

[54] METHOD AND APPARATUS FOR DESTROYING SUBMARINES

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[22] Filed: **Oct. 28, 1958**

[21] Appl. No.: **770,235**

[52] U.S. Cl. **114/20 A, 114/21 W, 114/23, 60/253, 60/263, 60/271, 60/230**

[51] Int. Cl. **F42b 19/00**

[58] Field of Search **89/1.7 B; 114/20, 23, 21 W, 114/21 R**

[56] **References Cited****OTHER PUBLICATIONS**

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[57] **ABSTRACT**

A submarine torpedo tube launched missile type weapon having a water-to-air-to-water flight path, comprising, a covered rocket motor wherein the rocket motor cover is explosively released by explosive bolt devices subsequent to launching and during an initial portion of water travel flight. The rocket propelled weapon incorporates electrically controlled vanes for water guidance by influence over the exhaust discharge of the rocket motor together with separation means for severance of the rocket motor portion from the missile during air travel and guidance system controlled aerodynamic control surfaces for guidance to a predetermined water re-entry point.

8 Claims, 13 Drawing Figures

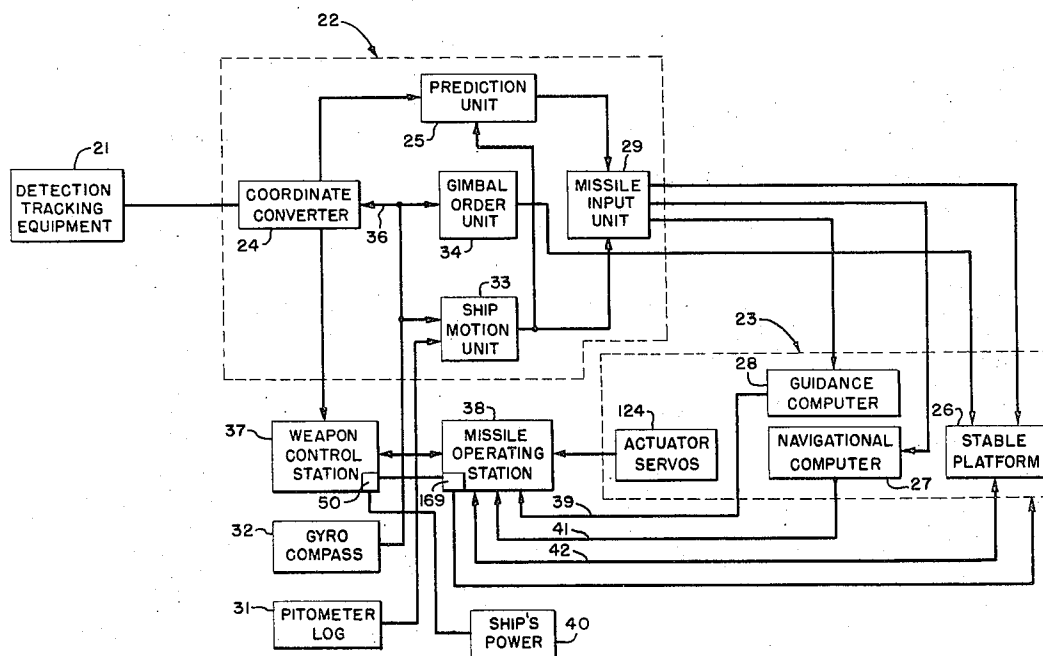


FIG.1.

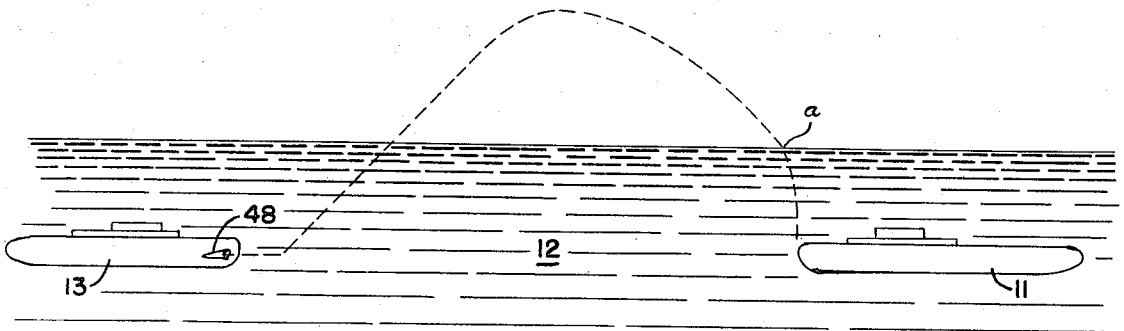


FIG.4a.

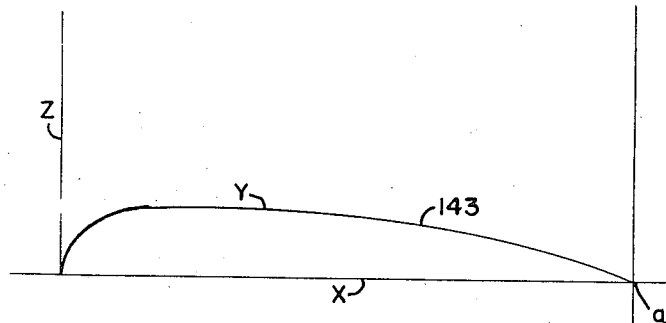
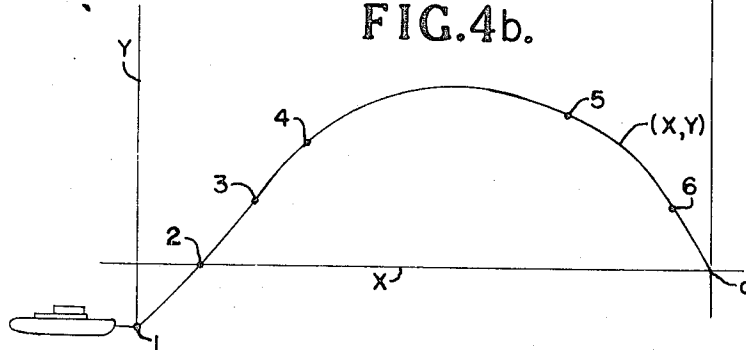


FIG.4b.



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FIG.5.

