TORPEDO DIRECTOR

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Fig. 1

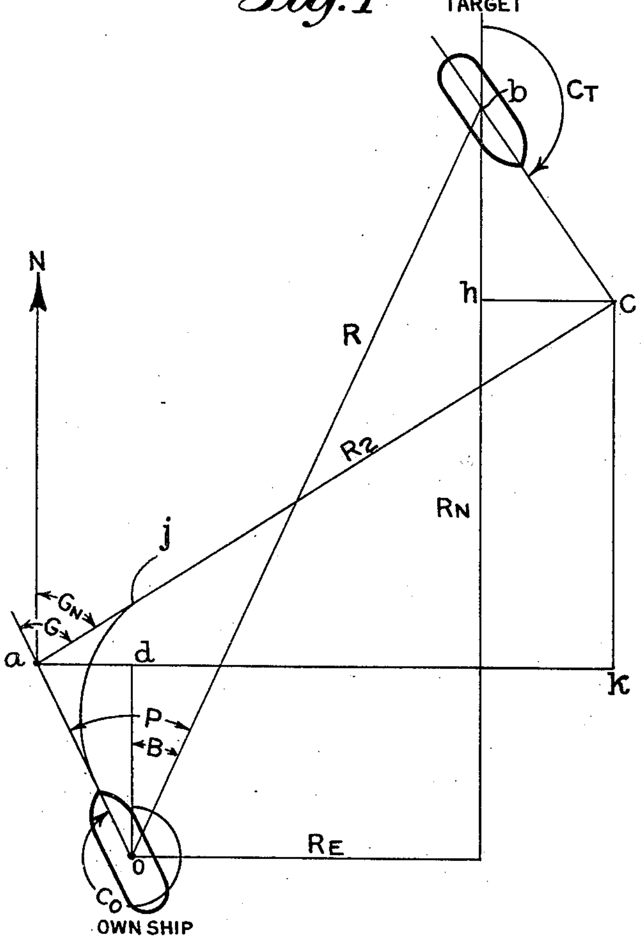

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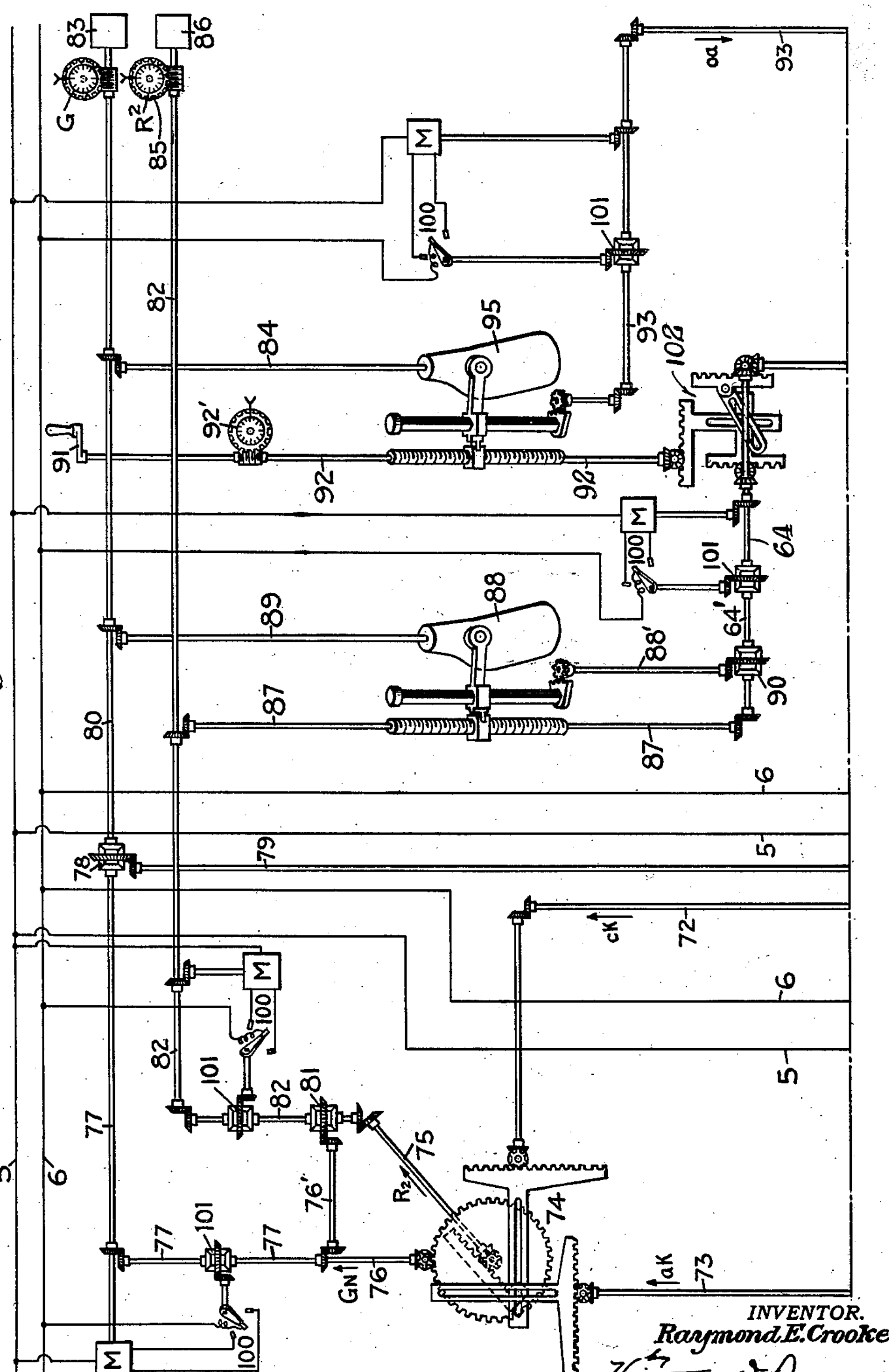
Fig. 2



