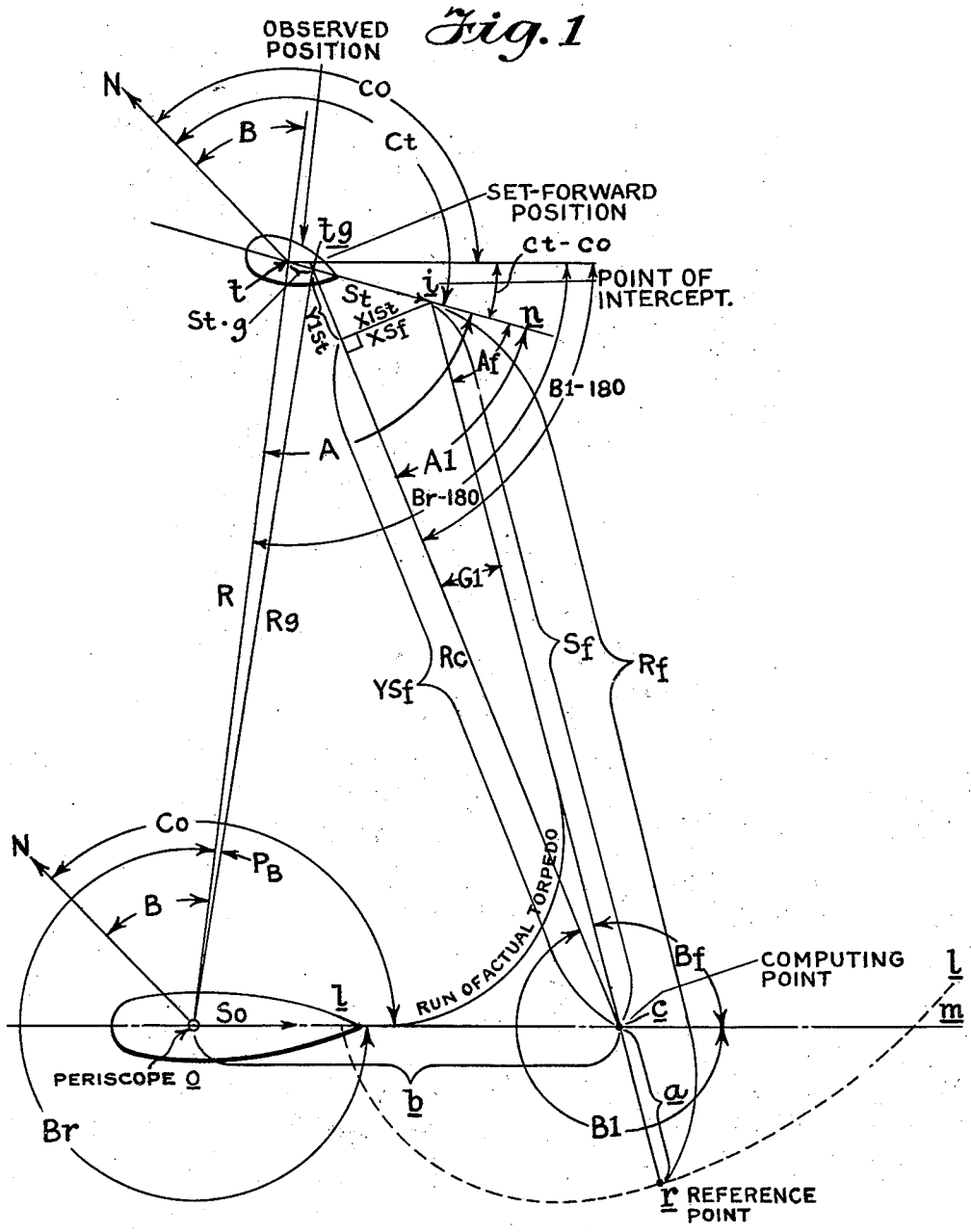
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June 11, 1946. E. P. ROSS 2,402,088

TORPEDO DIRECTOR

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Fig. 1



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Fig. 1a

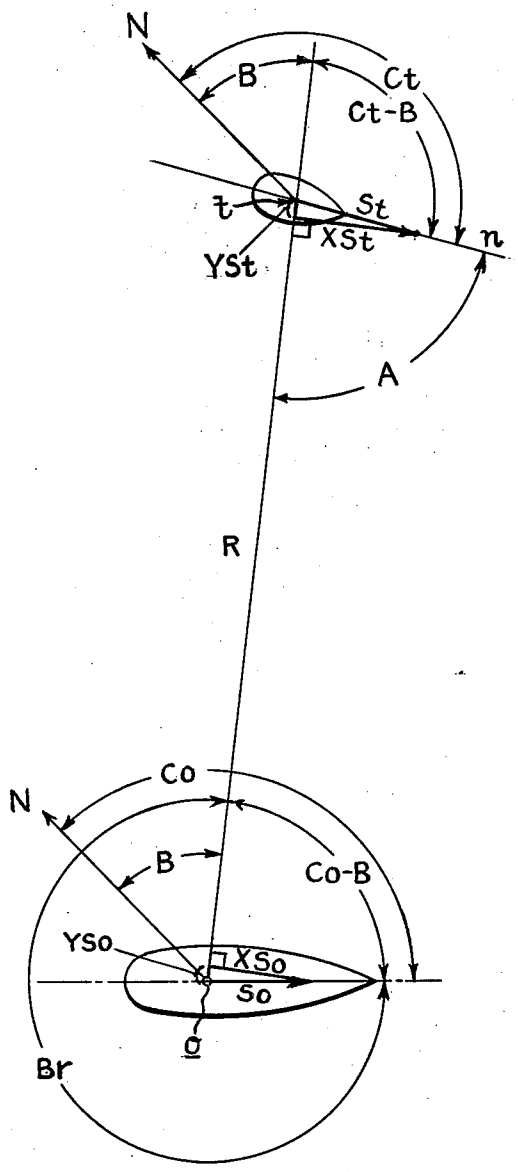
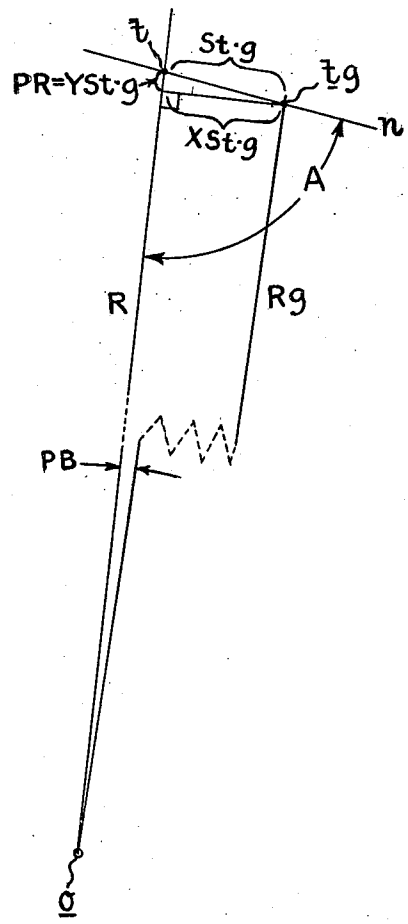