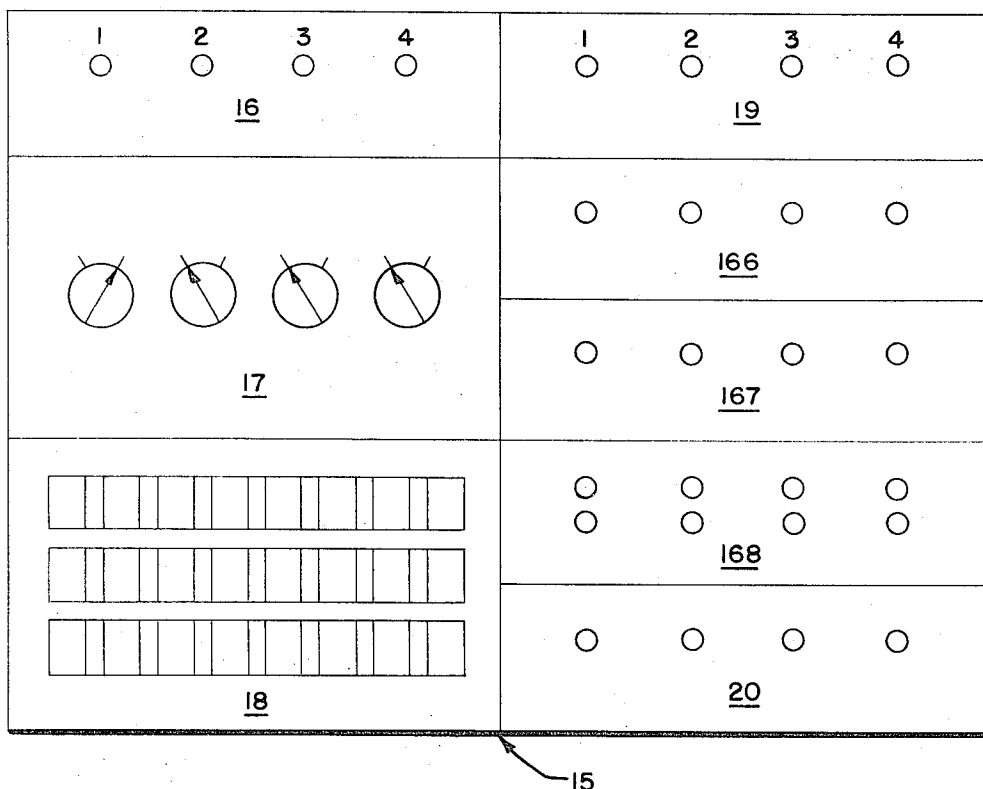
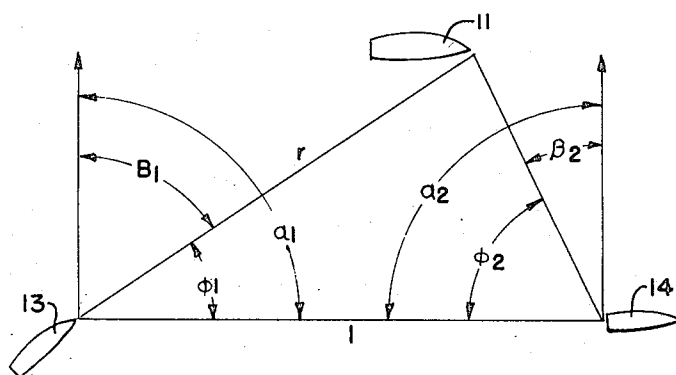


FIG.2.



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FIG. 8.

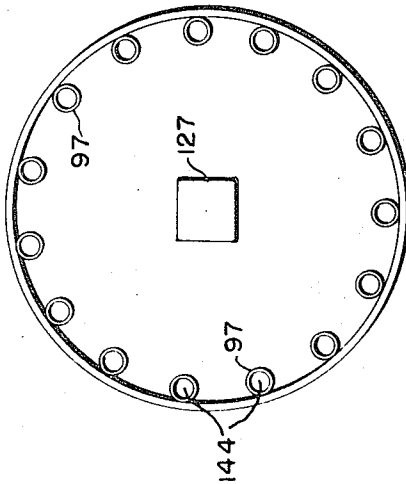


FIG. 7.

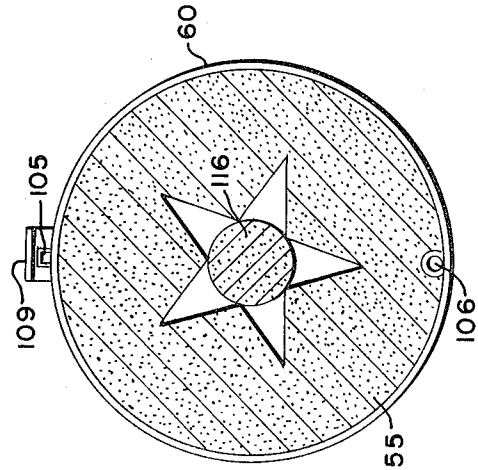
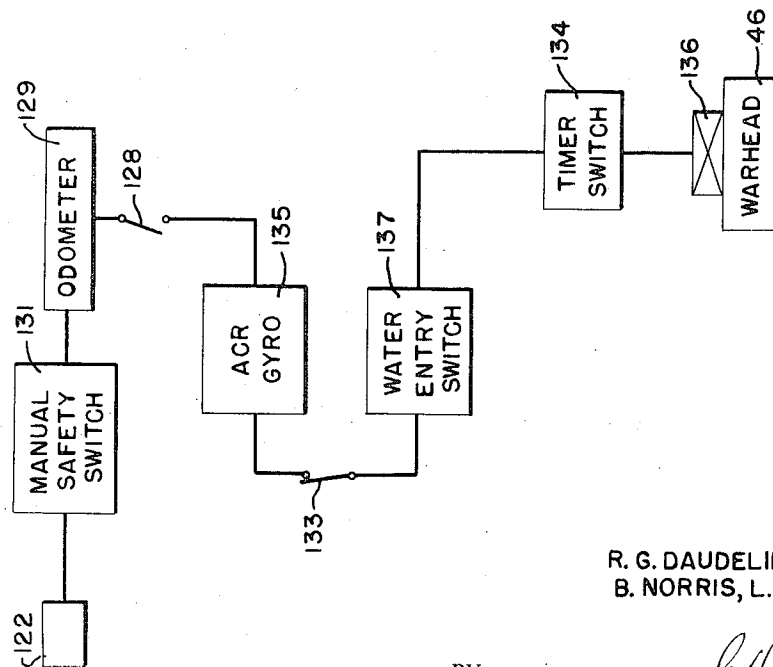


FIG. 9.