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June 11, 1946. R. E. CROOKE 2,402,024
TORPEDO DIRECTOR
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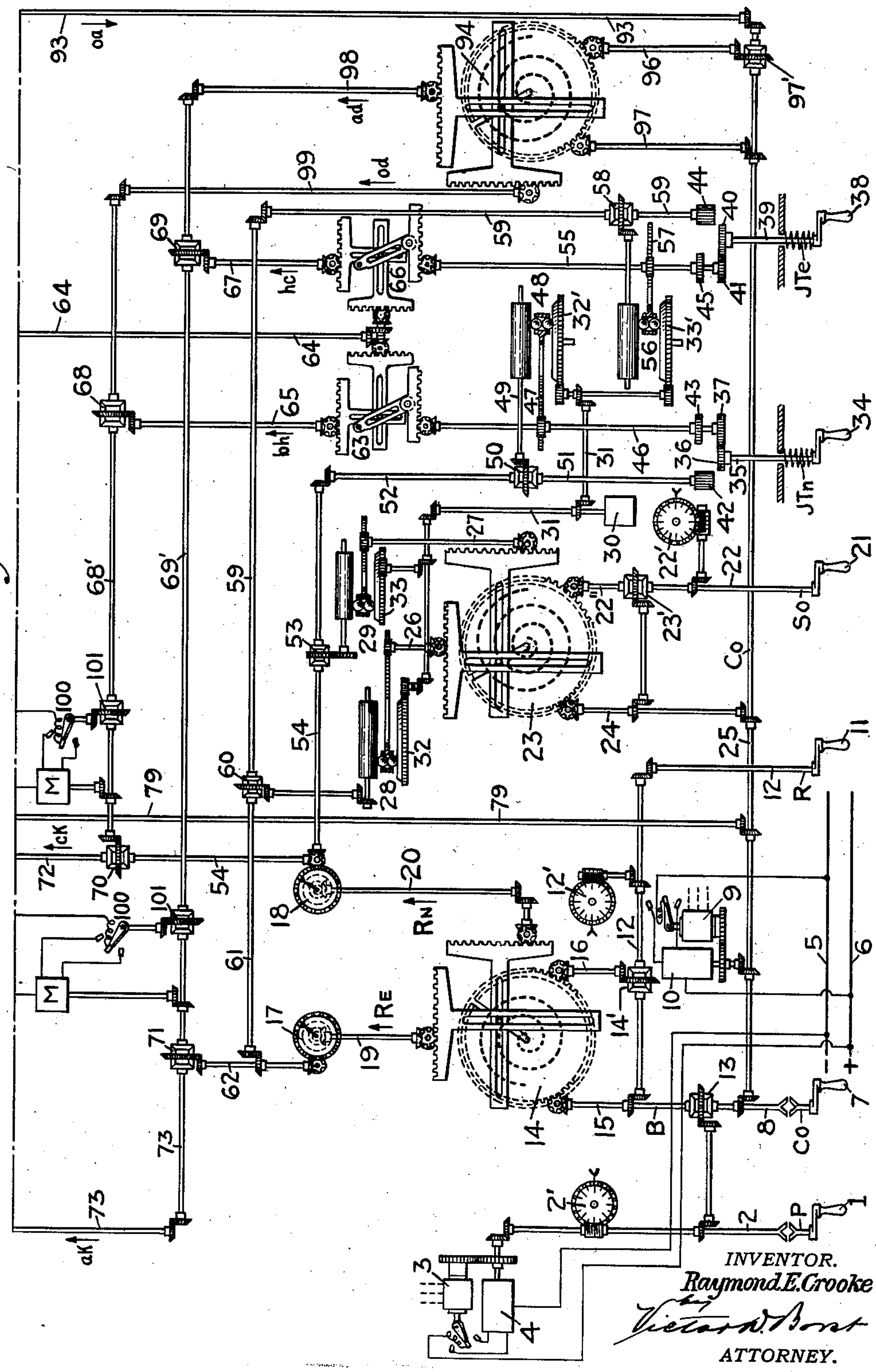

