July 9, 1946. W. H. NEWELL 2,403,542

TORPEDO DATA COMPUTER

Filed Aug. 3, 1940 4 Sheets-Sheet 1

Fig. 1

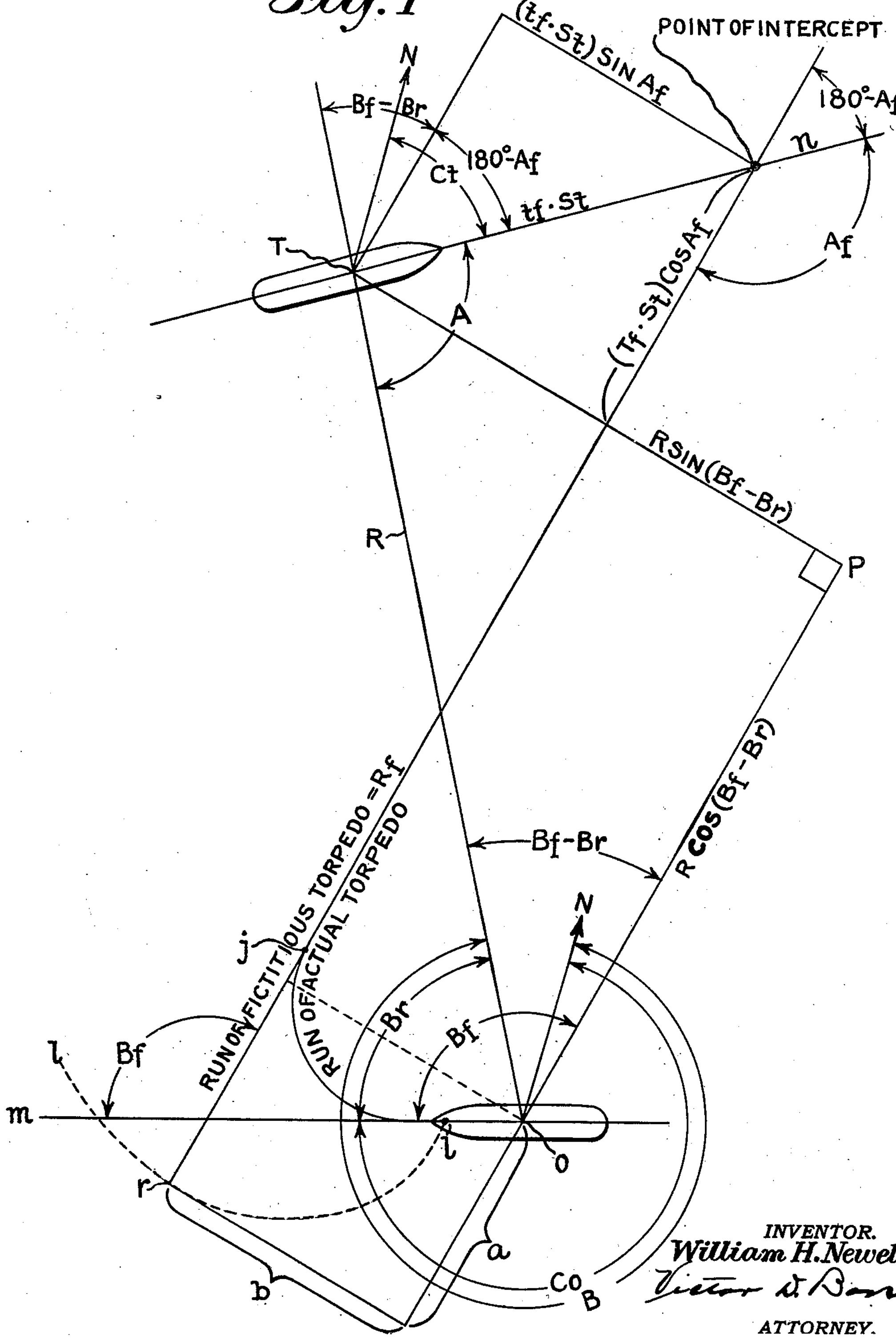

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Fig. 1a

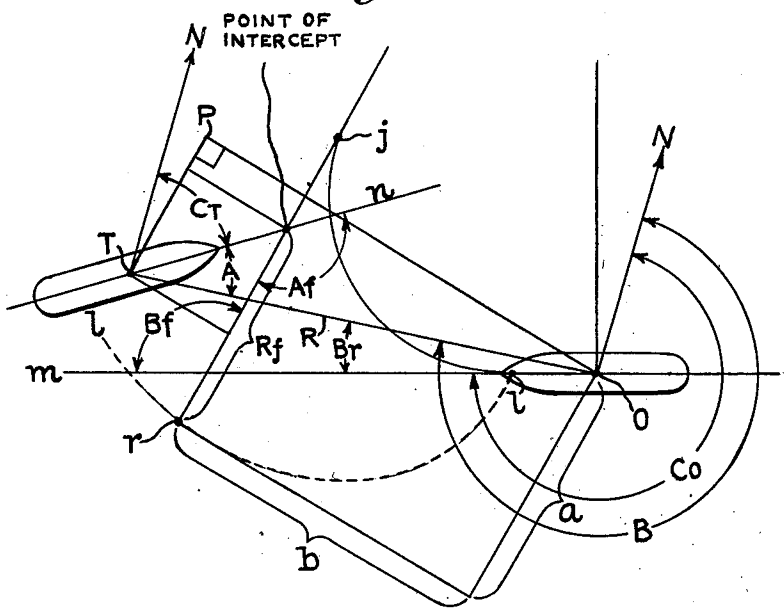
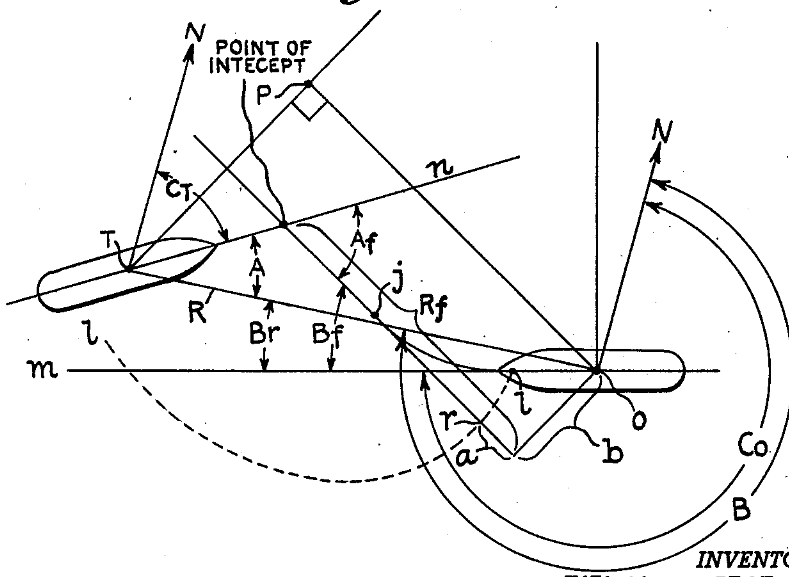


