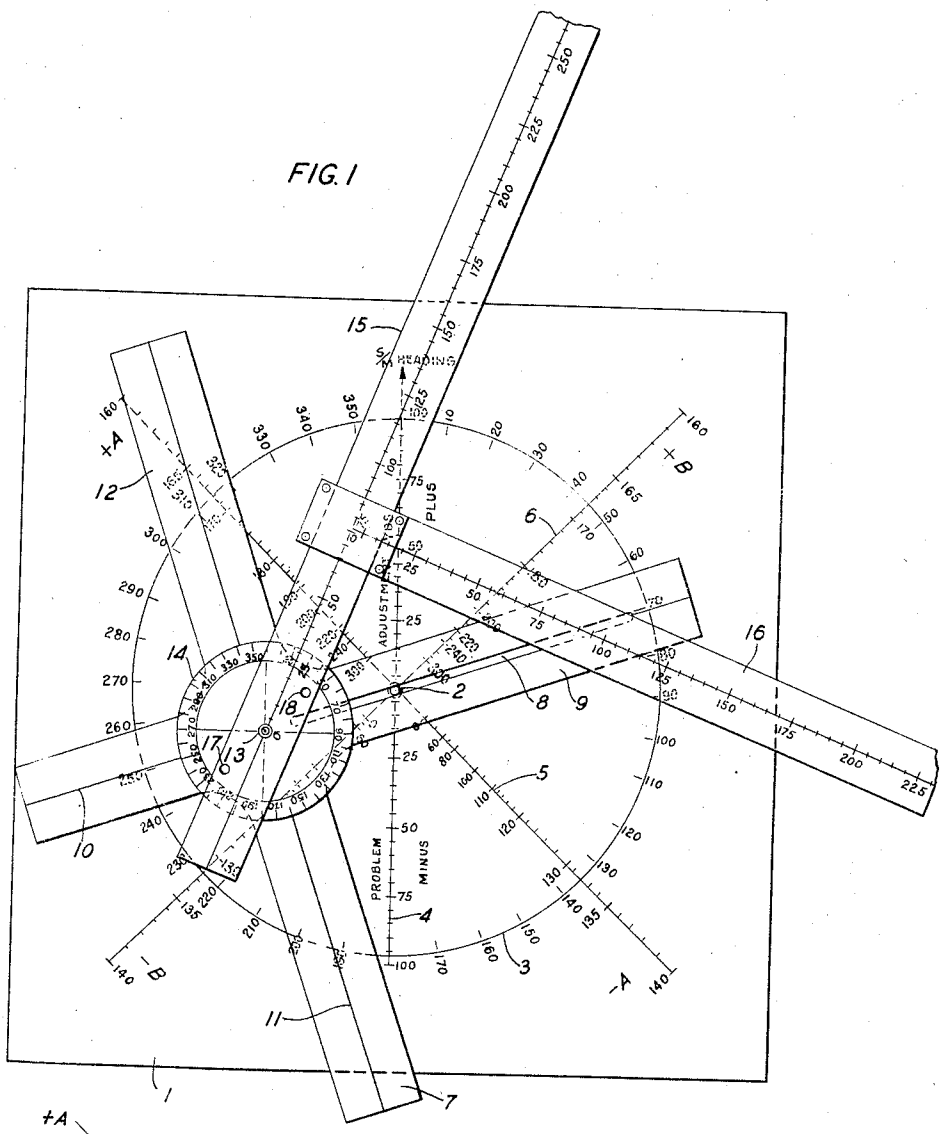
April 22, 1947. P. G. EDWARDS 2,419,203

PLOTTING BOARD

Filed May 6, 1944

FIG. 1



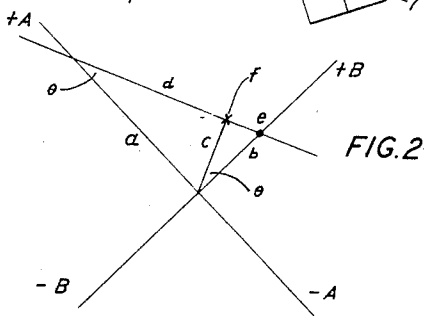


FIG. 2

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PLOTTING BOARD

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5 Claims. (Cl. 33—98)

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This invention relates to systems for locating the range and hearing of explosions with respect to a target point and particularly to apparatus for determining such ranges and hearings from measurements of the explosion wave at a pick-up point.