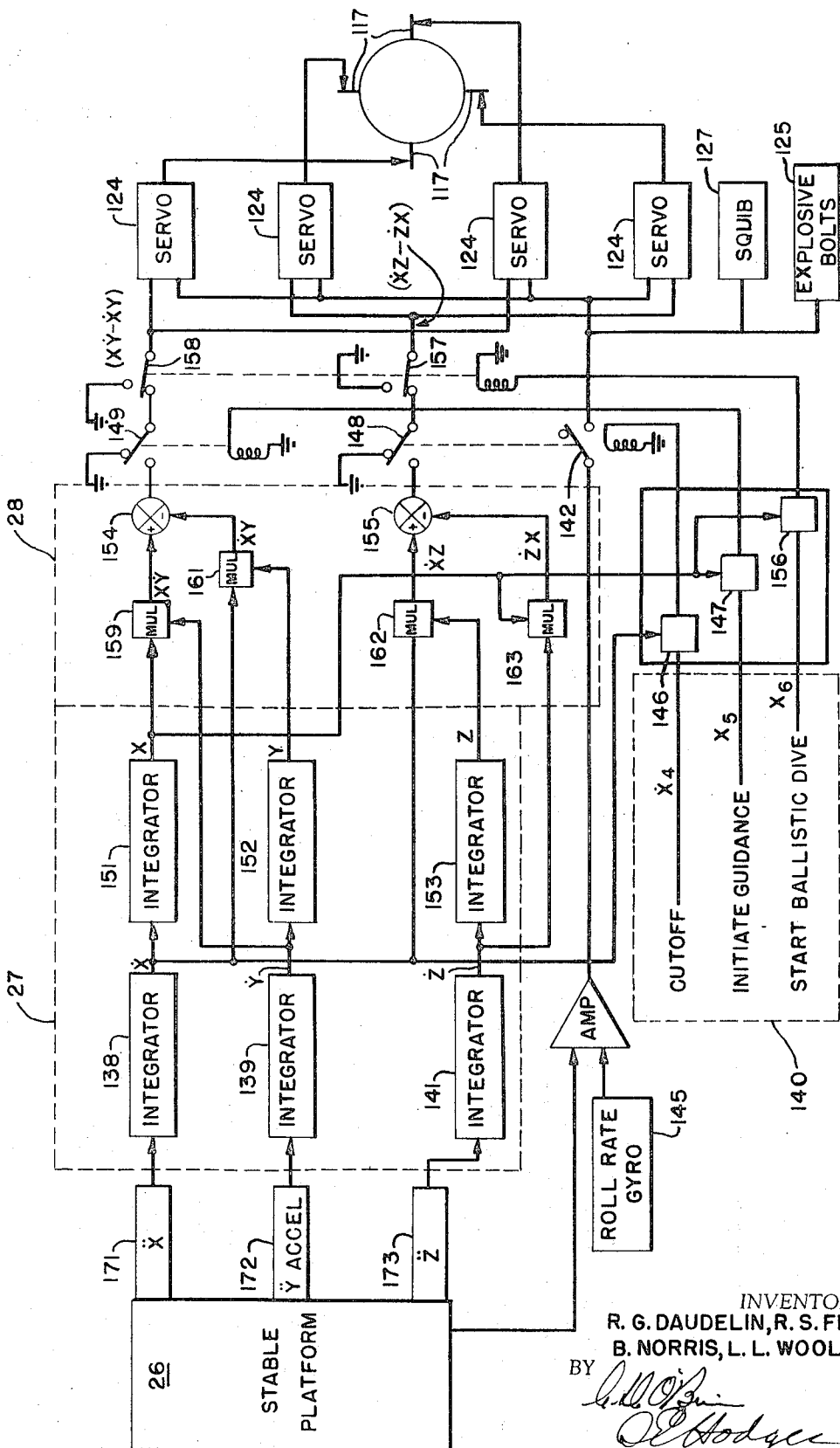


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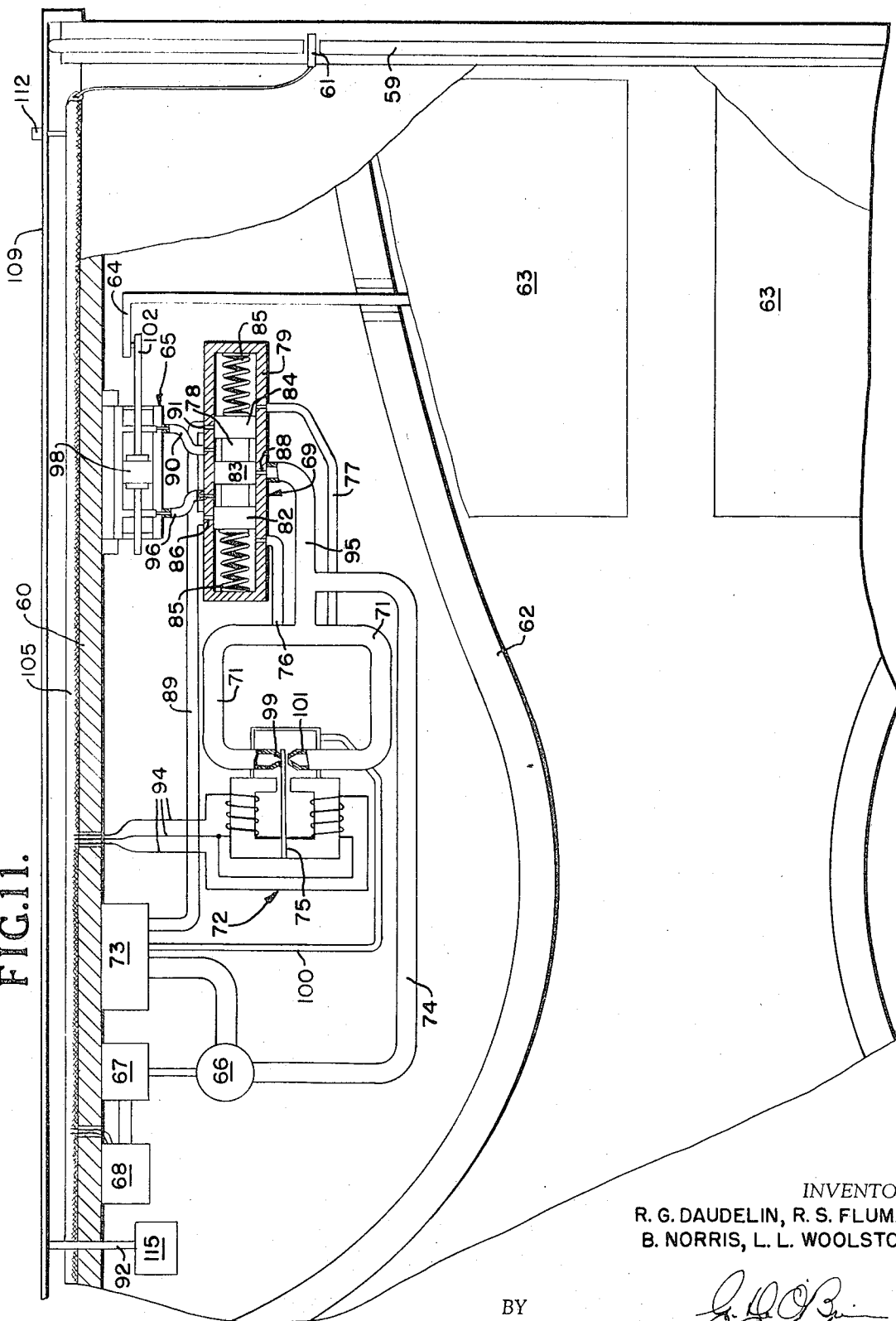
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FIG. 10.



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FIG. 11.



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METHOD AND APPARATUS FOR DESTROYING SUBMARINES

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This application relates to a novel rocket propelled depth bomb or torpedo and a method of attacking and sinking enemy submarines by utilizing this weapon.

The modern submarine has been so modified and improved in the past decade that, in many respects, it now possesses marked tactical advantages over the most up-to-date surface craft. A submarine can travel under water at high speed, undetectable by the radar of aircraft and able to effectively hide from the sonar of surface vessels by darting into banks of lower temperature water found at various depths of the ocean. Furthermore, a sub having a nuclear power plant may remain submerged for extended periods of time, thereby minimizing the already slight chance of detection. Such nuclear subs are capable of establishing a picket off the coast of a country and, by surfacing at night, fire intermediate range guided missiles directed at strategic targets within the country. Since the missiles would travel relatively short distances compared with intercontinental missiles they could be delivered with greater accuracy and would be less vulnerable to active countermeasures.