Fig. 1b



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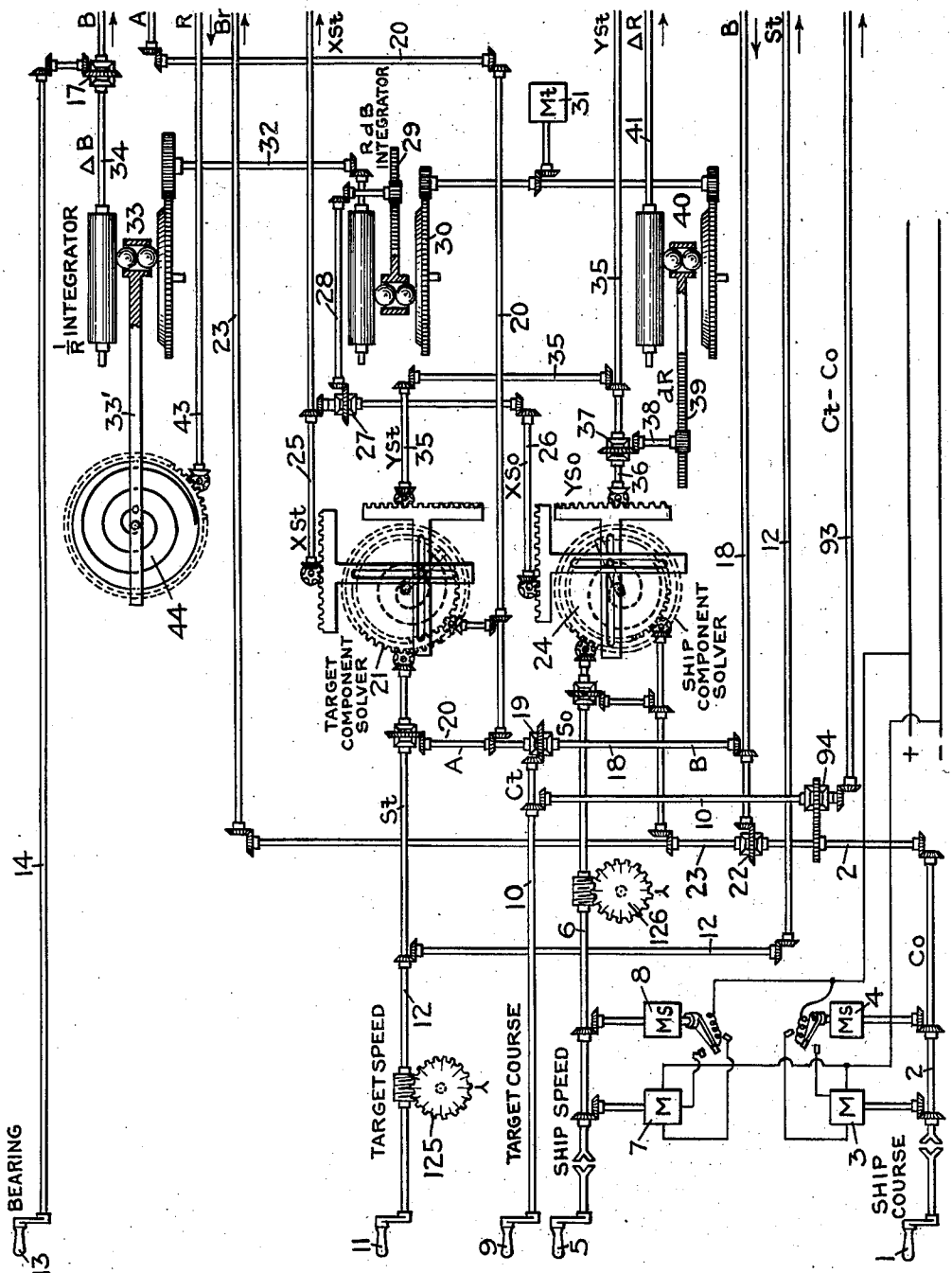


Fig. 2

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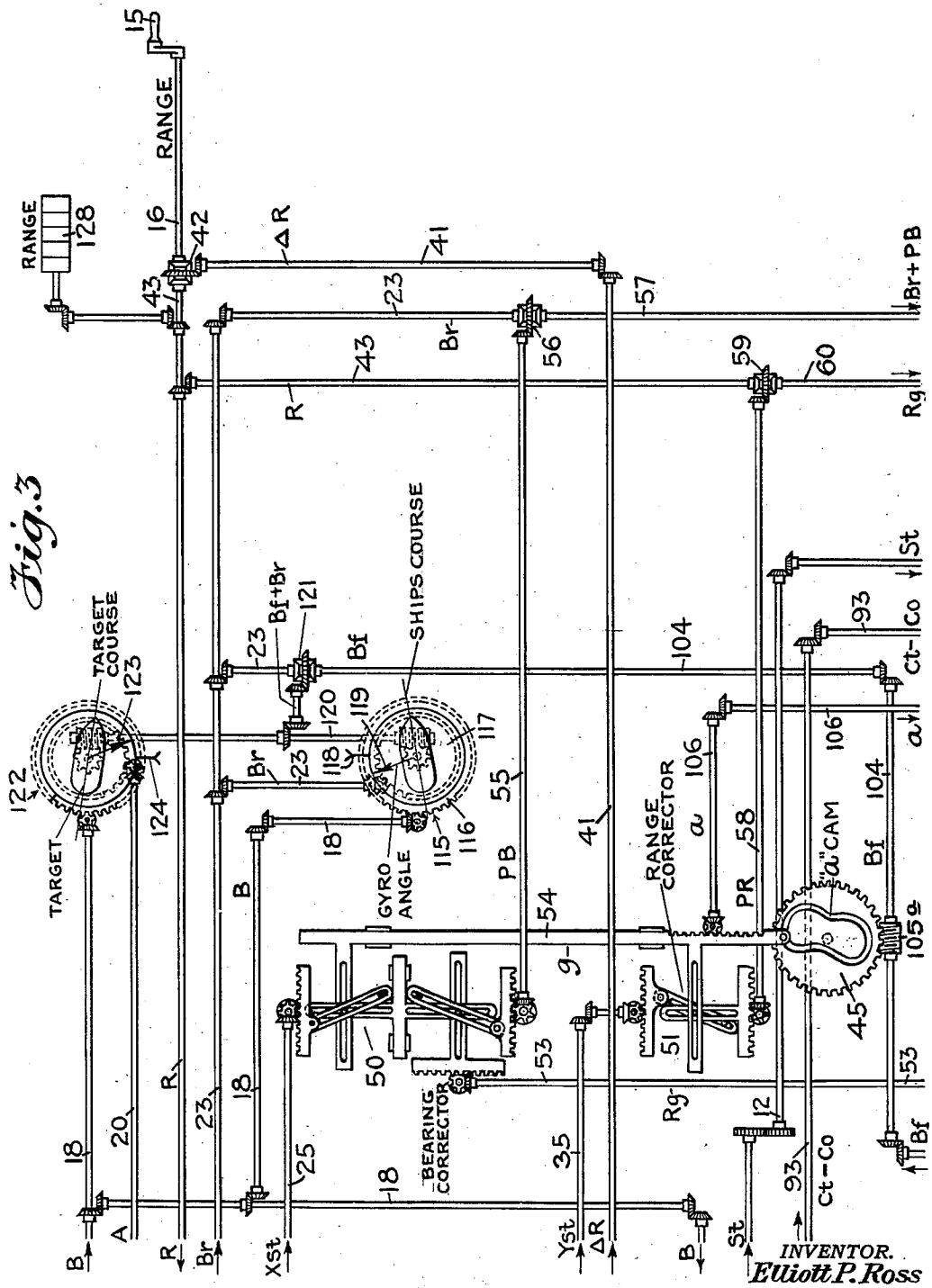
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Fig. 3