Fig. 3

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TORPEDO DIRECTOR

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5 Claims. (Cl. 235—61.5)

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This invention relates to a torpedo director and more particularly to a torpedo director based upon the use of rectangular coordinates.

The principal objects of this invention is to provide a torpedo director to solve mechanically the problem of directing the movement of the torpedo during the time of its run to the target, by the use of rectangular and particularly north-south, east-west coordinates.

Another object is to provide a mechanism for calculating the components of the curved path of the torpedo, that is, the path of the torpedo from the time of firing to the time it settles down on its steady course to the target, and for determining corrections required in the setting of the torpedo mechanisms therefor.

Another object of the invention is to provide a mechanism based upon the use of north-south, east-west coordinates for solving a torpedo directing problem wherein the first part of the run of the torpedo, which is in the form of a curve, is analyzed with reference to the point where the line representing the straight path of the torpedo, reversed in direction, intersects the extended center line of the ship.

Other objects of the invention will be apparent from a consideration of this specification and drawings.

Heretofore the analysis of the various factors involved in the solution of the problem of directing a torpedo to a target has been based upon components of movement of the target and torpedo relative to a base line such as the line between the firing ship and the target. When firing torpedoes, as heretofore, corrections in gyro angle to compensate for the curved part of the run of the torpedo were obtained from tables and applied to the torpedo gyro setting as that angle was transmitted to the firing station.

In the present invention, with the system of coordinates used, the corrections in gyro angle for the curved part of the run of the torpedo is primarily a function of gyro angle and the corrections are automatically applied, thus eliminating all delay and the possibility of personal errors.

In the drawings:

Fig. 1 is a geometric sketch showing the relation of the factors involved in the problem of directing a torpedo to a target;

Figs. 2 and 3 taken together are a diagrammatic sketch of an arrangement of mechanisms to solve the problem indicated in Fig. 1.

Referring particularly to Fig. 1, *o* represents the periscope of the firing or "own" ship proceeding on a course Co. The target is represented at

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b proceeding on a course C*t*. The path of the torpedo is represented as a curve extending from *o* to the line *ac* into which it merges, at the point *j*, which represents the position at which the torpedo settles down on its steady course. The line *ac* is obtained by extending in a reverse direction the line *jc*, which represents the path of the torpedo after it has settled down, until it intersects at the point *a* the line representing the extended center line of the firing ship. *c* is the point of intercept or advance position of the target, that is, where the torpedo hits the target. *bc* is the run of the target during the time of run of the torpedo. The spin axis of the gyro is set in the direction of run of the torpedo and the angle that the spin axis makes with the direction in which the torpedo is fired is the gyro angle. In the illustrated case the torpedo is assumed to be fired in the direction of the fore and aft line of the ship. G*n* is the angle of the straight portion of the path of the torpedo with reference to north and G is the gyro angle of the torpedo. B is the compass bearing of the target from the periscope of the own ship. The line *ob* represents the observed or generated range (R) of the target. The line *ojc*, composed of a curved portion *oj* and a straight portion *jc*, represents the run of the torpedo. The line *ac* represents the straight portion of the path of the torpedo, reversed in direction until it intersects the extended center line of the ship, at the point *a*. For the purpose of this case the line *ac* is designated as advance range (R2).

In the description to follow, the north-south components of rate of movement will be referred to only as north components or northings, it being understood that the values would be the same for like south components, with the sign changed. This also applies to the east-west components which will be referred to as eastings.