Fig. 1b



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TORPEDO DATA COMPUTER

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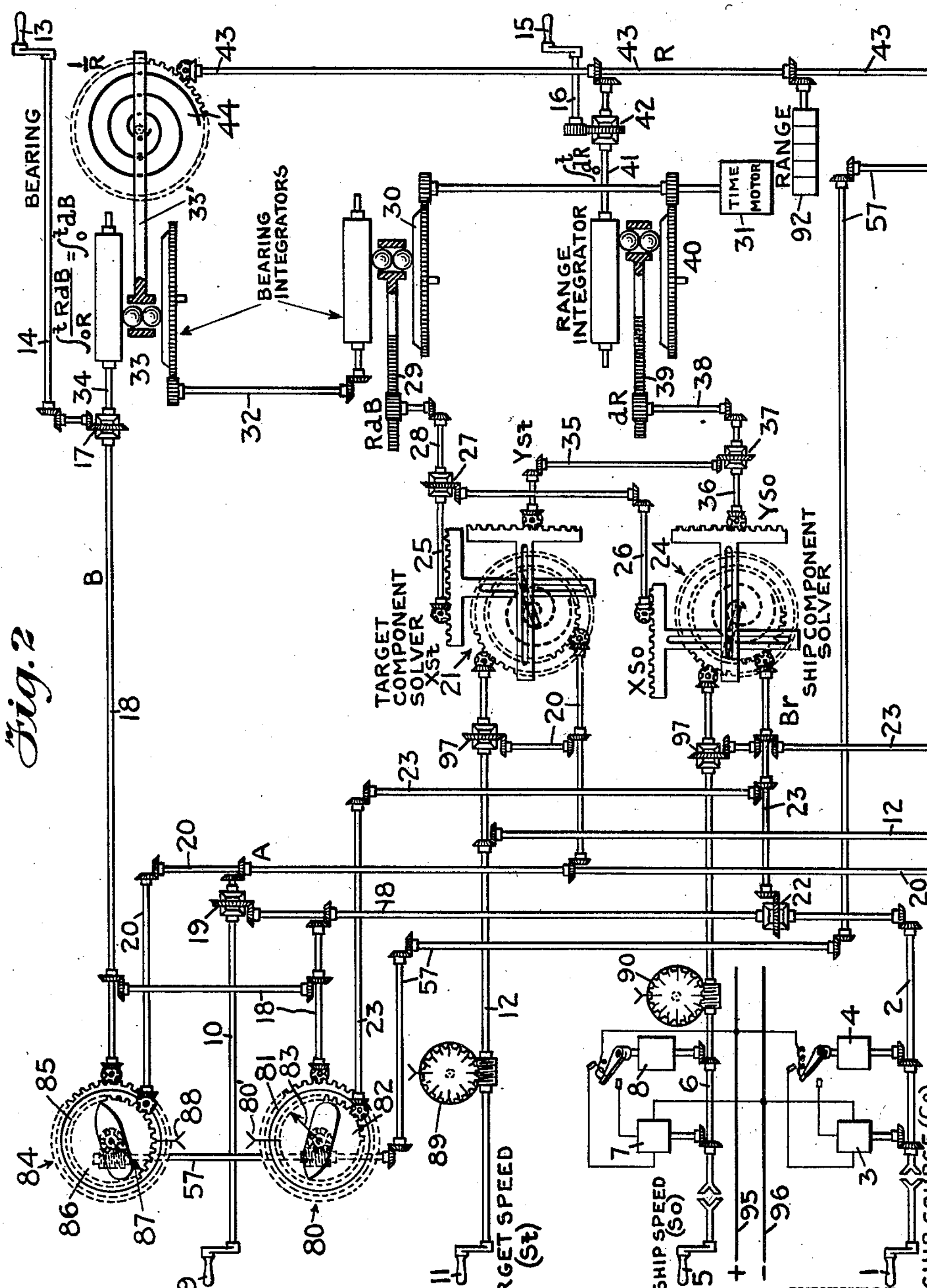