One scheme proposed as the defense against such submarines is to equip surface craft or killer-type submarines with homing torpedoes capable of tracking down and destroying an enemy submarine. This would not be completely effective and is subject to two major deficiencies: the homing torpedo may be detected by the target submarine which may then take appropriate action to evade the torpedo or destroy it; the second drawback is that the target sub is alerted to the presence of the attacking vessel and may engage it on substantially equal or better terms upon detecting the homing torpedo. The long running time of the torpedo is disadvantageous since the enemy has a long time to evade or effect countermeasures.

Accordingly, one object of this invention is the provision of an improved method of attacking and destroying enemy submarines with a weapon launched from a killer submarine which method minimizes the possibility of detection of the weapon by the target submarines.

Another object is to provide a new and novel method of attacking a submerged submarine which method does not allow the target sub sufficient time to take evasive action.

Still another object is to provide an underwater-to-underwater inertially guided missile.

A further object is the provision of a new and improved rocket propelled depth bomb or torpedo suitable for launching from a torpedo tube of a submerged submarine and which may be fired from a conventional tube without substantial modification of the firing submarine.

Still another object is the provision of a new and improved rocket propelled depth bomb which may be prepared for firing with a minimum of preparation time.

These and many other objects will become more readily apparent when the following specification is

read and considered together with the appended drawings wherein like numerals designate like or similar parts throughout the various views and in which:

FIG. 1 is a view showing the trajectory the weapon follows from the hunter submarine to the target sub;

FIG. 2 illustrates one mode of determining the range and bearing to the target;

FIG. 3 is a block diagram of a weapon system embodying the principles of this invention;

FIGS. 4a and 4b illustrate in detail the missile trajectory;

FIG. 5 illustrates a typical control panel at the weapon control station;

FIGS. 6a and 6a are views partly in section of a missile constructed in accordance with the principles of this invention;

FIG. 7 is a section taken along line 7—7 of FIG. 6b;

FIG. 8 is a section taken along line 8—8 of FIG. 6b;

FIG. 9 is a block diagram of the safing and arming section of the missile;

FIG. 10 is a block diagram of the missile guidance package; and

FIG. 11 illustrates the jet vane actuating system in detail.

For the sake of simplicity, this invention will be described with reference to but one embodiment wherein the pay load is a depth bomb; it being understood, however, the pay load may also be a homing torpedo which would seek out the target sub after water reentry.

Briefly, the instant invention embodies a method which involves detecting a submerged target, computing the course of the target to determine a predicted collision point, and launching a depth bomb from a killer submarine in the same manner as the conventional torpedo is launched. The depth bomb has a rocket motor which is automatically ignited at a safe distance from the attacking killer submarine. The rocket is programmed so that it moves out of the water and flies through the air during the major portion of the trajectory and reenters the water at a point calculated to be within lethal range of the target. Since the depth bomb completes most of its flight in the air it is extremely difficult for the target submarine to detect it. Furthermore, the time of flight is relatively short so that it is improbable that the target sub could escape even if it changed its course after the weapon was fired. The depth bomb can be launched as soon as the predicted future position of the target is computed by the attacking submarine because it is fired in the same manner as a conventional torpedo so that the attacking submarine requires only a minimum of time to prepare the weapon for launching. Utilizing a warhead which has a large lethal radius, target prediction may not be necessary at the shorter ranges in order to effect a reasonable kill probability.

Referring now with greater particularity to FIG. 1, the target submarine 11 is shown running submerged through a body of water 12 while the killer submarine 13 is maneuvering at distances up to about 70 miles [second sonar convergence zone] from the target 11. In order to determine the location of submarine 11, the killer sub 13 may employ, for example, a sonic detecting device. An active sonar system, one in which the sub 13 emits an acoustic signal and receives an echo pulse from the target, may be utilized. A suitable active

system is one having a low frequency high power sonar gear and adapted to utilize convergence zone, surface channel, and/or the bottom reflection method of acoustic propagation. This is accomplished by incorporating into a conventional projector and hydrophone array appropriate vertical and horizontal beam widths and means for tilting the transducers. Active sonar permits the submarine 13 to determine the bearing and range of submarine 11 but the disadvantage in the use of active sonar is that the target 11 may become alerted to the presence of submarine 13.

Passive sonar also may be used to detect the position of a cavitating vessel. A passive acoustic ranging system which gives both bearing and range to the target may be employed wherein range is obtained by measuring the radius of curvature of the arriving wave front pulse. Outputs of three hydrophones equally spaced on the line are processed in such a way that two correlograms are displayed simultaneously on an oscilloscope to provide bearing and range information. Such a system is described in detail in the copending application of Charles B. Brown Ser. No. 298,487 filed July 11, 1952 and which matured into U.S. Pat. No. 3,304,495 on Feb. 14, 1967.

Although this system gives bearing and range data suitable for fire control at distances up to about 20,000 yards, the radius of curvature of the approaching acoustic wave front at ranges above 20,000 yards is too large for indicating the range with sufficient accuracy to provide adequate target location information. Accordingly, if the depth bomb is a longer range weapon, it is necessary to modify existing passive sonar systems in order to obtain bearing and range data at greater distances.

A triangulation system employing passive sonar to provide reliable fire control data at greater ranges is shown in FIG. 2. This system requires two submarines 13 and 14 both equipped with passive sonar or two hydrophones bow and stern for making bearing determinations. Submarine 14 may carry rocket propelled depth bombs as does submarine 13; it may carry intermediate range missiles and utilize submarine 13 as protection against enemy submarines, or its sole function may be to establish the bearing and range triangle. These various functions will of course be determined by the mission of the subs 13 and 14. Submarine 13 measures the difference ϕ_1 between the bearing to the friendly submarine 14, α_1 , and the bearing to target 11, β_1 . Similarly, sub 14 measures the difference ϕ_2 between the bearing α_2 to sub 13 and the bearing to the target sub β_2 ; this information is communicated to sub 13 so that a solution of the bearing and range triangle may be computed. Communication between subs 13 and 14 and the determination of base line "1" can be made by transmitting from sub 13 a coded noise-like acoustic signal which, after reception by the friendly sub 14 may be cross correlated with an identical noise-like signal. The time schedule is controlled by a pair of accurate clocks [not shown] one in each of the submarines 13 and 14 and serve to synchronize the separate noise generators. A knowledge of the average velocity of sound through the water establishes the length of line 1. Knowledge of 1 , β_1 and β_2 permits the calculation of r , the range from the submarine 13 to target 11.

It may even be desirable to construct a detecting system across ocean passages by planting nuclear powered

sound sources at accurately determined points on the ocean floor. Echo detection and target location could then be performed passively by submarines stationed in the area. This method would have the advantages of the active system without revealing the presence of the monitoring submarines.

It should be borne in mind that each of the above systems has certain inherent advantages and disadvantages for that reason any of the systems or any combination of one or more systems may be employed to locate the target. Although the detection and location system per se forms no part of the instant invention, a few of the practical systems have been described in general terms. We do not intend to limit the scope of this invention by thus enumerating a few of the many existing systems. Rather, it should be apparent to anyone skilled in this art that the selection of one or more systems utilizing sonar, periscope, or radio link to air or surface craft depends upon which of the advantages and disadvantages of the various systems are deemed to be tactically controlling at the time of selection.