The various mechanisms used in the disclosed embodiment of the invention may be divided into two groups: (1) a component solver to resolve along two selected coordinates the observed present range and bearing of the target, two pairs of integrators the control members of which are set to the rate of movement of the firing ship and target respectively along the coordinates, two multipliers to determine the movement of the target along the coordinates during the time of run of the torpedo, and a component solver to resolve the distance *oa* of the point *a* from the periscope *o* along the selected coordinates; and (2) a vector solver to analyze the values of the factors determined by the mechanisms of the first group to determine the advance range (R2) and the angle

Gn, and two three-dimensional cam mechanisms to determine the time of run of the torpedo, and the distance oa to the reference point a which is the point of intersection of the steady course of the torpedo, reversed, and the extended center line of the ship, or the direction of the launching of the torpedo, if the torpedo is fired other than along the course of the ship.

The purposes of the integrators are two-fold: (1) They are settable in accordance with the rates of movement of the ship and target along the selected coordinates and they integrate the rates so that by combining their outputs the components of range of the target relative to the ship along the coordinates are available at all times whether the ship is submerged or not; and (2) the components of range of the target relative to the ship as determined by the combined integrated rates are compared with the components of the successively observed ranges of the target relative to the ship as determined by a component solver set in accordance with the successively observed ranges and bearings of the target. Since the rates of change of the integrated components are the result of combining the known rates due to the movement of the firing ship with the unknown rates due to the movement of the target, it will be seen that when the generated components of range remain equal to the observed components of range that the rates set in as representing the components of rate of movement of the target are correct.

The combined outputs of the integrators which are adjusted to represent the integrated components of range of the target relative to the ship are combined with the outputs of a pair of multipliers which represent the components of movement of the target during the time of run of the torpedo and the outputs of a component solver which represent the components of position of the point a relative to the observing point. The combined components are then introduced into a vector solver which determines the advance range (ac) and the angle Gn.

It may appear inconsistent, at first glance, that the values of advance range (R2) and the angle Gn are used to obtain the time of run of the torpedo and that these values are themselves dependent upon the values of the time of run. However, in the system of mechanisms generating these values there are also other mechanisms settable independently, such as one of the three-dimensional cams previously referred to, one of the inputs of which is the speed of the torpedo, and the two multipliers previously referred to, one of the inputs of which is the rates of movement of the target along the coordinates. These other inputs have sufficient effect upon the outputs relative to the regenerative effect of the output itself, that no difficulty is experienced from this source.

Referring to Figs. 2 and 3, the observed relative bearing of the target or periscope angle (P) is set up in the mechanism by crank 1 and shaft 2. This angle may also, if desired, be automatically set up in the machine by the use of a receiver motor 3, connected to an angle transmitter (not shown), controlling servo motor 4 which receives its power from electric leads 5 and 6. Indicating dial 2′ shows the instantaneous values of P. The course of the firing ship (Co) is set up in the machine by crank 7 and shaft 8 or, if desired, may be set up in the mechanism automatically by the receiver motor 9, connected to a gyro compass transmitter (not shown), controlling servo motor 10, which receives its power from electric leads 5 and 6. The range of the target (R) as observed is set up in the machine by crank 11 and shaft 12. Indicating dial 12′ shows the instantaneous values of R. The compass bearing of the target (B) is obtained by combining the compass course of the ship and the periscope angle P in differential 13. The compass bearing and the range are fed into component solver 14 through shafts 15 and 16 respectively from which are obtained in the conventional manner the east and north components of the observed range of the target, R_E and R_N respectively. These values are transmitted to one side, for example the pointers, of comparison dials 17 and 18 by shafts 19 and 20, respectively. The two input shafts of this component solver 14, as is the case in all of the component solvers, are connected together through a differential 14′ in order to rotate both shafts 15 and 16 and their corresponding plates upon a change in bearing, but to rotate only shaft 16 upon a change in range. The inherent characteristics of these component solvers are well known in the art.

The speed of the firing ship (So) is set up in the mechanism by crank 21 and shaft 22. Indicating dial 22′ connected to shaft 22 shows the instantaneous values of So. The compass course of the firing ship (Co) is fed into a component solver 23 by shaft 24 connected by shaft 25 to shaft 8. The ship's speed (So) is fed into component solver 23 by shaft 22″. Shafts 24 and 22 are connected together by differential 23′. The outputs of this component solver, the rate of eastings and the rate of northings, respectively, of the firing ship, are taken off by shafts 26 and 27 respectively. These shafts are connected to the control elements of integrators 28 and 29 respectively. Constant speed motor 30 and driving shaft 31 are connected to the driving plates 32 and 33 of the two integrators 28 and 29 and to driving plates 32′ and 33′ of integrators 48 and 56, to be described later.