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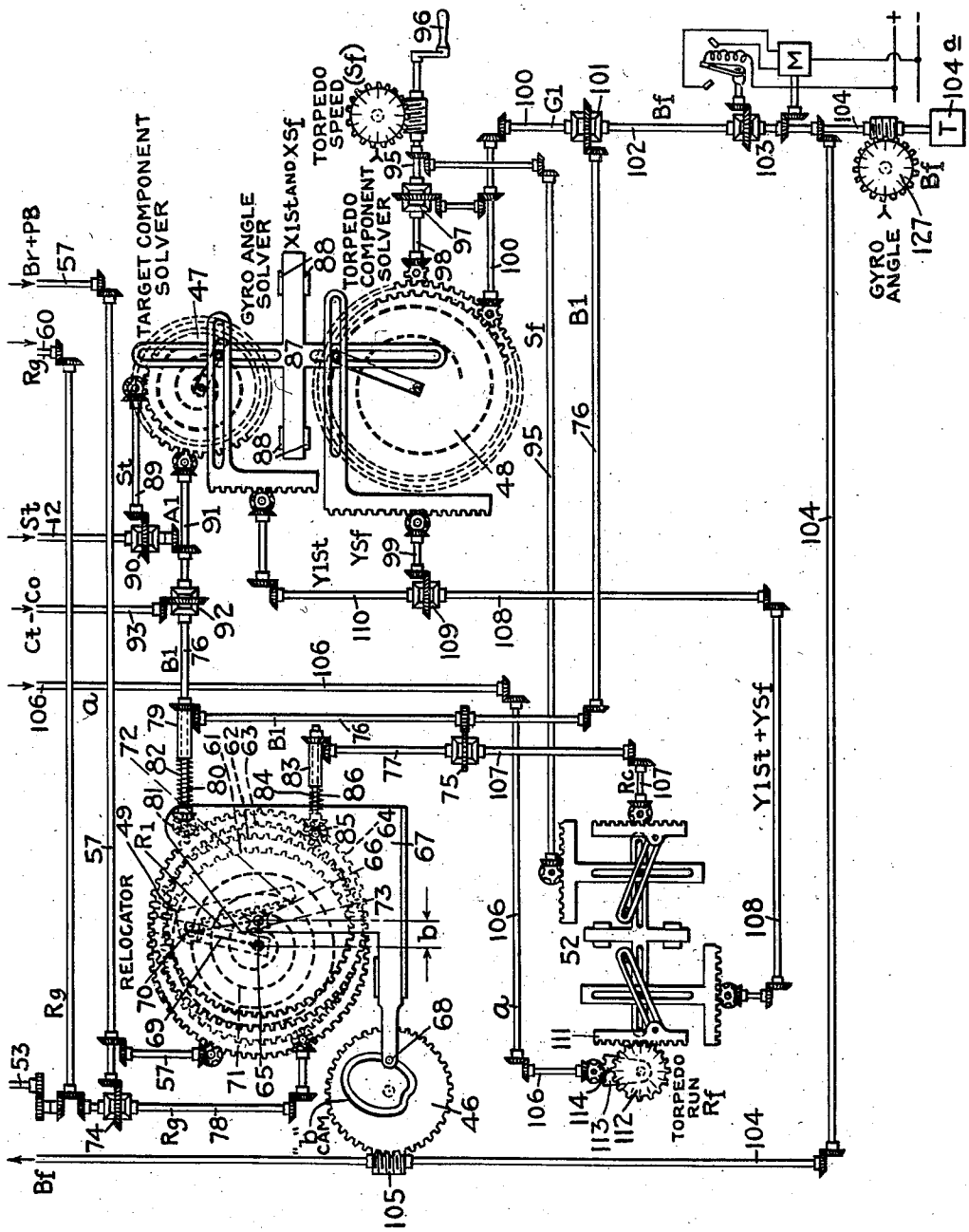


Fig. 4.