Fig. 2

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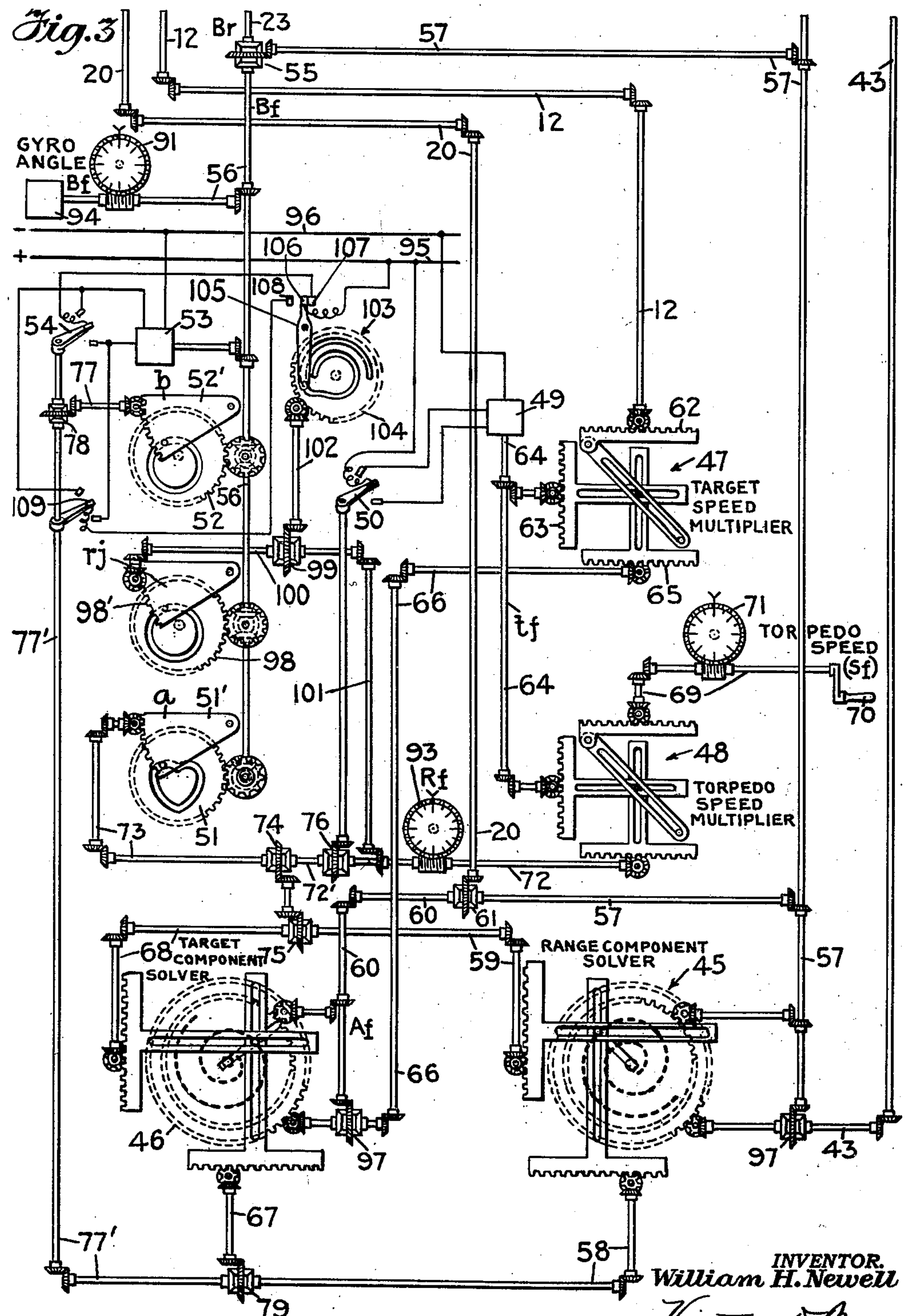
Fig. 3



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Patented July 9, 1946 2,403,542

UNITED STATES PATENT OFFICE

2,403,542

TORPEDO DATA COMPUTER

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Application August 3, 1940, Serial No. 350,897

4 Claims. (Cl. 235—61.5)

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This invention relates to torpedo directors and particularly to mechanisms for computing the values of the various factors involved.

The principal object of this invention is to provide a mechanism for computing the various factors involved in the directing of a torpedo to a point of intercept with the target.

Another object is to provide a torpedo director of a simpler construction and a greater accuracy than has heretofore been known.

A still further object of the invention is to solve the problem of directing a torpedo to a target on the basis of the analysis of a fictitious torpedo fired from a reference point and traveling throughout its run at a constant speed equal to the speed of the actual torpedo and on a constant course which is the same course that the actual torpedo takes upon its settling down on a steady course to the point of intercept.

A still further object of the invention is to provide a mechanism to solve the problem of directing a torpedo on the basis of a fictitious torpedo, as set forth in the preceding objects, but defining the reference point in coordinates parallel to and at right angles to the course of the fictitious torpedo.

Other objects will be apparent from a consideration of this specification and the drawings, forming a part of this application, in which:

Fig. 1 is a diagrammatic representation of the solution of the problem of directing a torpedo to a target in accordance with the present invention for a selected set of conditions;

Fig. 1*a* and Fig. 1*b* are modifications of Fig. 1 and illustrate the geometric aspects of the problem under certain critical short range conditions; and

Figs. 2 and 3, taken together, is a diagrammatic representation of the arrangement and cooperation of mechanisms to solve the problem disclosed in Fig. 1.

The present invention contemplates the solution of the problem of directing a torpedo to a target similar in some respects to that set forth in an application filed on January 27, 1940, by Raymond E. Crooke, Serial No. 315,901, entitled Torpedo director, wherein the trigonometric relations of the factors involved in the problem were analyzed and solved as of the instant of the starting of a fictitious torpedo from a reference point defined in coordinates parallel to and at right angles to the course of the firing ship.

In the present invention however the basis for the solution is on the consideration of the trigonometric relation of the factors analyzed from a reference point on coordinates parallel to and at right angles to the course of the torpedo after it has settled down on its course to the target.