The target detecting equipment, indicated generally at 21 in FIG. 3, furnishes the target information to the fire control system of the submarine which includes a shipboard computer 22 and certain shipboard controls and instruments. The bearing and range of the target is supplied to a coordinate converter 24 which translates the information into signals indicative of the target's position in a selected space coordinate system which preferably has its origin at the water reentry point a . These signals are continuously fed into an integrating prediction unit 25 which computes a predicted position of the target after a time interval equal to the missile time of flight. A predicted position signal is supplied, via a missile input unit 29, to the missile stable platform 26, navigational computer 27 and the guidance computer 28 in the missile guidance section 23. The missile input unit 29 shown in FIG. 3 is electrically connected via cable 106 to the input connector 103 shown of FIG. 6b. Speed, pitch, and roll data of the missile launching killer submarine 13 are fed from the pitometer log 31 and the ship's gyro compass 32 to the prediction unit 25 via a ship's motion unit 33 in the shipboard computer 22 thereby providing a continuous correction to the predicted target position which compensates for movement of submarine 13.

In order to assure that the stable platform azimuth for the missile is level at all times, the ship's gyro compass 32 also provides a level and cross-level signal to the gimbal order unit 34 in shipboard computer 22 to establish a proper correction in the stable platform 26 in missile guidance section 23, it being understood that the guide studs or lugs 35 [see FIGS. 6a and 6b] align the missile in the torpedo tube in a predetermined fixed manner with respect to the sub 13. To minimize hunting, a feedback loop 36 is also established between the coordinate converter 24 and the gimbal order unit 34 in shipboard computer 22. Another output from the coordinate converter 24 is fed into the shipboard weapon control station 37 which provides signals to the missile operating station 38 of the submarine. Missile operating station 38 also receives signals via lines 39, 41 and 42 from the missile guidance section 23 to indicate the state of readiness of the missile by means of a display panel 15 [see FIG. 5] which indicates which of the missile servo mechanisms and the gyroscopes are functioning properly and when the missile is warmed up suffi-

ciently for firing. The missile operating station 38 monitors the progress in readying the missile and repeats back to weapon control station 37 as important stages in the missile count down are reached. The control panel 15, FIG. 5, of the missile operating station 38 includes several displays and switches for each of the torpedo tubes. These displays include an indicator 16 showing whether the tube door is open or closed; a missile power switch 17 which connects the guidance equipment, arming circuits, distance and direction guarantee devices of the missile [described hereinafter] to the ship's power so that the missile circuits become operative and are stabilized on the ship's power plant 40, FIG. 3, rather than dissipating missile internal power before launching; indicators 18 which show the speed of rotation of the missile gyros; a display 19 to indicate whether the "missile internal power" switch 50, FIG. 3, in weapon control station 37 is "on." There are also indicators 166, 167 and 168 which are energized when the various servos and the input quantities of the missile are settled. The status of these various servos and input quantities is presented to the bridge by monitoring the error voltages in the missile circuitry, so that when the error is less than a specified level a relay [not shown] is closed lighting an appropriate indicator on the panel; a missile status switch 20 is thrown manually to "ready to fire position" when all the indicators on the missile operating panel 15 are lit and when the gyro wheel speed indicated by display 18 is normal. After switch 20 is thrown, the missile may be fired by the weapon control station 37.

The weapon control station 37 provides communication between the bridge and the missile operating areas so that the status of the weapon may be presented to the bridge for planning an attack. In addition to the various displays similar to those of panel 15 for indicating the state of readiness of the missile, this station includes a firing key [not shown] which is closed to launch the missile at the appropriate time provided that switch 20 in the missile operation station 38 is also closed.

The missile shown in FIGS. 6a and 6b comprises several sections which may be classified generally as the depth bomb 43 and the motor section 44. Depth bomb 43 is further broken down into the frangible nose section 45, the warhead section 46, the fuzing section 47 and the guidance section 23. The missile is relatively small in diameter since its greatest total diameter must be less than the inner diameter of the torpedo tube of present day submarines.

The cylindrical rocket motor casing 60 is closed by a bulkhead 52 near its forward end thereby dividing motor section 44 into a forward compartment 51 containing the propellant 54 which is ignited at the appropriate moment during the flight of the missile to begin thrust reversal, and the main propellant section 53 filled with a solid propellant 55. Disposed about the opposite end of the motor section is a cover 57 to prevent water entry into the motor section prior to ignition of propellant 55. Cover 57 is releasably secured to casing 60 by a ring 59 having several hinged segments held in place by explosive bolts, one of which is shown at 61, [see FIG. 11]. Bolts 61 are released upon receipt of an electrical signal from guidance section 23 which signal also fires igniter 116 to ignite the main propellant 55, FIG. 6b, so that cover 57 is blown off by the gases discharged from the thrust nozzle 62 upon ignition of propellant 55. As seen in FIG. 11, the thrust vectoring sys-

tem is composed of a plurality of vanes 63 which are disposed in quadrature relation within nozzle 62, downstream of the throat and are operatively connected by appropriate linkages 64 to actuators 65 for steering the missile. The necessary fluid pressure which operates each of the actuators 65 is generated by a pump 66 driven by a turbine 67. A solid propellant cartridge 68 secured to casing 60, is ignited just prior to the time the missile is launched to drive turbine 67 and operate pump 66. A four way spool valve 69 is associated with each of the control vanes 63 to operate each vane via linkage 64, thereby to stabilize and steer the missile after ignition of the main propellant charge 55.

The operation of the actuator 65 is controlled by an electromagnetic torque motor 72 which, in response to signals generated by the guidance section 23, controls the fluid flow through actuator 65. High pressure fluid is pumped from the sump 73 by the turbine driven pump 66 through a delivery line 74 to the hydraulic transfer system. A d-c electromagnetic torque motor 72 controls the hydraulic system in response to signals from the guidance section 23 of the missile by moving a balanced nozzle-flapper 75 disposed between two nozzles 99 and 101 which receive pressurized fluid from pump 66 via conduits 71, 74 and 95. Bleed lines 76 and 77 connect conduit 71 to the spool valve 69 at opposite sides of the spool 78.

Spool valve 69 consists of housing 79 secured to the rocket motor casing 60 by suitable brackets, spool 78 having three land areas 82, 83 and 84 operating within the housing 79 and a pair of opposed biasing springs 85 disposed at either end of the housing. Springs 85 tend to damp out oscillation of spool 78 and retain it in the null position so that the lands 82, 83 and 84 close the ports 86, 88 and 91 respectively. While the spool 78 is in this null position, the control vanes 63 are each disposed at zero degree angle of attack with respect to the exhaust gases. Accordingly, they do not tend to deflect the exhaust gases and steer the rocket.