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Fig. 5

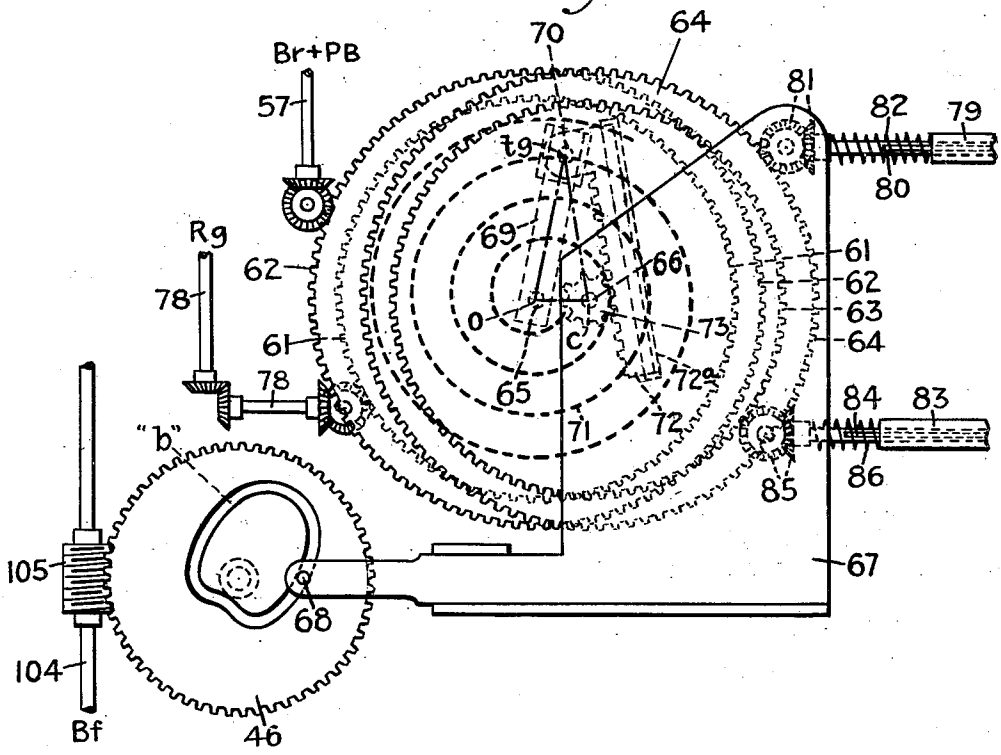
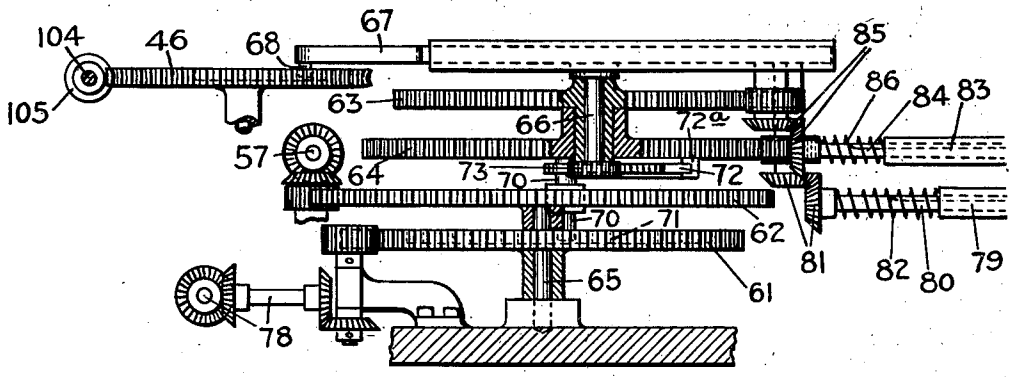


Fig. 6



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Patented June 11, 1946 2,402,088

UNITED STATES PATENT OFFICE

2,402,088

TORPEDO DIRECTOR

Elliott P. Ross, Forest Hills, N. Y., assignor to Ford Instrument Company, Inc., Long Island City, N. Y., a corporation of New York

Application April 29, 1940, Serial No. 332,245

4 Claims. (Cl. 235—61.5)

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This invention relates to torpedo directors and particularly to a mechanism for computing the values of the various factors involved when the path of the torpedo consists of a curved portion and a straight portion.

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 the movement 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 after it has been fired.

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 object but by considering the trigonometric aspects of the problem as of the instant the fictitious torpedo passes through the projected center line of the ship or torpedo tube.

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

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, and 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 the fictitious torpedo from a reference point, and which travels throughout its run at the constant speed of the actual torpedo and on a course the same as that of the actual torpedo after it has settled down on a steady course to the point of intercept.

In the present invention the path or run of a fictitious torpedo is also used and the reference point or starting point is determined in the same way, but the trigonometric relations of the factors involved in the problem are analyzed and solved as of the instant the fictitious torpedo passes through the projected center line of the

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ship or torpedo tube, designated in this application as the computing or calculating point *c*.

By the use of this basis of analysis the mechanisms required for the mechanical solution are greatly simplified and fewer mechanisms are required. Also, certain mechanisms may be used in their installed positions in the director to perform certain of the calculations and apply corrections that are otherwise required as separate mechanisms when using the system disclosed in the reference application.

For example: When using the system disclosed in the reference application in directing a torpedo based upon observations of ranges and bearings obtained sonically, corrections must be applied to such observations due to the time lag of the sound waves in their travel from the target to the firing ship. Likewise, parallax corrections must be applied to the bearings to compensate for the fact that the source of the sound waves on which observations are taken is at the propellers of the target whereas the point of aim is the center of the target. Independent mechanisms have to be made available to calculate these corrections when using the system disclosed in the reference application. In the system of the present invention, such mechanisms are used to calculate the position of the target relative to the firing ship at the instant the fictitious torpedo crosses the extended center line of the firing ship, the position of the target at that time being designated as the "set-forward" position. The corrections for time lag and parallax when using sonic observations can be made by the mechanism in the present system while it is performing other functions by including settings for sonic time lag and target length.

Also, in the application referred to, the mechanism for relocating the range and bearing of the target from the observing point to the reference point involves translations in two directions, one along the projected center line of the ship, and the other at right angles thereto. In the present application, the corresponding relocation of the range and bearing to the calculating point involves but one direction, viz., along the projected center line of the ship.

In the drawings:

Fig. 1 is a diagrammatic representation of the problem of directing a torpedo to a target;

Fig. 1*a* is a diagram, corresponding to a part of Fig. 1, showing the factors involved in the generation of range and bearing;

Fig. 1*b* is a diagram, on an enlarged scale, of

a part of Fig. 1 showing the factors involved in determining the set-forward position.

Figs. 2, 3 and 4, taken together, constitute a diagrammatic representation of the arrangement of mechanisms to solve the problem disclosed in Fig. 1 and Fig. 1*a*.

Fig. 5 is an enlarged view of the relocator mechanism of Fig. 4;

Fig. 6 is an elevation, partly in section, of the mechanism shown in Fig. 5.

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 *tn*, C*t* degrees from *t*N or North.

The dotted line *l*, *l* is the locus of reference points, *r*, at which a fictitious torpedo traveling along a course whose direction is the same as the direction of the straight portion of the path of the actual torpedo and 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 when it settles down on a steady course to the target. The relation of the reference point *r* and the periscope *o* of the firing ship is a function of the gyro angle B*f*, that is, for any particular gyro angle the position of the reference point is along the backward extension of the line representing that gyro angle and therefore the straight portion of the path of the actual torpedo. The distance of the reference point from the point at which the curved portion of the path of the actual torpedo merges into the straight portion is equal to the distance a fictitious torpedo, running at a constant speed the same as the final speed of the actual torpedo, would travel along the straight path to reach the merging point at the same time the actual torpedo reaches that point. The gyro angle B*f* is the angle of the steady course of the torpedo relative to the centerline of the firing ship. The positions of the reference point *r* for various values of gyro angle B*f* are expressed in terms of coordinates *a* and *b*. The coordinate *a* is the distance, measured along the path of the fictitious torpedo, from the reference point *r* to the intersection of the path with the extended centerline of the firing ship. The coordinate *b* is the distance measured along the centerline of the firing ship from the observing point or periscope *o* to its intersection with the path of the fictitious torpedo. In practice, the form of the curved portion of the path of the actual torpedo and the time required for the actual torpedo to reach the merging point is found by experiment for various gyro angles and the values of the coordinates *a* and *b* for the various gyro angles are determined therefrom. These values may be determined by plotting the curved path of the torpedo relative to the centerline of the ship and the periscope *o*. Tangents to this plot drawn at various angles will represent the straight portion of the actual torpedo for the various gyro angles. By extending these tangents to intersect the centerline *om* the resulting distance from the intersection to the periscope *o* is the coordinate *b* for the gyro angle B*f* corresponding to the particular tangent. The product of the torpedo speed and the time required for the actual torpedo to reach the point of tangency gives the distance of the reference point *r* from the point of tangency. The coordinate *a* for the selected gyro angle B*f* is then obtained as the distance from the point *r* to the intersection of the tangent with the course or centerline *om* of the firing ship, that is, the centerline of the torpedo tube. By fairing the line *l*—*l* through the points *r* determined for a number of selected values of gyro angle, intermediate values of the coordinates *a* and *b* may readily be obtained. Cams are then constructed to give the values of the coordinates for any gyro angle.