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It will be apparent on a consideration of the drawings of the reference application and the present application that with the use of the present basis of analysis the number of mechanisms required for the mechanical solution of the problem are reduced with attending decrease in cost and increase in accuracy.

Referring to Fig. 1, the firing ship, whose periscope is *o*, is on a course *om*, Co degrees from oN or North. The target at T is on a course T*n*, C*t* degrees from TN or North.

The dotted line *l*, *l* is the locus of reference points, *r*, at which a fictitious torpedo running at a constant speed equal to that of the final speed of the actual torpedo, and starting at the instant of the firing of the actual torpedo will merge with the path of the actual torpedo at the point *j*, when it settles down on a steady course to the target. The position of the reference point *r* relative to the periscope *o* of the firing ship is a function of the gyro angle B*f* and may be expressed as coordinates *a* and *b* parallel and at right angles respectively to the course of the fictitious torpedo. In practice, the values of the coordinates *a* and *b* are found by experimentally determining the turning radius and the time of turning to the point *j* of the actual torpedo for the various gyro angles. The reference point *r* for any selected gyro angle B*f* is obtained by extending backward the line representing the straight portion of the actual torpedo's course a distance *jr*, which represents the distance the fictitious torpedo, traveling at the normal speed of the actual torpedo, will move during the time required by the actual torpedo to reach the point *j* after being fired. Sufficient positions of the point *r* for different values of gyro angle are thus obtained to determine the form of the line *l*, *l* from which the coordinates *a* and *b* may be obtained for any gyro angle B*f*. Cams are then constructed to give the values of the coordinates for any gyro angle.

In referring to Fig. 1 it is seen that the known or estimated values or conditions of the problem are obtained as follows. The relative target bearing B*r* is obtained from the periscope or other instrument. The present or observed range R is obtained from a range finder or other range indicating means. The speed S*t* and course C*t* or target angle A of the target may be estimated from observation or may be determined by generating the values of target bearing and range, using the estimated target speed and course as part of the setting for generating the values. The target speed and course may then be adjusted until the generated values of range and bearing remain equal to the observed values which condition indicates that the settings of target speed and course are correct. The speed of the torpedo S*f* and the speed So and course Co of the firing ship are also known.

The values directly attainable from the known or estimated values just referred to are the true bearing B which is equal to course of own ship Co combined with relative bearing B*r*,

$$B=Br+Co \quad (1)$$

The value of target angle A is equal to the true bearing B minus 180° minus the target course C*t*,

$$A=B-Ct-180° \quad (2)$$

By substituting Equation 1 in Equation 2,

$$A=Br+Co-Ct-180° \quad (3)$$

The primary unknown values are the gyro angle B*f* and the time of run of the torpedo *tf*. With these values known all the other unknown values may be determined, for example the run of the fictitious torpedo R*f* equals the torpedo speed S*f* multipled by the time of run *tf*.

$$Rf=tf \cdot Sf \quad (4)$$

The angle of impact A*f* may be obtained from the gyro angle B*f*, the observed bearing B*r* and the target angle A as shown by the following equations:

$$180°-Af=180°-(Bf-Br)-A \quad (5)$$

or

$$Af=A+(Bf-Br) \quad (6)$$

In solving the problem in accordance with the principles of this invention the range R and the distance traveled by the target during the run of the torpedo *tf·St* are converted into components parallel and perpendicular to the course of the fictitious torpedo which as has been explained is parallel to the straight portion of the path of the real torpedo. These components are therefore parallel to the coordinates *a* and *b*.

The components OP and TP of the observed range R are proportional to the cosine and sine functions of the angle B*f*—B*r* and are expressed by the equations,

$$OP=R\cos(Bf-Br) \quad (7)$$

$$TP=R\sin(Bf-Br) \quad (8)$$

The components of the distance traveled by the target during the run of the torpedo are proportional to the cosine and sine functions of the angle of impact A*f* and are expressed mathematically as

$$(tf \cdot St)\cos Af \quad (9)$$

$$(tf \cdot St)\sin Af \quad (10)$$

From these components and the coordinates *a* and *b* the primary unknowns, gyro angle B*f* and time of run *tf*, may be obtained by simultaneous solution of the following equations:

$$Rf=tf \cdot Sf=a+R\cos(Bf-Br)-(tf \cdot St)\cos Af \quad (11)$$

$$b=R\sin(Bf-Br)-(tf \cdot St)\sin Af \quad (12)$$

Equations 11 and 12 are solved by a series of approximations for the primary and secondary unknowns, for example, R*f* may initially be taken as equal to R, B*f* as equal to B*r*, and A*f* as equal to A. From the use of these approximations successive values of the unknowns are obtained with increasing accuracy by the method of successive approximations. Mathematically this is a long and tedious method of solving the problem but by the use of the mechanism of this invention in which the successively obtained values of the unknowns immediately affect the related values the final solution is obtained practically immediately and a new solution is immediately obtained whenever new controlling values may be set into the mechanism.

The course of the firing ship Co is set up in the mechanism by crank **1** rotating shaft **2**, or it may be automatically introduced by servo-motor **3** controlled by repeater motor **4** in the conventional manner. The speed of the firing ship So is set up in the mechanism by crank **5** rotating shaft **6** or this value may be set up automatically in the mechanism by servo-motor **7** controlled by repeater motor **8**, in the conventional manner. The course of the target is set up in the mechanism by crank **9** rotating shaft **10** and the speed of the target is set up in the mechanism by crank **11** rotating shaft **12**. The true bearing of the target (B) is set up in the mechanism by crank **13** rotating shaft **14**. The range is set up in the mechanism by crank **15** rotating shaft **16**.