In one method of training the crews of surface ships in depth bombing technique the surface craft maneuvers into position with respect to a cooperating submarine and makes a practice attack by dropping a sub-caliber depth charge which is exploded by water pressure at the agreed depth at which the submarine is operating. These charges are designed to produce uniform explosive pressure pulses which are picked up by directional hydrophones mounted on the submarine.

As explained in detail in my copending joint application with D. D. Robertson, Serial No. 515,888, filed December 28, 1943, the submarine is provided with a practice attack metering system in which two coincident pressure gradient type hydrophone units mounted on the submarine with their axes of maximum sensitivity disposed in quadrature generate two electrical pulses which are of relative polarities indicative of the quadrant in which the point of the explosion is located, of relative magnitudes indicative of the angle of wave incidence within the quadrant and of absolute values indicative of the distance from the pick-up point to the point of the explosion of the standard charge.

The practical value of this information in the training process depends to a large extent on the rapidity with which this data can be translated into terms which are indicative of the degree of accuracy obtained in the practice attack.

In actual depth bombing attacks the enemy submarine may be submerged to a depth of as much as 600 feet but in practice attacks the cooperating submarine ordinarily operates at a maximum depth of about 90 feet to avoid exposing the crew to unnecessary hazard. The surface vessel makes sucessive attacks setting its course to pass ahead of the submarine by an amount such that the submarine will pass over the center of the theoretical barrage represented by a single bomb after the time interval required for the charge to fall to the assumed depth.

The problem of computing the error involved

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in a particular practice attack is further complicated by the fact that it is impracticable to design the practice bomb so that it will drop only to the level of the submarine in the time required for an actual bomb to fall to the much greater assumed depth. As a result of this the actual target in practice attacks often is a point, some distance ahead of the submarine, where a submarine travelling at the assumed depth would be at the instant an actual bomb would reach that depth.

The object of this invention is to simplify the procedure in converting the readings of the practice attack meter into terms of range and lateral error with respect to the actual target so that this information will be available promptly for the guidance of the crew of the attacking ship.

According to the invention the readings of the attack meter are set up on a plotting board by means of a slider designed to indicate directly the location of the point of the explosion with respect to the location of the pick-up point on the submarine at that time. From this point so located a pivoted member is set to the course of the attacking ship in proper relation to a line representing the course of the submarine and a scale sliding on this member is set to intersect the true target position on the submarine's course. The range and lateral errors can then be read directly from scales on the pivoted member and sliding scale and, if desired, the overall accuracy also can be obtained merely by scaling the distance between the explosion point and the true target.

In the drawing Fig. 1 shows a plotting board according to the invention and Fig. 2 is a diagram illustrating the theory of operation of the board.

In Fig. 1 the square base member 1 has a fixed center pin 2 representing the pick-up point on the submarine at the time of the explosion, an azimuth scale 3 concentric with the pin and a problem adjustment distance scale 4 extending diametrically through the pin and representing the course of the submarine under attack. Extending at right angles to each other through the center pin there are also two other scales 5 and 6 disposed at 45 degrees to the line representing the course of the submarine. The orientation of these scales corresponds to the maximum sensitivity axes of the pick-up units and they are calibrated in terms of the attack meter readings.