The estimated north and east components of the speed of the target are set up in the mechanism by crank 34 and shaft 35 through gears 36 and 37 for the northern component (JTn) and through crank 38, shaft 39, gear 40 and gear 41 for the eastern component (JTe). Gear 36 may also be brought into mesh with gear 42 to set the initial value of the integrated north component of range or to make corrections in the integrated north component of range. Corrections may be made to the integrated north component of range and the north component of speed of the target simultaneously by meshing gear 36 with both gears 42 and 43. Likewise, the initial setting of the integrated east component of range and corrections thereto may be made by meshing gears 40 and 44 or corrections in the east component of speed of the target may be made simultaneously by meshing gear 40 with both gears 44 and 45. Shaft 46 connected to gears 37 and 43 is connected to the control member 47 of integrator 48 the output of which, shaft 49, is connected to differential 50 where is added the movement of shaft 51 connected to gear 42. The third side of this differential 50 is connected by shaft 52 to differential 53 where is added the output of integrator 29 to produce in shaft 54 the integrated north component of range of the target and the firing ship. The output of differential 53, shaft 54, is connected to the other side or dial of the comparison dial 18.

The rate of target eastings represented by the rotation of gears 41 and 45 is set up in the mechanism by connecting shaft 55 thereto. Shaft 55 is connected to the control member 57 of integrator 56. The output of integrator 56 is combined with the setting of gear 44, in differential 58 the output of which is transmitted by shaft 59 to differential 60 where it is combined with the output of integrator 28, which represents the integrated eastings of the firing ship. The output of differential 60 represents the integrated east component of range and is transmitted by shaft 61 and shaft 62 to the other side or dial of the comparison dial 17.

In tracking a target, the operator by means of cranks 34 and 38, adjusts shafts 51 and 59 so that the arrows of the comparison dials 18 and 17 are in positional agreement with the pointers driven by shafts 20 and 19, respectively. The operator also by means of cranks 34 and 38 adjusts shafts 46 and 57 so that the combined integrated movement causes the arrows of the comparison dials 18 and 17 to remain in positional agreement with the pointers as successive readings of observed range and bearing are obtained.

When this condition is obtained the value of the integrated north component of range represented by shaft 54 is equal to the observed value represented by shaft 20 and the value of the integrated east component of range represented by shaft 62 is equal to the observed value represented by shaft 19. Also the rate of northings and eastings, that is, the north and east components of target speed represented by shafts 46 and 55, are correct.

Shaft 46, the angular position of which represents the rate of northing of the target, is connected to one input of multiplier 63, the other input of which multiplier is connected to shaft 64 whose movement is in proportion to the time of run, the manner of obtaining of which will be described later. The output of this multiplier represented in Fig. 1 by *bh* is transmitted through shaft 65. Similarly, the rate of eastings of the target, represented by the angular position of shaft 55, is set up in multiplier 66. The other input of this multiplier is shaft 64 previously described and the output of multiplier 66 is shaft 67. This output is represented in Fig. 1 by *hc*.

These motions are transmitted to differentials 68 and 69 respectively, where they are combined with the north and east components *od* and *ad* respectively of the triangle *oad* by shafts 99 and 98 as will be described hereinafter. The output of differentials 68 and 69 are connected by shafts 68′ and 69′ respectively to the differentials 70 and 71 respectively where they are combined with the generated north and east components of range respectively of the target as represented by the movements of shafts 54 and 62 respectively. The outputs of these differentials 70 and 71 are represented in Fig. 1 as *ck* and *ak* respectively which are the north and east components of position of the point of intercept *c* relative to the point *a*. These outputs are transmitted by shafts 72 and 73 respectively to the vector solver or analyzer 74 whose outputs are the advance range (R2) represented by the movement of shaft 75 and the angle G*n* of the path of the torpedo with reference to north represented by the movement of shaft 76. Shafts 75 and 76 are connected together by differential 81 and shaft 76′ to correct the rotation of shaft 75 for its rotation due to the rotation of the plate of analyzer 74, as is inherent in all analyzers of the plate type. Shaft 76 is connected by shaft 77 to differential 78 where its movement is combined with the course of the firing ship transmitted by shaft 79 connected to shaft 25. The output of differential 78, shaft 80, represents the gyro angle (G) and is transmitted to the gyro angle indicator and transmitter 83.

The advance range R2, which is represented by the rotation of shaft 75, is transmitted through differential 81, as described, and shaft 82, to range indicator 85 and transmitter 86.