When the flapper 75 is moved to the left, as seen in FIG. 11, the flow through nozzle 99 is restricted, consequently spool 78 is moved upwardly as shown in FIG. 11 under the influence of the increased pressure produced in bleed line 76 and the correspondingly decreased pressure in line 77. It is understood that the largest portion of the pressurized fluid always flows out the nozzles 99 and 101 and returns to sump 73 via line 100 to be recirculated by pump 66. As spool 78 moves upwardly, fluid moves through conduit 95 and port 88 which was closed by the land 83 on spool 78 when the spool was in the null position. This fluid flows downwardly within housing 79 of the spool valve 69 and out conduit 96 thereby moving the actuator piston 98 upwardly. Simultaneously, the fluid at the opposite side of the piston drains into the spool valve housing via conduit 90 and discharges to the sump 73 through the now open outlet 91 and a return conduit 89. If the error signal to the torque motor 72 reverses, then the nozzle 99 is opened to a greater degree while flow through nozzle 101 is correspondingly restricted, therefore, the ultimate movement of actuator piston 98 is reversed.

An extension rod 102 is fixed to piston 98 and is connected to one of the control vanes 63 by linkage 64 so that the vane is pivoted in response to movement of piston 98. This movement of the vane deflects the exhaust gases in the direction to stabilize the missile in yaw, roll and pitch or to cause it to execute a programmed turn.

The signals from the missile guidance section which control the operation of the actuator piston are sent through wires 94 in the conduit 105 mounted on the body.

A second conduit 106, FIG. 7, within the rocket motor casing 60 provides an electrical connection between the ship's power and the missile guidance and programming section 23 to supply warm-up power and target information to the missile computers prior to launching of the missile without draining the missile internal power. A connector 87, FIGS. 6a and 6b, is plugged into the torpedo tube door to connect cable 106 to the ship's power while the missile is in the torpedo tube. Guide studs 35, formed on the outer wall of the rocket motor section 44 and on fairing 123 of the depth bomb section 43, serve to align the missile within the tube and to orient the stable platform 26 of the missile guidance section 23 with respect to the submarine. Therefore, both guide studs and the aligning groove [not shown] in the torpedo tube which receives studs 35 must be located with greater precision than is usually required with ordinary relatively short range torpedoes.

A U-shaped arming bar 109 is fitted into a notch 111 at one end of the rocket motor section 44 and is secured at the opposite end of the motor section by a bolt or shear member indicated at 112. Arming bar 109 extends over the rearward end of the missile and has one end formed into a spring loaded plunger 113 which urges it upward tending to release it. When the missile is inserted into the launching tube, shear member 112 is removed and the inner wall of the tube serves to prevent the arming bar from being released. Upon launching of the missile, the connection between the submarine's power and the missile guidance section is broken by shearing cable 106 or pulling loose connector 87. Cable 106 may be destroyed at firing without adversely affecting the performance of the missile since it operates on its own internal power supply immediately prior to launching. The instant the missile clears the tube, bar 109 is jettisoned as the plunger 113 forces it away from the missile. A piston 92 [see FIG. 11] normally restrained by the arming bar 109 is then free to move outwardly to actuate a delay switch shown generally at 115. It is to be understood that the delay may be an hydraulic [dashpot], mechanical [cross mechanism], or electrical [R-C network] system and the particular delay mechanism forms no part of this invention. Upon closing, delay mechanism 115 completes the circuit between the guidance section 23 and an igniter squib 116 centrally disposed within the body of the propellant 55 in the embodiment shown. This mode of ignition is suitable for an internal burning grain but if an end burning propellant were used, the igniter would necessarily be positioned at the rearward end of the propellant. The delay mechanism allows the missile to travel a safe distance from the submarine 13 propelled by the force of compressed air in the torpedo tube before the rocket motor is ignited. Although the missile eventually tends to tumble and take an unpredictable course through the water when it is ejected from the torpedo tube 48, it has been found to be stable to about 2-5 missile lengths from submarine 13. It has been experimentally verified that ignition of the rocket motor does not damage the submarine if the missile is more than 2½ missile lengths from the submarine.

An auxiliary power unit generates electrical power for the guidance section and hydraulic power for actuation of fin 117 on the depth bomb. This auxiliary power unit includes a cartridge 118 of slow burning propellant which is ignited via cable 106 and connector 103 by the submarine immediately prior to launch. The gases produced drive a turbine 119 which is connected through suitable gearing to pump 121 and to an alternator 122. The alternator may supply a-c to the guidance section 23, preferably, however, the a-c produced by alternator 122 is fed to a rectifier 93 to provide a d-c output to the guidance section via wires 108. Pump 121 provides the required hydraulic pressure to a plurality of actuators 124 for operating the fins 117 at the proper time. Actuators 124 and their associated equipment are similar to the apparatus which controls the jet vanes in the thrust nozzle 62 and for that reason will not be described in detail. Prior to the separation of the rocket motor and the depth bomb, actuators 124 and their corresponding fins are locked in the null position by detents 107 so that they do not influence the missile trajectory prematurely.

The closing of a gate circuit 146, FIG. 10, supplies an ignition pulse to a plurality of explosive bolts 125 which secure a hinged clamping ring 126, FIG. 6, in place locking the rocket motor 44 to the depth bomb section 43. Upon ignition of the bolts 125, the rocket motor is released from the depth bomb. Simultaneously with the initiation of bolts 125, a gating pulse from the guidance section 23 is sent along one of the wires in cable 104 to initiate a squib 127 located in the forward section of the rocket motor to ignite the propellant 54 thereby to generate reverse thrust on the rocket motor as the exhaust gases are expelled from the forwardly directed nozzles 97 spaced circumferentially at the forward end of rocket motor 44. Upon separation of the rocket motor and the depth bomb, a segmented fairing 123 is blown off exposing control fins 117 and the fixed stabilizing fins 114 on the body of the depth bomb section 43, so that the fins become effective to exert aerodynamic forces upon the depth bomb to stabilize and steer it when actuators 124 are rendered operative.

The safing and arming section of the missile includes a manual safety switch 131 which is externally armed immediately prior to launching of the missile. After launching, an inertial odometer 129 computes the distance travelled by sensing missile acceleration and integrating with respect to time. The odometer may consist of an accelerometer and means for integrating the output of the accelerometer twice to indicate distance travelled. After the missile has travelled a predetermined distance, a switch 128 is closed to complete one phase of the arming cycle. A second switch 133 is connected in series with the switch 128 and is operated by an anti-circular gyro 135 which is oriented parallel to the control portion of the predicted flight path. Gyro 135 is a conventional two-degree-of-freedom type with pick offs in the pitch and yaw axes. This gyro opens the normally closed switch 133 disarming the fusing system in the event that the missile deviates excessively from the intended flight path which might indicate that the missile is returning the sub 13.

A mechanical inertial switch 137 initiates the final arming of the weapon as it is suddenly decelerated upon water reentry. In order to distinguish the water reentry shock pattern from others to which the missile might be subjected in handling, switch 137 may include

integrating devices which require a sustained acceleration of high magnitude over a minimum period of time for operation. Reentry switch 137 initiates a mechanical timer switch 134 which closes after a preselected delay to connect alternator 122 and an initiator 136 which is used to detonate the conventional or nuclear warhead 46. The delay in switch 134 corresponds to the length of time required for the depth bomb to reach a selected depth based upon the depth bomb sinking rate.