The slider 7 is slidably and rotatably mounted

on the center pin 2 by means of an elongated slot 8 in the arm 9. At the intersection of the center line 10 of this arm and the center line 11 of the cross arm 12 there is a pin 13 on which there is rotatably mounted a protractor or azimuth scale 14. The scale 15 is pivotally mounted on the pin 13 and carries a sliding scale 16 mounted at right angles to itself and capable of being reversed in direction as required. For convenience in using the board the scale 7 and all other movable scales are preferably made of a suitable transparent plastic material.

For a proper understanding of the use of this board to determine the accuracy of a practice bombing attack it is necessary to consider in more detail the manner in which the attack meter readings vary with the distance and direction of the explosion from the pick-up point on the submarine.

The pressure gradient pick-up units are mounted with their axes of maximum sensitivity at right angles to each other and each of these axes is at 45 degrees to the longitudinal axis or course of the submarine. Due to the cosine characteristic of the units, the response of either unit to a charge fired on its axis will be inversely proportional to its distance from the pick-up and the response of the other unit will be substantially zero. For a charge which is not on either axis the square root of the sum of the squares of the two responses is inversely proportional to its distance from the pick-up point and the ratio of the responses is the tangent of the angle between a line through the explosion point and the axis of one of the units. While each pick-up unit gives the same numerical response for each of two charges exploding in corresponding positions in opposite quadrants, there is no ambiguity as to the location of a particular charge on this account since the polarity of the response of each unit depends upon the direction from which the wave approaches the unit.

In Fig. 1 of the drawing the scale 5 is oriented to correspond to the axis of the "A" pick-up unit and the scale 6 therefore corresponds to the axis of the "B" unit. As indicated in the drawing charges exploding in the forward quadrant will give +A, +B readings and charges in the rear quadrant give −A, −B readings where charges in the right and left lateral quadrants give −A, +B and +A −B readings respectively.

The response of the attack meter to a charge as explained above may be expressed as follows:

$$D_A=\frac{K_1}{D}\cos\theta \tag{1}$$

and

$$D_B=\frac{K_1}{D}\sin\theta \tag{2}$$

Where D_A and D_B are the responses of the pick-up units, K_1 is a constant depending on the nature of the charge, the sensitivity of the pick-up system and various other known factors, D is the distance from the pick-ups to the point of explosion and θ is the angle between one pick-up axis and the direction line to the explosion point.

From (1) and (2)

$$D_A^2+D_B^2=\frac{K_1^2}{D^2}(\sin^2\theta+\cos^2\theta)=\frac{K_1^2}{D^2} \tag{3}$$

$$D=\sqrt{\frac{K_1^2}{D_A^2+D_B^2}} \tag{4}$$

which is the law of the attack meter as explained above.

Consider now Fig. 2 in which the lines A and B are at right angles to correspond with the axes of the pick-up units, and the line c is perpendicular to the lines d and e joining lines A and B. From the geometry of the figures

$$\frac{a}{b}=\frac{d}{c}=\frac{c}{e} \tag{5}$$

$$d=\frac{ac}{b};\ e=\frac{bc}{a}\text{ and }de=c^2 \tag{6}$$

$$a^2+b^2=(d+e)^2=d^2+2de+e^2 \tag{7}$$

Substituting from (6)

$$a^2+b^2=\frac{a^2c^2}{b^2}+2c^2+\frac{b^2c^2}{a^2}=c^2\left(\frac{a^2}{b^2}+2+\frac{b^2}{a^2}\right) \tag{8}$$

Dividing through by a^2, b^2

$$\left(\frac{1}{b^2}+\frac{1}{a^2}\right)=c^2\left(\frac{1}{b^4}+\frac{2}{a^2b^2}+\frac{1}{a^4}\right)=c^2\left(\frac{1}{b^2}+\frac{1}{a^2}\right)^2 \tag{9}$$

$$1=c^2\left(\frac{1+1}{b^2+a^2}\right) \tag{10}$$

$$C=\frac{1}{\sqrt{\left(\frac{1}{a^2}+\frac{1}{b^2}\right)}} \tag{11}$$

From Equation 11 it follows that if a and b are inversely proportional to the attack meter readings D_A and D_B respectively then the explosion is located as being at f, and c is the distance from the explosion to the pick-up point.