From the observations of the range of the target R, the relative bearing of the target B*r*, the course of the target C*t*, the speed of the target S*t*, and the value of *a*, which is the distance run by the fictitious torpedo until it crosses the extended center line of the firing ship, the set-forward position of the target *tg* is determined relative to the periscope *o*. The range and bearing of the target in its set-forward position are then relocated as from the periscope *o* to range and bearing as from the calculating point *o*. These values are designated as R*c* and B*l* respectively. By comparing and making equal the components of the speed of the target and the speed of the torpedo at right angles to the bearing of the target from the calculating point, the prediction angle G*l* is mechanically calculated. The gyro angle B*f* is then obtained by combining the prediction angle G*l* and the calculating point bearing B*l*.

As the observations of range and bearing of the target are obtained only intermittently especially if the firing ship is a submarine, it is desirable to generate corresponding values of range and bearing continuously. As is well known, the values of range and bearing between a firing ship and a target change as a function of the course and speed of the firing ship, the course and speed of the target, and the relative angular position and the range between the firing ship and the target. To integrate these changes it is customary to provide component solvers from which are obtained the components of rate of movement of the firing ship and target along and across the present line of bearing. These components of rate of movement are combined and applied to range and bearing integrating mechanisms to give outputs, which represent the changes of range and bearing respectively. In addition to providing continuous values of range and bearing between observations, the integration of range and bearing provides a means of checking the initial estimated speed and course of the target. As the speed and course of the target are the only unknown values in setting up the problem, any variation of the generated values from the observed values must be due to an inaccurate setting of the target course and speed. The amount and direction of any such variations are an indication to the operator of the corrections required to target course and speed. These factors and components are shown diagrammatically in Fig. 1*a* and are related to the mechanism of Fig. 2 in the following manner.

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 by servo motor **7** controlled by repeater motor **8**, in the conventional manner. The course of the target C*t* is set up in the mechanism by crank **9** rotating shaft **10** and the speed of the target S*t* 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**

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rotating shaft 15. The range R is set up in the mechanism by crank 15 rotating shaft 16.

The shaft 14 is connected to one member of differential 17 and a second member of this differential is connected to shaft 18, the rotation of which represents the true bearing of the target B, that is, the bearing of the target from north. The target angle A is the angle of the line of bearing from the target to the firing ship measured from the centerline of the target. From Fig. 1*a* it will be seen that

$$A=180°-(Ct-B) \quad (1)$$

The shaft 18, representing the value B is connected to differential 19 where it is combined with the course of the target C*t*, represented by the rotation of shaft 10, and the constant 180° of Equation 1 to position the shaft 20 to represent the target angle A. The target angle A and the speed of the target S*t* are fed into target component solver 21 by shafts 20 and 12 respectively.

The target component solver 21 is shown as the conventional type having a vector pin which is angularly adjusted by the target angle A input shaft 20, and which is positioned radially by the target speed input shaft 12. Associated with the vector pin are a pair of component slides, one of which is moved by the pin in accordance with the cross component XS*t*, and the other in accordance with the range component YS*t*, of the rate of movement of the target relative to the line of bearing from the observing point to the target. The value of these components may be expressed by the equations

$$XSt=St\cdot\sin A \quad (2)$$
$$YSt=-St\cdot\cos A \quad (3)$$

It will be seen from Fig. 1*a* that

$$Br=360°-(Co-B) \quad (4)$$

The true bearing of the target B, represented by rotation of shaft 18, is combined with the constant 360° and the course of the firing ship C*o*, represented by the rotation of shaft 2, in differential 22, the output of which positions shaft 23, in accordance with Equation 4, to represent the relative bearing B*r*. The relative bearing of the target B*r*, represented by the rotation of shaft 23, and the speed of the firing ship S*o*, represented by the rotation of shaft 6, are fed into ship component solver 24.

The ship component solver 24 is similar to the target component solver 21 except that the vector pin is located in accordance with the relative bearing of the target B*r* and the speed of the firing ship S*o*, and the movement of the component slides represents the cross component XS*o* and the range component YS*o* of the rate of movement of the firing ship relative to the line of bearing from the observing point to the target. The value of these components may be expressed by the equations

$$XSo=So\cdot\sin Br \quad (5)$$
$$YSo=-So\cdot\cos Br \quad (6)$$

The cross component XS*t* of the component solver 21 is represented by the rotation of shaft 25 and the cross component XS*o* of the ship component solver 24 is represented by the rotation of shaft 26. The rotation of shafts 25 and 26 are combined in differential 27, the output of which, shaft 28, represents the linear quantity R*d*B which is the rate of change of the true bearing

*d*B multiplied by the range R, and may be expressed by the equation

$$R\cdot dB=XSt+XSo \quad (7)$$

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

$$\frac{1}{R}$$

as will be explained later. The output of integrator 33, represented by the rotation of shaft 34, is proportional to IR*d*B divided by R or I*d*B or ΔB. Shaft 34 is connected to the third side of differential 17.

Likewise, the range component YS*t* of the speed of the target, represented by the rotation of shaft 35, and the range component YS*o* of the speed of the ship, represented by the rotation of shaft 36, are combined in differential 37. The output of this differential, represented by the rotation of shaft 38, is in proportion to the rate of change of range *d*R as expressed by the equation

$$dR=YSt+YSo \quad (8)$$

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

$$\frac{1}{R}$$

previously referred to.

The values of the coordinates *a* and *b* defining the reference point *r* are generated by cams 45 and 46 respectively as a function of the gyro angle B*f*. This gyro angle is obtained by a closed regenerative system comprising a target component solver 47, a torpedo component solver 48, relocator 49, target bearing corrector 50, target range corrector 51 and torpedo run calculator 52.