In order to more fully understand the missile guidance section reference should now be had to FIGS. 4a and 4b. The coordinate system utilized in the missile guidance unit 23 may be thought to originate at point *a*, the predicted point of water reentry. The firing bearing of the missile's stable platform must therefore be aligned so that the horizontal trace 143 of the missile's path projected onto the water surface goes through the point *a*. The missile guidance computer 28 operates in a cartesian coordinate system X, Y, Z having its origin at *a* and having its orientation fixed in space, at the instant of firing of the missile. Therefore, the shipboard computer 22 continuously transmits the following input signals to the missile prior to launching:

1. $X_0 Y_0 Z_0$, initial integrator settings in the navigational computer 27 of the missile; these are essentially range and bearing data from the firing point to point *a*.

2. $\dot{X}_0 \dot{Y}_0 \dot{Z}_0$, initial velocity integrator settings in the missile; these values are essentially due to the motion of submarine 13 resolved into X, Y, Z coordinates.

3. Firing bearing to which the stable platform 26 in the missile is aligned to hit point *a*.

4. Gimbal orders for the stable platform 26 so that it is level at all times.

5. $\dot{X}_4$, missile velocity at point 4 on the predicted trajectory terminating at point *a*. At point 4 on the trajectory, thrust should be terminated and rocket motor separated from the depth bomb 43 so that the bomb will fly semiballistically to point 5. At point 4, the depth bomb guidance control is actuated and stabilizes the depth bomb in roll and provides cross wind correction.

6. X_5 , missile position at point 5 on the predicted trajectory terminating at point *a*. At point 5 the pitch controls are initiated to correct errors and to steer the missile glide path toward point *a*.

7. X_6 , missile position at point 6 on the predicted trajectory terminating at point *a*. At this point the missile fins are set to zero lift and locked and the missile dives ballistically to point *a*.

As indicated in FIG. 10, signals proportional to the X, Y, Z acceleration, $\ddot{X}$, $\ddot{Y}$, $\ddot{Z}$, respectively, are produced at the stable platform 26 by accelerometers 171, 172 and 173 and fed into the missile guidance computer 28. A simple pendulum, spring suspended mass, or vibrating reed type accelerometer may be used or a more complicated acceleration sensing gyro may be employed to provide to the $\ddot{X}$, $\ddot{Y}$, $\ddot{Z}$ signals. Each of these signals is integrated in the appropriate integrating circuits 138, 139 and 141 to provide an output signal $\dot{X}$, $\dot{Y}$, $\dot{Z}$, proportional to the instantaneous velocity of the missile in the space coordinate system X, Y, Z. A signal proportional to $\dot{X}$ is introduced into the gating circuit 146. When the missile velocity reaches a predetermined value calculated by the ship's computer 22 and stored in the missile programmer 140, thrust is cut

off at point 4 on the missile's trajectory by a pulse from the gating circuit 146; and the rocket is separated from the depth bomb in the aforescribed manner. This gating pulse closes a relay 142 which initiates the squib 127 to ignite the thrust reversal propellant 54 [FIG. 6] to produce a reverse thrust through nozzles 97. Nozzles 97 are covered by plugs 144 to resist high external pressures but may be blown off by a slight excess of internal pressure over external pressure.

Simultaneously, with initiation of squib 127, the explosive bolts 125 are ignited and the clamping ring 126 is blown apart thereby allowing separation of the rocket motor and the depth bomb. The servo actuators 124 associated with the fins 117 stabilizes the missile in roll in response to error signals from the roll rate gyro 145 and the roll angle signal generated from the stable platform 26. The azimuth deflection is corrected to zero also. The depth bomb travels to the zenith of its trajectory; it then begins to lose altitude and fall toward the water impact point *a*. At point 5 [a distance X_5 from point *a* along the X axis of the coordinate system], a signal from the gating circuit 147 closes relays 148 and 149 to operate the actuators 124 so that the fins 117 may be adjusted to correct errors in pitch as well as errors in yaw and roll. Integration of the signals $\dot{X}$, $\dot{Y}$, $\dot{Z}$ by the integrating circuits 151, 152 and 153, respectively produces signals X, Y, Z indicative of the missile's position in space. The signals X, $\dot{X}$, Y, $\dot{Y}$, Z and $\dot{Z}$ are fed into the multiplying circuits 159, 161, 162 and 163 respectively to produce signals proportional to the products XY, $\dot{X}Y$, XZ and $\dot{X}\dot{Z}$. The product $\dot{X}Y$ subtracted from the product XY in the difference circuit indicated at 154 to produce an error signal $XY - \dot{X}Y$ which is indicative of the instantaneous error in the XY plane of the missile coordinate system. That is to say, when:

$$XY - \dot{X}Y = 0,$$

[1]

the missile is on a straight line glide path which passes through the preselected water impact point *a*. The theoretical verification of equation is explained in greater detail in the copending application of William B. Coffman, Ser. No. 762,187, filed Sep. 19, 1958 which matured into U.S. Pat. No. 3,249,324 on May 3, 1966. however, equation [1] may be verified intuitively by referring to FIG. 4b which shows the trajectory of the missile. At the instant the terminal guidance has been actuated, at some point 5 after the zenith of its trajectory, and the missile has begun to glide downwardly toward point *a*, it is positioned at some point [X, Y] in the X, Y plane and has instantaneous velocity components $\dot{X}$ and $\dot{Y}$. Now, when the ratio $X/\dot{X}$ is equal to the ratio $Y/\dot{Y}$, the missile will travel the distance Y remaining to point *a* in the same time it travels the distance X remaining to point *a*. Accordingly, it will hit the water at point *a*. Since X, Y and $\dot{X}$, $\dot{Y}$ are instantaneous values available in the missile, the guidance system will constantly correct for errors in the predicted straight line glide path to point *a* due to gravitational acceleration and/or wind effects.

Setting: $X/\dot{X} = Y/\dot{Y}$ and cross multiplying, $X\dot{Y} = \dot{X}Y$ or $XY - \dot{X}Y = 0$ and this is equation of a straight line passing through point *a* from the missile position X, Y. Similarly, a signal [$\dot{X}Z - X\dot{Z}$] is produced by the difference circuitry 155; this signal is utilized to correct er-

rors in the X, Z plane, in the same manner that the signal $[X\dot{Y} - Y\dot{X}]$ is used to correct range errors.

The depth bomb thus stabilized and guided flies toward its target until it reaches point 6 in its trajectory at which time the gating circuit 156 in response to the output of the integrator circuit 151 opens switches 157 and 158 thereby returning fins 117 to a zero lift position in which they are locked by detents 107 [see FIG. 6a] and the missile dives ballistically toward point a. Since electronic integrators and multipliers are well known to those skilled in the art, for the sake of brevity, they are not described in detail.

OPERATION

Referring now to FIGS. 3, 4b, 6a and 6b, to more fully understand the entire sequence of operation of the missile; bearing, range and speed information are fed into the ship's computer 22 which predicts the future position of the target sub 11 and supplies that information to the missile guidance section 23. During this interval, the missile computer is run by ship's power. When sufficient tracking information is obtained the internal missile power is turned on and the missile is then launched from the torpedo tube in the same manner as the conventional torpedo. The arming bar 109 flies off as soon as the missile leaves the tube. After a short time interval, the delay switch 115 closes, firing igniter 116 to initiate the missile propellant 55 at some underwater point on the missile's trajectory a safe distance from the launching submarine 13. The flight path between the instant of firing and point 2 on the missile trajectory is underwater. During this phase, the missile is stabilized and programmed by vanes 63 so that it emerges from the water at about a 50° angle and, on water emergence, it is flying a trajectory lying in the X, Y plane which trajectory contains point a. Vanes 63 are hydraulically powered by actuators 65 which are operated by signals from the guidance section 23 in the aforescribed manner.