Referring again to Fig. 1 it will be seen that when the slider 7 is set with the line 11 on the proper attack meter readings on the scales 5 and 6 the pin 13 represents the location of the explosion with respect to the pick-up point 2 on the submarine. To avoid possible confusion the use of plus and minus attack meter readings of the same numerical values is avoided by providing the meter with a scale, such as from 0 to 300, in which 150 is zero response, 0 is maximum negative response and 300 is maximum positive response as indicated by the numerical values on the meter scales 5 and 6.

For each practice attack the actual target will be some point on the scale 4 which is determined in accordance with the speed of the submarine, the direction of its course and the difference in the times required for the practice charge and a real depth bomb to sink to the assumed depth. In the case shown for purposes of illustration this point is at +50 yards or 50 yards ahead of the actual pick-up point on the submarine. To determine the error with respect to this point, the scale 15 is put in place with the pin 13 in a hole at the zero point and the scale is aligned with the course of the attacking ship. This operation is greatly facilitated by the use of the protractor 14 which is rotated until its reading on the line 10 of the slider 9 is the same as the reading on the azimuth scale 3, in this case about 251, at which time the radial line through the zero on the protractor is parallel to the submarine's course. The angle between the courses of the two ships is determined by known means outside the scope of this invention and the scale 15 is then readily located by rotating it to this angle on the protractor.

The slider 16 is then moved along the scale 15 until it intersects the true target position on the scale 4, in this case +50 yards. The range and lateral errors are then directly from the scales 15 and 16 and if required the overall error is deter-

mined merely by scaling the straight line distance between the target point and the pin 13.

The use of the board is not limited to the ranges indicated by the numerical values shown for illustration on the scales 4, 15 and 16 since in practice the sensitivity of the response of the attack meter may be adjusted and one or more suitable additional calibrations may be provided for the scales as required. In the case shown the hole in the scale 15 for the pin 13 is at the zero of the scale on the assumption that the practice charge is dropped from the attacking ship at the dropping point of an actual bomb. Actual depth charges are usually dropped from the stern of the ship whereas it is sometimes preferable to drop the practice charges over the side. Any such lateral or longitudinal differences in the dropping points may be compensated automatically by providing one or more alternate holes such as 17 and 18 suitably located with respect to the zero point of the scale.

What is claimed is:

1. A plotting board having scales intersecting in quadrature to represent the axes of a pair of pressure gradient microphones and calibrated in terms of the microphone responses to explosion waves of known intensity originating at different positions with respect to the microphones, a slider having arms intersecting in quadrature at a point representing the origin of an explosion wave and means for mounting one arm of the slider on the board for rotary and sliding motion with respect to the intersection of the scales to locate on the board a point representing the origin of a wave corresponding to the settings of the other arm of the slider on the scales.

2. A plotting board according to claim 1 in which the board has an azimuth circle about the point of intersection of the scales and the slider

has an azimuth scale member rotatably mounted at the intersection of its arms.

3. A plotting board according to claim 1 in which the board has a line through the intersection of the scales at 45 degrees thereto representing a direction of motion of the microphones.

4. A plotting board according to claim 1 in combination with a scale pivotally mounted on the slider at the intersection of the arms and a scale member removably mounted on the pivoted scale and adapted for sliding motion at right angles to the pivoted scale.

5. A plotting board having scales intersecting in quadrature at a point representing the location of a moving pick-up device, an azimuth circle about the point, a line through the point at 45 degrees to the scales representing the course of the pick-up device, a slotted member mounted for sliding and rotary motion about the point, a cross arm on the member, an azimuth scale and a first linear scale pivotally mounted at the intersection of the cross arm and slotted member and a second linear scale slidably mounted on the first at right angles thereto.

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