The set-forward position of the target, that is, the position of the target when the fictitious torpedo crosses the extended centerline of the firing ship, is obtained by multiplying the component rates of the target, XS*t* and YS*t*, by the time *g* which would be required by the fictitious torpedo to travel from the reference point *r* to the calculating point *c*. As the fictitious torpedo is considered to run at a constant speed it is apparent that the time *g* is a direct function of the coordinate *a*. From Fig. 1*b* it will be seen that the bearing correction PB, which is the angular movement of the target relative to the observed or generated bearing, may be expressed by the equation,

$$\sin PB=\frac{XSt\cdot g}{Rg} \quad (9)$$

or since the sines of small angles are proportional to the angles,

$$PB=k\frac{XSt\cdot g}{Rg} \quad (10)$$

Also from Fig. 1*b* it will be seen that the change of range PR to the set-forward position is ap-

proximately equal to the target range rate component multipled by the time g or

$$PR=YSt\cdot g \qquad (11)$$

and therefore the range to the set-forward position may be expressed approximately by the equation

$$Rg=R+PR \qquad (12)$$

The bearing corrector **50** solves Equation 10 and consists of a multiplier unit and a dividing unit which may be of any form but for purpose of illustration are shown as the type based on the proposition that the sides of similar triangles are proportional. The multiplier unit consists of an angularly adjustable input arm and two rectangular movable slides one of which acts as the second input and the other as the output. The dividing unit is structurally the same as the multiplier but the two slides are the inputs and the angularly movable arm is the output. In the combined unit the output slide of the multiplier unit is shown as directly connected to actuate one of the input slides of the dividing unit.

The inputs to the multiplier unit of corrector **50** are moved in accordance with the target cross component XSt and the time g by the shaft **25** and the bar **54** respectively. The bar **54** is moved by the cam **45**. The resulting position of the output slide of the multiplier unit and the corresponding input slide of the dividing unit therefor represent $XSt\cdot g$. The second input of the dividing unit is moved in proportion to the set-forward range by shaft **53**, the generation of the movement of which will be described hereinafter. The constant k is provided for in the ratio of the output gearing to shaft **55**.

The output of this corrector, which is the bearing correction PB, represented by the rotation of shaft **55**, is combined with the relative bearing of target Br, represented by the rotation of shaft **23**, in differential **56**, the output of which, Br plus PB, is represented by the rotation of shaft **57**.

The range corrector **51** solves Equation 11 and is of the same type as the multiplying unit of corrector **50**. The input ySt is obtained from shaft **35** and the input g is obtained from bar **54**, previously referred to. The output PR, represented by the rotation of shaft **58**, is combined with the range R of the target, represented by the rotation of shaft **43**, in differential **59**, the output of which, the set-forward range Rg (see Equation 12), is represented by the rotation of shaft **60**, which is connected to drive shaft **53**, previously referred to.

The relocator **49** determines the range Rc and the bearing Bl from the calculating point c to the set-forward point tg, and the bearing Bl which is the bearing of the line c—tg relative to the centerline of the ship. These determined values are based upon input values of range Rg, and of bearing Br+PB of the set-forward point from the periscope o, and of the coordinate b. It may be of any suitable type but for purpose of illustration is shown of the type which duplicates the triangle o—c—tg mechanically on a reduced scale.

The relocator **49** consists of four gear disks, **61**, **62**, **63** and **64**, the lower disks **61** and **62** revolving about a common center pin **65** and the upper two disks **63** and **64** revolving about a common center pin **66**. The two pairs of disks are movable relative to each other by having the pin **65** secured to a solid support and by having pin **66** mounted on frame **67** which is constrained to horizontal movements and is moved by pin **68** engaging the groove in cam **46**.

In disk **62** is cut a radial slot **69** in which slides a pin **70**, which also engages a groove **71** cut in the upper surface of disk **61**. Pin **70** also engages a hole near the end of rack **72** which is restrained by the guide **72***a* secured to disk **64** so that the hole in rack **72** moves radially from the center of disk **64**. Secured to disk **63** is gear **73** which meshes with rack **72**. As in all mechanisms of this type, such as component solvers and relocators in which range and bearing are the inputs of two disks, the input shafts are connected together by a compensating differential to correct the rotation of the range input shaft for the rotation of the bearing disk. Differential **74** is connected between shafts **57** and **60** and differential **75** is connected between shafts **76** and **77** for this purpose. The third side of differential **74** is shaft **78** whose rotation represents the range of the target in its set-forward position.

The operation of the relocator is as follows: The input of bearing Br+PB and range Rg of the target in its set-forward position are set up by shafts **57** and **78** respectively, shaft **57** being connected to disk **62** and shaft **78** being connected to disk **61**. The rotation of these disks determines the movement of pin **70** that rotates disk **64**, and also moves rack **72** by passing through the hole near the end thereof. Rack **72** engages gear **73** which is secured to the hub of disk **63** so that disk **63** rotates in accordance with the distance of the pin **70** from the movable center pin **66**. Disks **63** and **64** are further rotated by their translational movement relative to disks **61** and **62**. Shaft **76** is connected to disk **64** through hollow shaft **79**, into which fits shaft **80** in spline teeth relation, and gears **81**. A spring **82** keeps gears **81** in mesh. Similarly shaft **77** is connected to disk **63** through hollow shaft **83**, shaft **84** and gears **85**. Spring **86** keeps gears **85** in mesh.

Target component solver **47** and torpedo component solver **48** are of the conventional type similar to target component solver **21**. The cross component links of both solvers are connected to the single slide **87** which is constrained to horizontal movements by guides **88**. In this manner the cross component of movement of the torpedo is made equal to that of the target, as required by the solution of the problem.

The input of target speed St to target component solver **47** is by shaft **89**, connected by the conventional compensating differential **90** to shaft **12**. From Fig. 1 it will be seen that the target angle Al may be determined, as follows:

$$Al=Co+(Bl-180)-Ct \qquad (13)$$

or

$$Al=(Bl-180)-(Ct-Co) \qquad (14)$$

The input of the target angle Al to target component solver **47** is by shaft **91** which is connected to differential **92**, which combines the rotation of shafts **93** and **76**, which represent $(Ct-Co)$ and Bl, respectively. Shaft **93** is driven by shafts **2** and **10** to which it is connected by differential **94** (Fig. 2). It will thus be seen from Equation 14 that the rotation of shaft **91** represents the target angle Al. It is understood that the 180 degree constant is allowed for in setting the gearing.