From Fig. 1 it is seen that the distance run for any selected or fixed speed of the torpedo is substantially proportional to the advance range (R2) and differs from the advance range (R2) by the difference between the length of the curved path *oj* of the torpedo and the distance *ja*. The length and character of the curved path *oj* of a fired torpedo have been determined experimentally for various settings of the gyro angle and the said lengths have been tabulated and have been plotted in curves in their relation to the distances *ja*. As the distance *ja*, shown in Fig. 1, is always less than the curved path *oj* it follows that the run of the torpedo is equal to the advance range (R2) plus an additional distance which is equal to the difference in the length of the path *oj* and the distance *ja*. It is evident that the actual run may therefore be expressed as a direct function of range (R2) and the gyro angle (G) of the torpedo.

The apparatus used to determine the said additional distance consists of a three-dimensional or solid cam mechanism 88 the solid cam of which is rotated about the extended axis of shaft 89 in accordance with the gyro angle, as transmitted to shaft 89 by shaft 80. The cam follower carriage of the mechanism is moved parallel to the rotation axis of the cam in accordance with advance range (R2) by a threaded nut on the follower carriage engaging the threaded portion of shaft 87, which is driven by shaft 82. The angular position of the follower support arm of the mechanism with reference to the plane including shafts 87 and 89 is in accordance with the distance of the point of contact of the follower with the cam surface from the rotation axis. The surface of the solid cam is determined from the experimental data previously referred to and is of such form that for any value of gyro angle as represented by the position of shaft 89 and for any value of range as represented by the position of shaft 87, the angular position of the follower support arm will be in accordance with the corresponding additional distance.

This angular position of the follower support arm is transmitted to shaft 88′ by a square bar on which the follower support arm slides, on the end of which bar is a toothed arcuate segment engaging a gear on shaft 88′. The advance range (R2) and the said additional distance are combined in differential 90, which is connected to shafts 87 and 88′. The output of differential 90, shaft 64′, therefore represents the actual length of the run of the torpedo.

Likewise from experimental data, the distance *oa* has been determined for torpedoes running at various speeds and fired with various gyro angles. These data are available in tables and in curves from which is constructed a three-dimensional or solid cam mechanism 95 similar in principle and operation to cam mechanism 88 previously described.

The solid cam of cam mechanism 95 is rotated about the extended axis of shaft 84, which is connected to shaft **80**, in accordance with the gyro angle (G). The cam follower carriage is moved parallel to the said rotation axis by a threaded portion of shaft **92** which is rotated to a position in accordance with the actual speed of the torpedo by handle **91**. Indicating dial **92'** is connected to shaft **92** and shows the set values of the speed of the torpedo. The follower support arm is angularly moved in accordance with the distance of the point of contact of the follower with the surface of the cam and the said axis of rotation. The angular motion of the follower support arm is transmitted to shaft **93** by a square bar on which the follower support arm slides, on the end of which bar is a toothed arcuate segment engaging a gear on shaft **93**. The shape of the cam is made such that the rotation of shaft **93** represents the distance *oa* for any combination of torpedo speed and gyro angle.

The output of this three-dimensional cam mechanism **95** is transmitted to component solver **94** by shafts **93** and **96**. The other input into component solver **94** is the compass course of the firing ship taken from shaft **25** and transmitted by shaft **97**. Shafts **96** and **97** are connected together in the conventional manner by differential **97'**. The outputs of the component solver **94** represent the sides *ad* and *od* of the triangle *oad* and rotate the shafts **98** and **99** respectively. These values are connected to differentials **69** and **68** respectively, referred to hereinbefore.

As previously described the shaft **64'** represents the actual length of run of the torpedo for various conditions of range and gyro angle of a torpedo having a selected speed and if that is the only speed torpedo it is desired to use, shaft **64'** may be directly connected to drive shaft **64** at a ratio such that shaft **64** represents time of run. If it is desired to provide for variations in torpedo speed a dividing mechanism **102** or other ratio changing mechanism may be introduced between shaft **64'** and **64**. The time of run for any speed is equal to the time of run for the selected speed modified by the ratio of the selected speed to the actual speed. Therefore, since the selected speed is a constant the time of run for any speed may be obtained by dividing the time of run for the selected speed by the actual speed. Shaft **64'** representing the length of run for the selected torpedo speed is introduced into the dividing mechanism **102** as the dividend at a ratio such that the input to the dividing mechanism represents time of run, shaft **92** representing the actual torpedo speed is introduced as the divisor and the resulting quotient is connected to drive shaft **64** which in turn actuates the multipliers **63** and **66** in accordance with the time of run for the actual torpedo speed.