As these factors may be observed intermittently, it is desirable that they be continuously generated. To this end, the bearing setting shaft **14** is connected to differential **17**. A second side of this differential is connected by shaft **18** to differential **19** where the rotation of shaft **18**, which represents the true bearing B, is combined with the course of the target C*t*, represented by rotation of shaft **10**, to obtain the target angle A, represented by the rotation of shaft **20**. The target angle A and the speed of the target S*t* are fed into target component solver **21**. Likewise the true bearing of the target B, represented by the rotation of shaft **18**, is combined with the course of the firing ship Co, represented by the rotation of shaft **2**, in differential **22** from which is obtained, as the third side of the differential, the angle B*r* or the relative bearing of the target, represented by the rotation of shaft **23**. The relative bearing of the target B*r* and the speed of the firing ship So are fed into ship's component solver **24**. The component of movement XS*t* of the target across the line of bearing B*r* is represented by the rotation of shaft **25** connected to one output slide of the target component solver **21** and the component of movement XSo of the own ship across the line of bearing B*r* is represented by the rotation of shaft **26** connected to one output slide of the ship component solver **24**. The values of the components XS*t* and XSo are expressed mathematically by the equations,

$$XSt=St\sin A \quad (13)$$

$$XSo=So\sin Br \quad (14)$$

The rotation of shafts **25** and **26** are combined in differential **27**, the output of which shaft **28**, represents the rate of change of the true bearing *d*B multiplied by the range R or R*d*B. The value R*d*B, which is the relative lateral rate of movement of the own ship and target across the line of bearing B*r*, is obtained in accordance with the equation,

$$RdB=XSt+XSo \quad (15)$$

Shaft **28** is connected to the control member **29** of an integrator whose driving plate **30** is rotated at a constant speed, representing time t, by motor **31**. The output of this integrator

$$\int_0^T RdB$$

represented by the rotation of shaft **32**, is connected to the driving plate of an integrator **33** whose control element **33'** is moved in proportion to 1/R, as will be explained later. The output of integrator **33**, represented by the rotation of shaft **34**, is proportional to

$$\int_0^T RdB$$

divided by R or

$$\int_0^T dB$$

Shaft **34** is connected to the third side of differential **17** and thereby continuously drives shaft **18** in accordance with the true bearing B.

Likewise, the range component of the speed of the target Y*St*, represented by the rotation of shaft **35**, and the range component of the speed of the ship Y*So*, represented by the rotation of shaft **36**, are combined in differential **37**. The values of the components Y*St* and Y*So* are expressed mathematically by the equations,

$$YSt=-St \cos A \qquad (16)$$
$$YSo=-So \cos Br \qquad (17)$$

The output of this differential, represented by the rotation of shaft **38**, is in proportion to the rate of change of the range *d*R, which is expressed mathematically by the equation

$$dR=YSt+YSo \qquad (18)$$

Shaft **38** is connected to the control element **39** of integrator **40**. The output of this integrator **40**,

$$\int_0^T dR$$

represented by the rotation of shaft **41**, is connected to shaft **16** by differential **42**, the output of which, represented by the rotation of shaft **43**, is in proportion to the range R. Shaft **43** is connected to a cam mechanism **44** whose output **33'** is in proportion to 1/R previously referred to.

The gyro angle and torpedo run are obtained from a closed or regenerative system comprising a range component solver **45**, a target component solver **46**, a target speed multiplier **47**, a torpedo speed multiplier **48**, a time of run motor **49**, a time of run motor control **50**, an *a* component cam **51**, a *b* component cam **52**, a gyro angle motor **53**, and a gyro angle motor control **54**.

The inputs to the range component solver **45** are the angle $Bf-Br$ and the range R. The angle $Bf-Br$ is obtained from a differential **55**, the inputs of which are the shaft **23** representing the value B*r* and a shaft **56** representing the gyro angle B*f*. The shaft **56** is driven by the gyro angle motor **53** under the control of the gyro angle motor control **54** or **109** as will be hereinafter described. The output $Bf-Br$ of the differential **55** drives shaft **57** which is connected to the range component solver **45**. The shaft **43** is connected as an input to the range component solver **45**, thereby introducing the range (R). The output of range component solver **45** are $R \sin (Bf-Br)$ and $R \cos (Bf-Br)$ and are represented by the rotation of shafts **58** and **59** respectively. See Equations (8) and (7).

The inputs to the target component solver **46** are the angle of impact A*f* and the distance traveled by the target during the time of run of the torpedo. Referring to Equation 6 it will be seen that $Af=A+(Bf-Br)$. The value A*f* is introduced into the target component solver **46** by the shaft **60**, which is connected to differential **61**, where the rotation of shaft **20**, representing the target angle A, is combined with the rotation of shaft **57**, representing the value $Bf-Br$. The second input to the component solver **46**, distance traveled by the target during the time of run of the torpedo, is obtained by multiplying the target speed S*t* by the time of run *tf* in the target speed multiplier **47**. Input slide **62** of the multiplier **47** is driven by shaft **12** whereby it is moved in accordance with target speed. Input slide **63** is driven in accordance with time of run of the torpedo *tf* by shaft **64** which is connected to the time of run motor **49**. The output slide **65** of the multiplier is moved in the well known manner proportional to the product of the inputs, in this case target speed multiplied by time of run or $tf \cdot St$. This movement is communicated to the target component solver **46** by shaft **66**. The outputs of target component solver **46** are

$$(tf \cdot St) \sin Af \text{ and } (tf \cdot St) \cos Af,$$

which are represented by the rotation of shafts **67** and **68** respectively.