The movement of the component slides of the target component solver **47** represent the cross component $XlSt$ and the range component $YlSt$,

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which may be expressed by the following equations

$$XlSt = \sin Al \cdot St \quad (15)$$
$$YlSt = -\cos Al \cdot St \quad (16)$$

Although the torpedo component solver **48** is structurally of the conventional type, its use is not conventional in that the inputs are the length of the vector and the value of one of the components instead of the usual inputs of length and direction of the vector. Under this condition, where the inputs are the length of the vector and the value of one of the components the outputs are the direction of the vector and the value of the other component. The component input to the torpedo component solver **48** is the cross component of torpedo speed *XSf*, represented by movement of slide **87** which is positioned by the target component solver in accordance with the cross component of target speed *XlSt*. It is well known and will be seen from Fig. 1 that the torpedo will be on a course to intercept the target when the cross component of torpedo speed XSf is equal to the cross component of target speed *XlSt*. The input to the torpedo component solver **48** which adjusts the length of the vector is the speed of the torpedo S*f* which is introduced by shaft **95** rotated by crank **96**, the compensating differential **97** and shaft **98**. The outputs are the range component of torpedo speed YS*f*, represented by the rotation of shaft **99**, and the prediction angle G*l*, represented by the rotation of shaft **100**. It will be seen that when the pin of the vector is set to represent torpedo speed and the component slide **87** is set to represent the cross component of speed of the target and therefore the required cross component of speed of the torpedo, the slot of the slide **87** cooperating with the pin of the vector will cause the vector to take up an angular position representing the prediction angle G*l*, that is, the required direction of the torpedo course relative to the line from the computing point *c* to the set forward position of the target *tg*. As the direction of the vector is thus determined by the position of the cross component slide **87** the other component slide will be positioned by the vector pin to represent the range component of torpedo speed YS*f*. Shafts **100** and **76** are connected to differential **101**, the output of which is shaft **102**, the rotation of which represents the gyro angle or B*f*. Shaft **102** is connected to a conventional follow-up mechanism **103**, the output of which is shaft **104** whose rotation represents the gyro angle B*f* the same as the rotation of shaft **102**. Shaft **104** is connected to cam **46** by worm gear **105** and cam **45** by worm gear **105***a*. Shaft **104** is also connected to transmitter **104***a* for remote control of a receiver (not shown) for directing the setting of the torpedo gyro angle.

The run of the fictitious torpedo R*f* is determined from the relation of the sides of the triangle *c*, *i*, *tg* of Fig. 1 from which it will be seen that

$$\frac{Rf-a}{Rc} = \frac{Sf}{YlSt+YSf} \quad (17)$$

or

$$Rf = \frac{Rc \cdot Sf}{YlSt+YSf} + a \quad (18)$$

The mechanism to solve this equation is the torpedo run calculator **52**, which is a conventional multiplier and divider similar to the target bearing corrector **50**, to the output of which is added the value of the coordinate *a* represented by the

rotation of shaft **106**, geared to a rack on bar **54**. The input Rc is obtained by shaft **107** connected to the output of differential **75**, previously described. The input S*f* is obtained by shaft **95** and the input YlSt+YS*f* is obtained by shaft **108** which is the output of differential **109** which combines the rotation of shafts **99** and **110**, the range component outputs of torpedo component solver **48** and target component solver **47** respectively. The output of the torpedo run calculator **52** is represented by the movement of rack **111** which meshes with disk **112** which carries appropriate graduations. The value of the coordinate *a* is added by shaft **106** rotating the frame **113** which carries the reference line **114** for the graduations on disk **112** which indicate run of the torpedo when read against the reference line **114**.

The angles of ship's course and gyro angle are set up for visual observation in dial group **115**. The true bearing of the target (B) is connected to the larger dial **116** by shaft **18**. The relative bearing of the target Br is connected to dial **117** by shaft **23**. These dials are read against a fixed index **118** to respectively indicate true and relative bearing of the target. A pointer **119** indicates gyro angle B*f* when read against the dial **117** and receives its motion from shaft **120** which is connected to differential **121**. The inputs into this diffeerntial are the relative bearing of the target Br, represented by the rotation of the shaft **23**, and the gyro angle B*f*, represented by the rotation of shaft **104**. The ship's course is observed by referring the center line of the represented ship on dial **117** to the larger dial **116**.

The dial group **122** indicates the angles at the target. The larger dial is rotated in accordance with the true bearing B of the target and is driven by shaft **18**. The smaller dial rotates in accordance with target angle A and is driven by shaft **20**. The pointer **123**, representing the angle of impact A*f* when read against the target angle dial, is rotated by shaft **120**. When the bow of the target is read against the large dial, the reading is target course C*t*. The fixed pointer **124** 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 **125** indicating the speed of the target, dial **126** indicating the speed of the firing ship, dial **127** indicating the gyro angle. The instanteous ranges are indicated by counter **128**.

It is obvious that various changes may be made by those skilled in the art in the details of the embodiment of the invention illustrated in the drawings and described above within the principle and scope of the invention as expressed in the appended claims.

I claim:

1. In a torpedo director for directing a torpedo from a firing ship to a target along a path having a curved portion and a straight portion, means settable in accordance with the range of the target from the firing ship, means settable in accordance with the direction of the line of bearing of the target from the firing ship measured relative to a reference line on the firing ship including members settable in accordance with the course of the firing ship and the true bearing of the target from the firing ship, means settable in accordance with the speed of the target, means settable in accordance with the course of the target, a target component solver including a vector member adjustable in length by the target speed settable means and angularly adjustable in ac-

cordance with the direction of movement of the target relative to the line of bearing as differentially determined by the true bearing settable means and the target course settable means, said component solver also including first and second component members operably associated with the said vector member and representing the components of the target speed along and across the line of bearing respectively, an element positionable to represent the direction of the straight portion of the torpedo path defined relative to the reference line, first multiplying means having input members positioned by the first component member and the output member of a first cam mechanism actuated by the element and having an output member operably associated with said input members, means for differentially connecting the output member of the first multiplying means with the range settable means to position a second range settable means in accordance with the range of a set-forward position of the target relative to the firing ship, second multiplying means having input members positioned by the second component member and the output member of the cam mechanism and having an output member operably associated with the input members, dividing means having input members positioned by the output member of the second multiplying means and the second range settable means and having an output member operably associated with the input members, means for differentially connecting the output member of the dividing means with the line of bearing settable means to position a second line of bearing settable means in accordance with the line of bearing of the set forward position of the target relative to the firing ship, a second cam mechanism actuated by the element having an output member whose position represents the location of a calculating point on the extended reference line, relocating means having input members actuated in accordance with the output member of the second cam mechanism, the position of the second range settable means and the second line of bearing settable means, said relocating means having output members operatively associated with the input members and positioned thereby to represent the range and the direction of the line of bearing of the set-forward position of the target relative to the calculating point, a second target component solver including a vector member adjustable in length by the target speed settable means and angularly adjustable in accordance with the direction of movement of the target relative to the line of bearing of the set-forward position as differentially determined from the bearing output member of the relocating means, the member settable in accordance with the course of the firing ship and the member settable in accordance with the course of the target, said second target component solver also including a component member operably associated with the said sector member, a torpedo component solver having a vector member whose length represents the speed of the torpedo and having a component member operably associated with the vector member and the component member of the second target component solver, whereby the resultant direction of the last mentioned vector member represents the direction of the straight portion of the path of the torpedo measured relative to the line of bearing of the set-forward position of the target from the calculating point, and differential means for positioning the element in accordance with the bearing output of the relocating means and the direction of the vector member representing the straight portion of the path of the torpedo.

