 1960, and entitled "Wire Guided Torpedo," may be employed. In such case remote selector **26,** FIG. **4,** could be in continuous communication with torpedo to provide selective control of the adjustment of elements of the apparatus **24** throughout the torpedo run. Also with such a guidance wire link, certain elements of the apparatus shown as in the torpedo could be located at a remote station. 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. The method of effecting control and guidance of an anti-submarine torpedo of the type having a high yield warhead, said torpedo being launched from a hunter submarine against a submerged target submarine, said warhead when exploded beneath the surface of the water having explosive properties such that the maximum distance at which a predetermined damage inflicting effect occurs increases in a predetermined manner in accordance with the depth at which the warhead is exploded, said method comprising the steps:

a. placing the hunter submarine at a torpedo launching depth and launching the torpedo thereat and thereafter maintaining the hunter submarine at said depth or above until the warhead is exploded, said launching depth being above a predetermined depth from the surface of the water, said explosive properties defining a hunter submarine safety surface of revolution, said surface of revolution being generated by an upwardly convex curve, the upper end of which is rotated about the periphery of a circle on the surface of the water formed around a vertical axis passing through the hunter submarine, the volume of water within and the volume of water surrounding the hunter submarine safety surface of revolution constituting an unsafe-to-detonate volume of water, and a safe-to-detonate volume of water, respectively,

b. guiding the torpedo outwardly from the hunter submarine along a first substantially horizontal course,

c. guiding said torpedo downwardly and outwardly through the safe-to-detonate volume along a second slant dive course at a fixed dive angle after the torpedo travels across said surface of revolution and into the safe-to-detonate volume,

d. guiding the torpedo along a third horizontal course at a desired explosion depth after the torpedo dives to said explosion depth, said desired explosion depth being chosen to provide optimum damage inflicting effects upon the target submarine at various depths within said predetermined range of depths over which the target submarine may maneuver, and

e. detonating the warhead at a desired distance from the hunter submarine along said second or third courses within said safe-to-detonate volume.

2. In combination with a torpedo adapted to be launched from a hunter submarine disposed at a depth above a predetermined depth from the surface of the water, and against a submerged target submarine which may maneuver within a predetermined range of depths,

a. a high yield warhead, said warhead when exploded beneath the surface of the water having explosive properties such that the maximum distance at which a predetermined damage inflicting effect occurs increases in a predetermined manner in accordance with the depth at which the warhead is exploded, said explosive properties and said predetermined range within which the target submarine may maneuver defining a desired depth at which to explode the warhead to produce optimum damage inflicting effects upon the targe target at various depths within said predetermined range of depths,

d. a depth of explosion placement and steering programmer for sequentially initiating various courses in depth, said explosive properties of the warhead defining a hunter submarine safety surface of revolution, said surface of revolution being generated by an upwardly convex curve, the upper end of which is rotated about the periphery of a circle on the surface of the water formed around a vertical axis passing through the hunter surmarine, the volume of water disposed within and the volume of water surrounding the hunter submarine safety surface of revolution constituting an unsafe-to-detonate volume of water, and a safe-to-detonate volume of water, respectively, said programmer being operative to steer said torpedo outwardly from the submarine along a first substantially horizontal course until the torpedo has traveled across said surface of revolution and a predetermined horizontal distance beyond the surface of revolution into the safe-to-detonate volume of water, thence operative to steer the torpedo along a second slant dive course at a fixed dive angle downwardly and outwardly through the safe-to-detonate volume until after the torpedo has reached said desired depth at which to explode the warhead, and thence operative to steer the torpedo along a third horizontal course through said safe-to-detonate volume, and

c. adjustable means for detonating the warhead at a desired distance from the hunter submarine along the second or third courses within said safe-to-detonate volume.

3. Apparatus in accordance with claim 2, wherein said torpedo is of the type having a propulsion system including a propeller, wherein,

d. the magnitude of fixed dive angle of the second slant dive course is approximately 5°.

e. said depth of explosion placement and steering programmer and said adjustable means for detonating the warhead both being responsive to number of revolutions of the propeller.

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