In a mechanism of this type the power available in the outputs of component or vector solvers, three-dimensional cams and multipliers, is usually not sufficient for accurate operation of other mechanisms. Resort is had to a conventional follow-up mechanism, shown schematically as consisting of a motor M, connected electrically to power leads **5**, **6**, through a control switch **100** which receives its motion from a differential **101** geared in the shaft, the power of which is desired to be amplified. The motor is mechanically connected to the reproduced motion shaft and thereby to the third side of the differential. This follow-up mechanism is well known in the art and is not a part of the present invention.

I claim:

1. In a mechanism for determining the gyro angle setting for directing a torpedo from a firing ship to a target, means for resolving the range of the target into components of position along selected rectangular coordinates, integrating means including rate control members and output members moved at rates proportional to the setting of the rate control members, means for setting said rate control members in accordance with the rates of movement of the firing ship along the coordinates, second integrating means including rate control members and output members moved at rates proportional to the setting of the rate control members, means for setting the rate control members of the second integrating means in accordance with the rates of movement of the target along the coordinates, means for combining the movement of the output members representing movement of the firing ship and target along each of the coordinates to position third output members, means to adjust said third output members to represent the components of relative position of the target and the firing ship measured along the selected coordinates, means for comparing the movement of the third output members with the corresponding components of position, multiplying means having input members positioned in accordance with the setting of the rate control members of the second integrating means and the time of run of the torpedo and output members positioned thereby to represent the distance traveled by the target along the coordinates during the time of run of the torpedo, means actuated in accordance with the speed and gyro angle of the torpedo for positioning an output member to represent the position of a reference point along the extended centerline of the firing ship, a component solver including an input vector and output component members positioned thereby, means for angularly positioning the vector in accordance with the course of the firing ship relative to the coordinates, means for adjusting the length of the vector in accordance with the position of the output member representing the position of the reference point, combining means having input members actuated in accordance with the position of the output members of the multiplying means and the position of the component members of the component solver and the position of the third output members to position output elements to continuously represent the components relative to the reference point of the position of the target at the end of the time of run of the torpedo, a vector solver having input component members and an output vector positioned thereby, means to position said input component members in accordance with the position of the output elements whereby the resulting angular position and length of the output vector represent the direction relative to the coordinates and the distance from the reference point to the point of intercept with the target, a cam mechanism actuated in accordance with the course of the firing ship relative to the coordinates and the angular position and length of the output vector to position an output member in accordance with the time of run of the torpedo to the point of intercept, and means to position the corresponding input members of the multiplying means in accordance with the position of the output member of the cam mechanism.

2. In a mechanism for determining the gyro angle setting for directing a torpedo from a firing ship to a target, a component solver including

an input vector and output component members positioned thereby, means for angularly positioning the vector in accordance with the bearing of the target from the firing ship measured relative to selected rectangular coordinates, means for adjusting the length of the vector in accordance with the range of the target from the firing ship whereby the position of said component members represent the components of position of the target relative to the firing ship measured along the coordinates, a second component solver including an input vector and output component members positioned thereby, means for angularly positioning the vector in accordance with the course of the firing ship measured relative to the coordinates, means for adjusting the length of the vector in accordance with the speed of the firing ship whereby the position of the component members represent the component rates of movement of the firing ship along the coordinates, means positionable to represent the component rates of movement of the target along the coordinates, integrating means including rate control members and output members moved at rates proportional to the position of the rate control members, means for positioning the rate control members in accordance with the position of the component members of the second component solver and the means positionable to represent the component rates of movement of the target, means combining the movement of the output members to represent relative movement of the firing ship and target along the respective coordinates, means for adjusting the position of the last mentioned output members to represent the relative position of the target and firing ship along each of the coordinates, means for comparing the position of the said output members with the position of the component members of the first mentioned component solver along each of the coordinates, means interconnecting the means representing the component rates of movement of the target and the corresponding comparing means, means for adjusting said interconnecting means to simultaneously adjust the means representing the component rates of movement of the target and the corresponding comparing means, multiplying means having input members positioned in accordance with the position of the means representing the component rates of movement of the target and in accordance with the time of run of the torpedo and output members positioned thereby to represent the components of distance traveled by the target during the time of run of the torpedo, means actuated in accordance with the speed and gyro angle of the torpedo for positioning an output member to represent the position of a reference point along the extended centerline of the firing ship, a third component solver including an input vector and output component members positioned thereby, means for angularly positioning the vector in accordance with the course of the firing ship relative to the coordinates, means for adjusting the length of the vector in accordance with the position of the output member representing the position of the reference point, combining means including input elements actuated in accordance with the position of the output members of the multiplying means, the position of the output component members of the third component solver and the position of the output component members of the first mentioned component solver and output elements the position of which represent the components, relative to the reference point along the corresponding coordinates, of the position of the target at the end of the time of run of the torpedo, a vector solver having input component members and an output vector positioned thereby, means to position the input component members in accordance with the position of the output elements of the last mentioned combining means whereby the resulting angular position and length of the output vector represent the direction relative to the coordinates and the distance from the reference point to the point of intercept with the target, a cam mechanism actuated in accordance with the course of the firing ship relative to the coordinates and the angular position and length of the output vector to position an output member in accordance with the actual length of run of the torpedo to the point of intercept, and means connecting the output member of the cam mechanism to the corresponding input members of the multiplying means at a ratio to convert length of run to time of run.