The torpedo speed multiplier **48** is similar in all mechanical respects to the target speed multiplier **47**. One input is moved in accordance with torpedo speed as represented by rotation of shaft **69**, which is rotated by handcrank **70**. The value of torpedo speed introduced is indicated by dial **71**. The other input is moved in accordance with time of run of the torpedo as represented by the shaft **64**. The output, represented by rotation of shaft **72**, is the product of torpedo speed and time of run or R*f*, the distance run by the torpedo. See Equation 4.

The *a* coordinate cam **51** and the *b* coordinate cam **52** are rotated in accordance with gyro angle B*f* by the shaft **56**. The movement of the output member **51'** of the *a* component cam **51** is transmitted by shaft **73** to differential **74** where it is combined with the output of differential **75**, which output represents the combined movement of the shafts **59** and **68**. The movement of the output shaft **72'** of differential **74** therefore represents $a+R \cos (Bf-Br)-(tf \cdot St) \cos Af$, which will be recognized as one side of Equation 11. The movement of shaft **72** represents $tf \cdot Sf$ or R*f*, which is the other side of Equation 11. The movements of shafts **72** and **72'**, representing the two sides of Equation 11, act through differential **76** to which they are both connected to actuate the time of run motor control **50** to control the time of run motor **49**, in the usual manner, until the movement of the shaft **72**, driven by the motor **49** through the torpedo speed multiplier **48** to equal one side of the Equation 11, equals the movement of the shaft **72'**, which represents the other side of Equation **11** as determined from the combined outputs of the *a* component cam **51**, the target speed component solver **46**, and the range component solver **45**.

The movement of the output member **52'** of the *b* component cam **52** is connected by a shaft **77** to one member of differential **78**, where it is compared to the output of differential **79** to which a second member of differential **78** is connected by shaft 77'. The rotation of shaft 77' is the result of the combination in differential 79 of the rotation of shafts 58 and 67, which have been shown to represent R sin (Bf—Br) and ($tf \cdot$St) sin Af respectively. The gyro angle motor control 54 is connected to the third member of differential 78 and its movement therefore represents a comparison of the rotation of shafts 77 and 77', which represent the values b and

$$R \sin (Bf - Br) - (tf \cdot St) \sin Af$$

respectively. These values will be recognized as the two sides of Equation 12. The gyro angle motor 53 is controlled in the usual manner from control 54 to drive the b component cam 52 until the value b equals R sin (Bf—Br)—($tf \cdot$St) sin Af as compared in differential 78.

The simultaneous operation of the time of run motor 49 and the gyro angle motor 53 result in the continuous solution of Equations 11 and 12 to give the gyro angle Bf and time of run of the torpedo tf. From time of run, the distance run Rf is obtained through the torpedo speed multiplier 48. If the torpedo speed is fixed, the length of run of the torpedo Rf then bears a fixed relation to the time of run tf. When this condition exists the torpedo speed multiplier 48 may be omitted and shaft 64 connected directly to drive shaft 72 at the appropriate fixed ratio.

The angles of ship's course and gyro angle are set up for visual observation in dial group 80. The true bearing of the target B is connected to the larger dial 81 by shaft 18. The relative bearing of the target Br is connected to plate 82 by shaft 23. These dials are read against a fixed index 80' to respectively indicate true and relative bearing of the target. A pointer 83 indicates gyro angle when read against the dial or plate 82 and receives its motion from shaft 57 which is connected to differential 55. The inputs into this differential are the relative bearing of the target Br, represented by the rotation of the shaft 23, and the gyro angle Bf, represented by the rotation of shaft 56. The ship's course is observed by referring the center line of the represented ship on dial 82 to the large dial 81.

The dial group 84 indicates the angles at the target. The larger dial 85 is the true bearing of the target and is driven by shaft 18. The smaller dial 86 is target angle and is driven by shaft 20. The pointer 87, representing the angle of impact Af when read against the target angle dial, is rotated by shaft 57. When the bow of the target is read against the large dial, the reading is target course. The fixed pointer 88 read against the target dial gives the target angle A.

Dials indicating the instantaneous values of the various factors are inserted as may be desired, such as dial 89 indicating the speed of the target, dial 90 indicating the speed of the firing ship, dial 91 indicating the gyro angle. The instantaneous range is indicated by counter 92 and the run of the torpedo Rf is indicated by dial 93. A transmitter 94, driven by shaft 56, is provided for transmitting the value Bf.

Power for the various motors and their controls is obtained from electric leads 95 and 96. As the operation of such motors from their controls is well known in the prior art, no further description of their operation is believed to be required.

A compensating differential 97 is provided for each of the four component solvers 21, 24, 45 and 46. The purpose of this differential is to cause the cam gears to rotate with the vector direction

gear so that change of direction of the vector will not cause movement relative to the cam gear and therefore change of length of the vector. Because of these differentials 97 a change of length of the vector is caused to be proportional only to the desired value.

It will be noted from the description of the invention hereinbefore disclosed that a false solution of the problem may be given by the instrument in certain critical cases where the computed range is so short that the point of joining of the track of the fictitious torpedo and the track of the actual torpedo is beyond the range of the target, i. e., for the computed course of the torpedo the fictitious torpedo intercepts the target before the actual torpedo has reached its steady course portion of its track and joins the track of the fictitious torpedo. Such a condition is illustrated in Fig. 1a, in which like reference characters indicate like designations in Fig. 1. From an examination of Fig. 1a, it will be seen that a false solution occurs when for an obtained gyro angle the distance run Rf is less than the distance rj, from the reference point r to the point j where the tracks of the fictitious and the actual torpedo join, that is, the actual torpedo in following the curved path crosses in front of the target.

The geometrical aspects of the true solution of critical cases are shown in Fig. 1b in which it will be seen that the distance run Rf is greater than the distance from the reference point r to the point j. Since the distance from the reference point r to the point j is a function of the gyro angle, a cam mechanism may be constructed to furnish this value.