The path between points 2 and 4 is the boost phase in the air during which the missile is attitude-stabilized at approximately 50°. When the missile has reached a minimum safe range [point 3] odometer 129 arms the fuzing system. At point 4, the guidance section 23 develops a signal which cuts off the rocket motor by igniting the reversal propellant 54 and simultaneously releasing the band 126 to free the rocket motor from the depth bomb. At this point, the programmer 140 activates the roll and azimuth control system of the depth bomb and signals are generated by the computer which compares the instantaneous velocity $\dot{X}$ or some combination of $\dot{X}$, $\dot{Y}$ from the navigational computer 27 with a precalculated velocity along the X coordinate or in the X, Y plane, respectively to achieve the desired range as above described. This comparison is done in the gating circuit 146 which operates a relay 142 when $\dot{X}$ or the $\dot{X}$, $\dot{Y}$ combination exceeds the calculated value.

Beyond point 4, the depth bomb continues to ascend flying semiballistically with no pitch correction so that it flies at nearly zero angle of attack in pitch but has roll stabilization and cross wind correction. At some point 5 shortly after the depth bomb has reached the zenith of its trajectory, the guidance computer activates the pitch controls to guide the bomb toward point a on the water's surface. To prevent the depth bomb from reentering the water at a large angle of attack which would

set up transverse forces of undesirably high magnitudes or cause the bomb to ricochet, broach, or exhibit excessive underwater dispersion, all control fins are set to zero at point 6 and are locked in position by detents 107. Upon water reentry, the switch 133 is closed and the missile sinks to the desired depth at which the warhead is detonated.

Although we have described our invention with reference to but a single embodiment it is by no means so limited but is susceptible of many alterations and modifications without departing from the spirit thereof. Accordingly, this invention is not to be construed as limited in any way by the specific embodiment described. Rather the scope of the invention is defined only by the scope of the appended claims.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. An anti-submarine missile adapted to be launched from the torpedo tube of a submarine which comprises; a weapon portion including a guidance section, a rocket motor portion secured to said weapon portion, means fixed to said missile for orienting the missile within the torpedo tube, a cover, explosive bolt means disposed about said cover to releasably secure the cover to said rocket motor portion and prevent water entry therein prior to ignition of said rocket motor, means electrically connected to said guidance section for igniting the rocket motor in the water when the missile is at a safe distance from the submarine, said explosive bolt means being electrically connected to said guidance section for initiation by an electric signal therefrom to release the cover from the rocket motor substantially simultaneously with the ignition of said rocket motor to permit exhaust gases from the rocket motor to blow off said cover, a plurality of vanes disposed in the rocket exhaust and electrically connected to said guidance section whereby said vanes are controlled by signals from the guidance section to stabilize the missile and steer it out of the water, means in said rocket motor portion electrically connected to said guidance section for separating said rocket motor portion from said weapon portion upon receipt of a signal from the guidance section, and aerodynamic control means on said weapon portion operatively connected to said guidance section for guiding the missile toward a predetermined water reentry point.

2. A weapon system for a submarine having a torpedo tube comprising; target tracking and computing apparatus aboard the submarine, a missile disposed within the torpedo tube and adapted to be launched therefrom, said missile including an explosive warhead, a gyro controlled guidance section, a rocket motor section and means disposed within said rocket motor section electrically connected to said guidance section for igniting the rocket motor after the missile is launched, and cable means releasably connecting the target tracking and computing apparatus in the said submarine to the guidance section of said missile to provide target information to the guidance section and to connect said guidance section to the submarine's power to operate said guidance section when the missile is in the torpedo tube prior to launching of the missile.

3. A method of destroying an enemy undersea craft comprising the steps of; tracking the craft, launching a missile having a warhead and a reaction type motor, igniting the motor under water, steering the missile out of the water toward the craft, steering the missile into

the water near the craft, and detonating the warhead within lethal range of the craft.

4. The method of claim 3 wherein the missile is ignited at about 2 to 5 missile lengths from the attacking submarine.

5. A system for destroying a submerged target submarine comprising; target tracking and computing equipment aboard a submerged killer submarine for tracking the target submarine and computing its probable future position, a missile disposed within the torpedo tube of the killer submarine for launching therefrom, said missile including a depth bomb having a warhead and a guidance section, a rocket motor releasably secured to said depth bomb, said rocket motor containing a propellant and an igniter electrically connected to said guidance section, lug means fixed to the depth bomb and to said rocket motor to align the missile in the torpedo tube with respect to said target tracking and computing equipment, expendable cable means electrically connecting said shipboard target tracking and computing apparatus to the guidance of said missile, power supply means electrically connected to said cable means for initiation by the killer submarine immediately prior to launching and electrically connected to said guidance section to provide power thereto subsequent to launching, a delay switch connected between said guidance section and the igniter, said switch being open while the missile is in the torpedo tube, spring means on said rocket motor to close said delay switch to detonate the igniter and light off said rocket motor at about 2-5 missile lengths from the attacking submarine, thrust vectoring means disposed within said rocket motor for deflecting the exhaust gases thereof and connected to said guidance section to receive guidance signals therefrom for controlling the missile in roll, pitch and azimuth and steer it out of the water, thrust reversal means on said rocket motor and electrically connected to said guidance section for initiation when the missile is at a predetermined position, explosive bolt means releasably connecting said rocket motor and said depth bomb and electrically initiated by

said guidance section to effect separation of the missile and the depth bomb substantially simultaneously with the initiation of said thrust reversal means to thereby separate the depth bomb from the rocket motor, aerodynamic control means for steering the depth bomb toward the target after separation.

6. The system of claim 5 further including a cover disposed over one end of the rocket motor, explosive bolt means electrically connected to said guidance section and releasably securing said cover to the rocket motor, said guidance section producing a signal to release said explosive bolt means substantially simultaneously with the detonation of said igniter.

7. A method of destroying an enemy submarine at distances up to the second sonar convergence zone which comprises the steps of; tracking the enemy submarine from a submerged attacking submarine to determine the probable further position of the enemy submarine, ejecting a missile having a warhead and a solid propellant rocket from the torpedo tube of the attacking submarine, igniting the rocket motor under water when the missile is a safe distance from the attacking submarine, programming the missile out of the water, propelling and guiding the missile toward the probable position of the enemy submarine so that the missile re-enters the water when the enemy submarine reaches said position, and exploding the warhead when the missile sinks to a predetermined depth at said position.

8. A method of destroying a submerged enemy submarine which comprises detecting the enemy submarine from a submerged attacking submarine, ejecting a missile from the torpedo tube of the attacking submarine, said missile including a depth bomb section and a rocket motor section, igniting the rocket motor while the missile is in the water, steering the missile out of the water, separating the rocket motor from the remainder of the missile, flying the remainder of the missile semiballistically to reenter the water at a point near the enemy submarine, and detonating the depth bomb in the water to destroy the enemy submarine.

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