3. In a mechanism for computing the direction and length of run of a torpedo from a firing ship to a target, a component solver including an input vector and output component members positioned thereby, means for angularly positioning the vector in accordance with the bearing of the target from the firing ship measured relative to selected rectangular coordinates, means for adjusting the length of the vector in accordance with the range of the target from the firing ship, multiplying means having input members positioned in accordance with the rates of component movement of the target along the coordinates and in accordance with the time of run of the torpedo, said multiplying means having output members positioned by the input members to represent the components of distance traveled by the target along the coordinates during the time of run of the torpedo, combining means including input elements and output elements actuated thereby, means for positioning the input elements in accordance with the position of the output component members of the component solver and the corresponding output member of the multiplying means, a vector solver including input component members and an output vector positioned thereby, means to position said input component members in accordance with the position of the output elements of the combining means, whereby the angular position and length of the output vector represent the direction relative to the coordinates and the distance of run of the torpedo from the firing ship to the point of intercept, converting mechanism actuated in accordance with the course of the firing ship relative to the coordinates and the length and direction of the output vector to position an output member to represent the time of run of the torpedo to the point of intercept, and means to position the corresponding input members of the multiplying means in accordance with the position of the output member of the converting mechanism.

4. In a mechanism for determining the gyro angle setting for directing a torpedo from a firing ship to a target, a component solver including an input vector and output component members positioned thereby, means for angularly positioning the vector in accordance with the bearing of the target from the firing ship relative to selected rectangular coordinates, means for adjusting the length of the vector in accordance with the range of the target from the firing ship, multiplying means having input members positioned in accordance with the rates of component movement

of the target along the coordinates and in accordance with the time of run of the torpedo, said multiplying means having output members positioned by the input members to represent the components of distance traveled by the target during the time of run of the torpedo, means actuated in accordance with the speed and gyro angle of the torpedo for positioning an output member to represent the position of a reference point along the extended centerline of the firing ship, a second component solver including an input vector and output component members positioned thereby, means for angularly positioning the vector in accordance with the course of the firing ship relative to the coordinates, means for adjusting the length of the vector in accordance with the position of the output member representing the position of the reference point, combining means including input elements and output elements actuated thereby, means for positioning the input elements in accordance with the position of the output members of the multiplying means, the position of the output component members of the second component solver and the position of the output component members of the first mentioned component solver, a vector solver including input component members and an output vector positioned thereby, and means to position said input component members in accordance with the position of the output elements of the combining means, whereby the angular position and length of the output vector represent the direction relative to the coordinates and the distance from the reference point to the point of intercept.

5. In a mechanism for determining the gyro angle for directing a torpedo, means for generating movements in proportion to the movement of the firing ship along selected coordinates, means for generating movements in proportion to the movement of the target along the coordinates,

means for combining the corresponding generated movements to position first output members, means to adjust the said first output members to represent the components of relative position of the target and the firing ship measured along the selected coordinates, computing means including input elements settable according to an interval of time and the rates of movement of the target along said coordinates, said computing means being operable to position output elements to represent the actual movement of the target along said coordinates in the interval of time, means actuated in accordance with the speed and gyro angle of the torpedo for positioning a second output member to represent the position of a reference point along the extended centerline of the firing ship, a component solver including an input vector and component members positioned thereby, means for adjusting the length and direction of the vector according to the position of the second output member and the direction of movement of the firing ship relative to said coordinates, means for combining the vector components represented by the position of the component members and the positioned components represented by the first output members with the position of the output elements of the computing means to obtain new components of position of the target relative to the reference point along said coordinates, a vector solver, means to set said new components into the vector solver and thereby obtain a vector whose length and direction represent the advance range from the reference point and the angle thereof to one of the coordinates, and means settable according to the direction of movement of the firing ship relative to said coordinates and by the length and direction of the vector of the vector solver to determine the said interval of time.

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