The instrument automatically gives a true solution of critical as well as normal cases, as follows:

The rj cam is mounted on a gear 98 driven from shaft 56 in accordance with the gyro angle determined by the mechanism. The cam is so shaped that the movement of the output member 98' represents the distance from the reference point r to the point j and is designated as rj.

As previously explained, if this value exceeds the run of the torpedo Rf the solution is false. The values rj and Rf are therefore compared by a differential 99 which is connected to the output member 98' by a shaft 100 and to shaft 72 by a shaft 101. The output of differential 99, represented by the rotation of shaft 102, drives a cut-out mechanism 103. This cut-out mechanism consists of a gear 104 having a cam cut in one side. This cam consists of two circumferential sections of slightly different radii and an interconnnecting section connecting the two. A follower arm 105 is positioned by this cam so that a contact 106 on the end of the arm is normally in contact with fixed contact 107 and power from lead 95 is supplied to the gyro angle motor control 54. This normal position of the follower arm 105 prevails when the torpedo run Rf is greater than the value of rj and the operation of the gyro angle motor 53 under its control 54 is as previously described.

If for any reason the determined torpedo run Rf becomes less than the value rj due to the corresponding gyro angle Bf obtained by the mechanism, the follower arm 105 shifts to the smaller radius section of the cam and the contact 106 is moved away from contact 107 and brought into contact with the fixed contact 108 which is connected to the common contact of a control member 109 driven by the shaft 77'. By this shift from normal gyro-angle control 54 to the control member 109, the effect of the *b* element of Equation 12 as represented by the position of member 52' is temporarily eliminated from the solution. The gyro angle motor 53 under this condition runs in a direction to reduce the gyro angle to bring the course of the torpedo in line with the torpedo tube. This reduction in the gyro angle changes the angle inputs of the component solvers 45 and 46 and thereby repositions the associated members. The repositioning of the members representing components parallel to the course of the torpedo causes the control 50 to actuate the time of run motor 49 until the resulting torpedo run R_f is greater than the value r_j obtained from the cam output 98' when the control arm shifts back to contact 107 and normal operation of the mechanism under control 54 is resumed and the correct solution obtained, as indicated by Fig. 1*b*.

It is apparent that the control member 109 and the arm of the motor control 54 must be yieldably connected to their respective shafts. This may be accomplished by controlling the contact arm through a cam, as shown in Fig. 19 of Patent 1,904,215.

It is evident that various changes or variations from the exact structure indicated in the drawings and specification may be made by those skilled in the art without departing from the scope of the invention as covered in the appended claims.

I claim:

1. In a torpedo director of the regenerative type for determining the distance run and the course of the torpedo to reach a point of intercept with a target, means settable in accordance with the range and relative bearing of the target from an observing point on a firing ship, an element positionable in accordance with the steady course of the torpedo relative to the firing ship, members acuated in accordance with the position of said element and moved in proportion to components of position relative to the observing point of a reference starting point of a fictitious torpedo starting at the instant of firing of the actual torpedo and traveling to the point of intercept at a constant speed equal to that of the actual torpedo and on a course the same as that of the actual torpedo after it has settled down on its steady course to the target, the position of said members representing components along coordinates parallel to and at right angles to the steady course of the torpedo, a part positionable in accordance with the time of run of the torpedo, multiplying means having inputs actuated in accordance with the position of the part and the speed of the target and an output whose position represents the distance run by the target to the point of intercept during the time of run of the torpedo, vector means adjustable in length by the range settable means and angularly positioned by the relative bearing settable means and the position of the element, component members associated with said vector means and positioned thereby in accordance with components of the range of the target along coordinates parallel and at right angles to the steady course of the torpedo, means settable in accordance with the target angle, second vector means adjustable in length by the output of the multiplier and angularly positioned by the relative bearing settable means and by the position of the element and by the target angle settable means, component members associated with said second vector means and positioned thereby in accordance with components of the distance run run by the target to the point of intercept along coordinates parallel and at right angles to the steady course of the torpedo, means differentially combining the positions of the members representing the three said components along coordinates parallel to the steady course of the torpedo, means responsive to the combining means and moved from normal position for controlling the positioning of the part in accordance with the time of run of the torpedo, said combining means including a member actuated by the part in accordance with the distance run by the fictitious torpedo to the point of intercept to restore the responsive means to normal position, means differentially combining the positions of the members representing the three said components at right angles to the steady course of the torpedo, and means responsive to the last mentioned combining means for positioning the element in accordance with the steady course of the torpedo relative to the firing ship.

2. In a torpedo director of the regenerative type for determining the distance run and the course of the torpedo to reach a point of intercept with a target, means settable in accordance with the range and relative bearing of the target from an observing point on a firing ship, an element positionable in accordance with the steady course of the torpedo relative to the firing ship, members actuated in accordance with the position of said element and moved in proportion to components of position relative to the observing point of a reference starting point of a fictitious torpedo starting at the instant of firing of the actual torpedo and traveling to the point of intercept at a constant speed equal to that of the actual torpedo and on a course the same as that of the actual torpedo after it has settled down on its steady course to the target, the position of said members representing components along coordinates parallel to and at right angles to the steady course of the torpedo, a part positionable in accordance with the time of run of the torpedo, multiplying means having inputs actuated in accordance with the position of the part and the speed of the target and an output whose position represents the distance run by the target to the point of intercept during the time of run of the torpedo, vector means adjustable in length by the range settable means and angularly positioned by the relative bearing settable means and the position of the element, component members associated with said vector means and positioned thereby in accordance with components of the range of the target along coordinates parallel and at right angles to the steady course of the torpedo, means settable in accordance with the target angle, second vector means adjustable in length by the output of the multiplier and angularly positioned by the relative bearing settable means and by the position of the element and by the target angle settable means, component members associated with said second vector means and positioned thereby in accordance with components of the distance run by the target to the point of intercept along coordinates parallel and at right angles to the steady course of the torpedo, second multiplying means having inputs actuated in accordance with the position of the part and the speed of the torpedo and an output whose position represents the distance run by the fictitious torpedo to the point of in-

tercept, means differentially equating the positions of the members representing the three said components along coordinates parallel to the steady course of the torpedo against the position of the output of the second multiplying means, follow-up means responsive to the equating means for positioning the part in accordance with the time of run of the torpedo, means differentially combining the positions of the members representing the three said components at right angles to the steady course of the torpedo, and means responsive to the combining means for positioning the element in accordance with the steady course of the torpedo relative to the firing ship.