2. In a torpedo director for directing a torpedo from a firing ship to a target along a path having a curved portion and a straight portion, means settable in accordance with the range of the target from the firing ship, means settable in accordance with the direction of the line of bearing of the target from the firing ship measured relative to a reference line on the firing ship including members settable in accordance with the course of the firing ship and the true bearing of the target from the firing ship, means settable in accordance with the speed of the target, means settable in accordance with the course of the target, a target component solver including a vector member adjustable in length by the target speed settable means and angularly adjustable in accordance with the direction of movement of the target relative to the line of bearing as differentially determined by the true bearing settable means and the target course settable means, said component solver also including first and second component members operably associated with the said vector member and representing the components of the target speed along and across the line of bearing respectively, an element positionable to represent the direction of the straight portion of the torpedo path defined relative to the reference line, first multiplying means having input members positioned by the first component member and the output member of a first cam mechanism actuated by the element and having an output member operably associated with said input members, means for differentially connecting the output member of the first multiplying means with the range settable means to position a second range settable means in accordance with the range of a set-forward position of the target relative to the firing ship, second multiplying means having input members positioned by the second component member and the output member of the cam mechanism and having an output member operably associated with the input members, dividing means having input members positioned by the output member of the second multiplying means and the second range settable means and having an output member operably associated with the input members, means for differentially connecting the output member of the dividing means with the line of bearing settable means to position a second line of bearing settable means in accordance with the line of bearing of the set forward position of the target relative to the firing ship, a second cam mechanism actuated by the element having an output member whose position represents the location of a calculating point on the extended reference line, relocating means having input members actuated in accordance with the output member of the second cam mechanism, the position of the second range settable means and the second line of bearing settable means, said relocating means having output members operatively associated with the input members and positioned thereby to represent the range and the direction of the line of bearing of the set-forward position of the target relative to the calculating point, a second target component solver including a vector member adjustable in length by the target speed settable means and angularly adjustable in accordance with the direction of movement of the target relative to the line of bearing of the set-forward position as

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differentially determined from the bearing output member of the relocating means, the member settable in accordance with the course of the firing ship and the member settable in accordance with the course of the target, said second target component solver also including component members operably associated with the said vector member, a torpedo component solver having a vector member whose length represents the speed of the torpedo and having component members operably associated with the vector member. means for actuating one of the last mentioned component members in accordance with the position of one of the component members of the second target component solver, whereby the resultant direction of the vector member of the torpedo component solver represents the direction of the straight portion of the path of the torpedo measured relative to the line of bearing of the set-forward position of the target from the calculating point, differential means for positioning the element in accordance with the bearing output of the relocating means and the direction of the vector member of the torpedo component solver, and calculating mechanism having input members adjustable in accordance with the speed of the torpedo, the output member of the relocating means representing range, and the second component members of the second target component solver and the torpedo component solver, said calculating mechanism having an output member cooperatively positioned by the input members, whereby the position of the output member represents the range from the calculating point to the target along the direction of the straight portion of the path of the torpedo.

3. In a torpedo director for directing a torpedo from a firing ship to a target along a path having a curved portion and a straight portion, means settable in accordance with the range of the target from the firing ship, means settable in accordance with the direction of the line of bearing of the target from the firing ship measured relative to a reference line on the firing ship including members settable in accordance with the course of the firing ship and the true bearing of the target from the firing ship, means settable in accordance with speed of the target, means settable in accordance with the course of the target, a target component solver including a vector member adjustable in length by the target speed settable means and angularly adjustable in accordance with the direction of movement of the target relative to the line of bearing as differentially determined by the true bearing settable member and the target course settable means, said component solver also including first and second component members operably associated with the said vector member and representing the components of the target speed along and across the line of bearing respectively, an element positionable to represent the direction of the straight portion of the torpedo path measured relative to the reference line, bearing correction means having three input members actuated by the second component member and by the output member of a first cam mechanism actuated by the element and by a second range settable means respectively and having an output member operably associated with the input members, range correction means having input members actuated by the first component member and by the output member of the first cam mechanism and having an output member operably associated with the input members, means for differentially

connecting the output member of the bearing correction means with the line of bearing settable means to position a second line of bearing settable means to represent the line of bearing of a set-forward position of the target relative to the ship, means for differentially connecting the output member of the range correction means with the range settable means to position the second range settable means to represent the range of a set-forward position of the target relative to the ship, a second cam mechanism actuated by the element and having an output member whose position represents the location relative to the firing ship of a calculating point on the extended reference line, relocating means having input members actuated in accordance with the output member of the second cam mechanism, the second bearing settable means and the second range settable means, said relocating means having output members operably associated with the input members and positioned thereby to represent the range and the direction of the line of bearing of the set-forward position of the target relative to the calculating point, a second target component solver including a vector member adjustable in length by the target speed settable means and angularly adjustable in accordance with the direction of movement of the target relative to the line of bearing of the set-forward position as differentially determined from the bearing output member of the relocating means, the member settable in accordance with the course of the firing ship and the member settable in accordance with the course of the target, said target component solver also including a component member operably associated with the said vector member, a torpedo component solver having a vector member whose length represents the speed of the torpedo and having a component member operably associated with the vector member and the component member of the target component solver, whereby the resultant direction of the last mentioned vector member represents the direction of the straight portion of the path of the torpedo measured relative to the line of bearing of the set-forward position of the target from the calculating point, and differential means for positioning the element in accordance with the bearing output of the relocating means and the direction of the vector of the torpedo component solver.

4. In torpedo control mechanism, means settable in accordance with the range of a target, means settable in accordance with the direction of the line of bearing of the target relative to the centerline of the firing ship, means settable in accordance with the target course, means settable in accordance with the course of the firing ship, a target component solver including a vector member adjustable in length to represent the speed of the target and jointly adjustable in direction by the bearing settable means and means settable in accordance with the course of the firing ship and the target course settable means to represent the rate and the direction of movement of the target relative to the line of bearing, said target component solver also including component members operably associated with the said vector member, a torpedo component solver having a vector member adjustable in length in accordance with the speed of the torpedo and having component members operably associated with the vector member, means for actuating one of the last mentioned component members in accordance with the position of one of the component members of the target component solver,

whereby the angular position of the torpedo vector member represents the direction of the path of the torpedo relative to the line of bearing, and calculating mechanism having input members adjustable in accordance with the speed of the torpedo, the range settable means and the second component members of the target component

solver and the torpedo component solver, said calculating mechanism having an output member cooperatively positioned by the input members, whereby the position of the output member represents the range of the target along the path of the torpedo.

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