3. In a torpedo director of the regenerative type for determining the distance run and the course of a torpedo to reach a point of intercept with a target, means settable in accordance with the range and relative bearing of the target from an observing point on a firing ship, an element positionable in accordance with the steady course of the torpedo relative to the firing ship, members actuated in accordance with the position of said element and moved in proportion to components of position relative to the observing point of a reference starting point of a fictitious torpedo starting at the instant of firing of the actual torpedo and traveling to the point of intercept at a constant speed equal to that of the actual torpedo and on a course the same as that of the actual torpedo after it has settled down on its steady course to the target, the position of said members representing components along coordinates parallel to and at right angles to the steady course of the torpedo, a part positionable in accordance with the time of run of the torpedo, multiplying means having inputs actuated in accordance with the position of the part and the speed of the target and an output whose position represents the distance run by the target to the point of intercept during the time of run of the torpedo, vector means adjustable in length by the range settable means and angularly positioned by the relative bearing settable means and the position of the element, component members associated with said vector means and positioned thereby in accordance with components of the range of the target along coordinates parallel and at right angles to the steady course of the torpedo, means settable in accordance with the target angle, second vector means adjustable in length by the output of the multiplier and angularly positioned by the relative bearing settable means and by the position of the element and by the target angle settable means, component members associated with said second vector means and positioned thereby in accordance with components of the distance run by the target to the point of intercept along coordinates parallel and at right angles to the steady course of the torpedo, means differentially combining the positions of the members representing the three said components along coordinates parallel to the steady course of the torpedo, means responsive to the combining means and moved from normal position for controlling the positioning of the part in accordance with the time of run of the torpedo, said combining means including a member actuated by the part in accordance with the distance run by the fictitious torpedo to the point of intercept to restore the responsive means to normal position, means differentially combining the positions of the members representing the three said components at right angles to the steady course of the torpedo, means responsive to the last mentioned combining means for positioning the element in accordance with the steady course of the torpedo relative to the firing ship, means positioned by the member actuated in accordance with the distance run by the fictitious torpedo to the point of intercept, means positioned by the element in proportion to the distance run by the fictitious torpedo to the point where the actual torpedo has settled down on its steady course to the target, means differentially comparing the positions of the last two mentioned means, and means operatively responsive to the comparing means for reducing the effective value of the component of position of the reference point measured at right angles to the course of the torpedo when the distance represented by the means positioned by the member is less than the distance represented by the means positioned by the element.

4. In a torpedo director of the regenerative type for determining the distance run and the course of a torpedo to reach a point of intercept with a target, means settable in accordance with the range and relative bearing of the target from an observing point on a firing ship, an element positionable in accordance with the steady course of the torpedo relative to the firing ship, members actuated in accordance with the position of said element and moved in proportion to components of position relative to the observing point of a reference starting point of a fictitious torpedo starting at the instant of firing of the actual torpedo and traveling to the point of intercept at a constant speed equal to that of the actual torpedo and on a course the same as that of the actual torpedo after it has settled down on its steady course to the target, the position of said members representing components along coordinates parallel to and at right angles to the steady course of the torpedo, a part positionable in accordance with the time of run of the torpedo, multiplying means having inputs actuated in accordance with the position of the part and the speed of the target and an output whose position represents the distance run by the target to the point of intercept during the time of run of the torpedo, vector means adjustable in length by the range settable means and angularly positioned by the relative bearing settable means and the position of the element, component members associated with said vector means and positioned thereby in accordance with components of the range of the target along coordinates parallel and at right angles to the steady course of the torpedo, means settable in accordance with the target angle, second vector means adjustable in length by the output of the multiplier and angularly positioned by the relative bearing settable means and by the position of the element and by the target angle settable means, component members associated with said second vector means and positioned thereby in accordance with components of the distance run by the target to the point of intercept along coordinates parallel and at right angles to the steady course of the torpedo, second multiplying means having inputs actuated in accordance with the position of the part and the speed of the torpedo and an output whose position represents the distance run by the fictitious torpedo to the point of intercept, means differentially equating the positions of the members representing the three said components along coordinates parallel to the steady course of the torpedo against the position of the

output of the second multiplying means, follow-up means responsive to the equating means for positioning the part in accordance with the time of run of the torpedo, means differentially combining the positions of the members representing the three said components at right angles to the steady course of the torpedo, means responsive to the combining means for positioning the element in accordance with the steady course of the torpedo relative to the firing ship, means positioned by the output of the second multiplier in accordance with the distance run by the fictitious torpedo to the point of intercept, means positioned by the element in proportion to the distance run by the fictitious torpedo to the point where the actual torpedo has settled down on its steady course to the target, means differentially comparing the positions of the last two mentioned means, and means operatively responsive to the comparing means for reducing the effective value of the component of position of the reference point measured at right angles to the course of the torpedo when the distance represented by the means positioned by the output of the second multiplier is less than the distance represented by the means positioned by the element.

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