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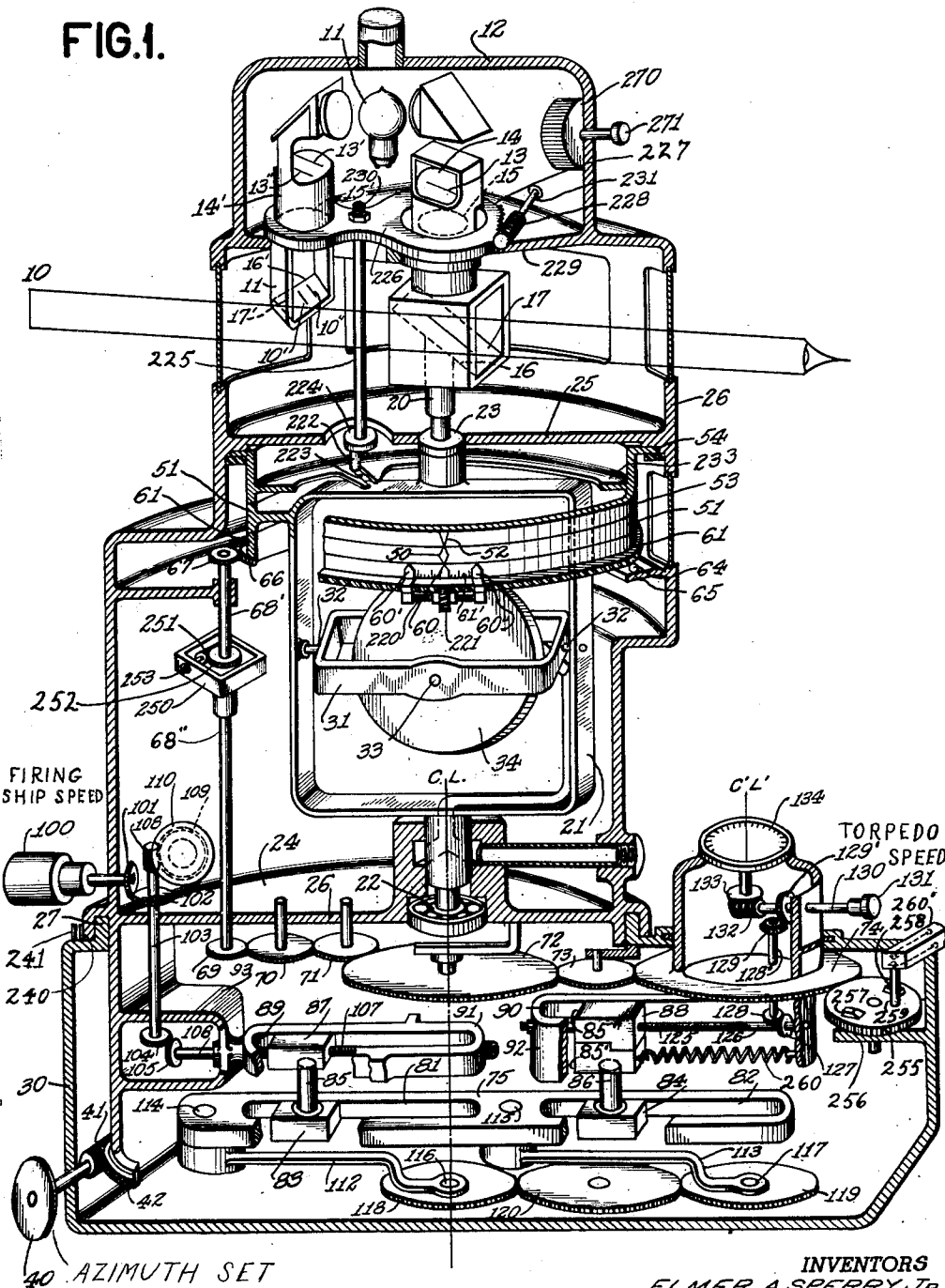
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2,391,357

TORPEDO DIRECTOR

Filed July 8, 1941

4 Sheets-Sheet 1



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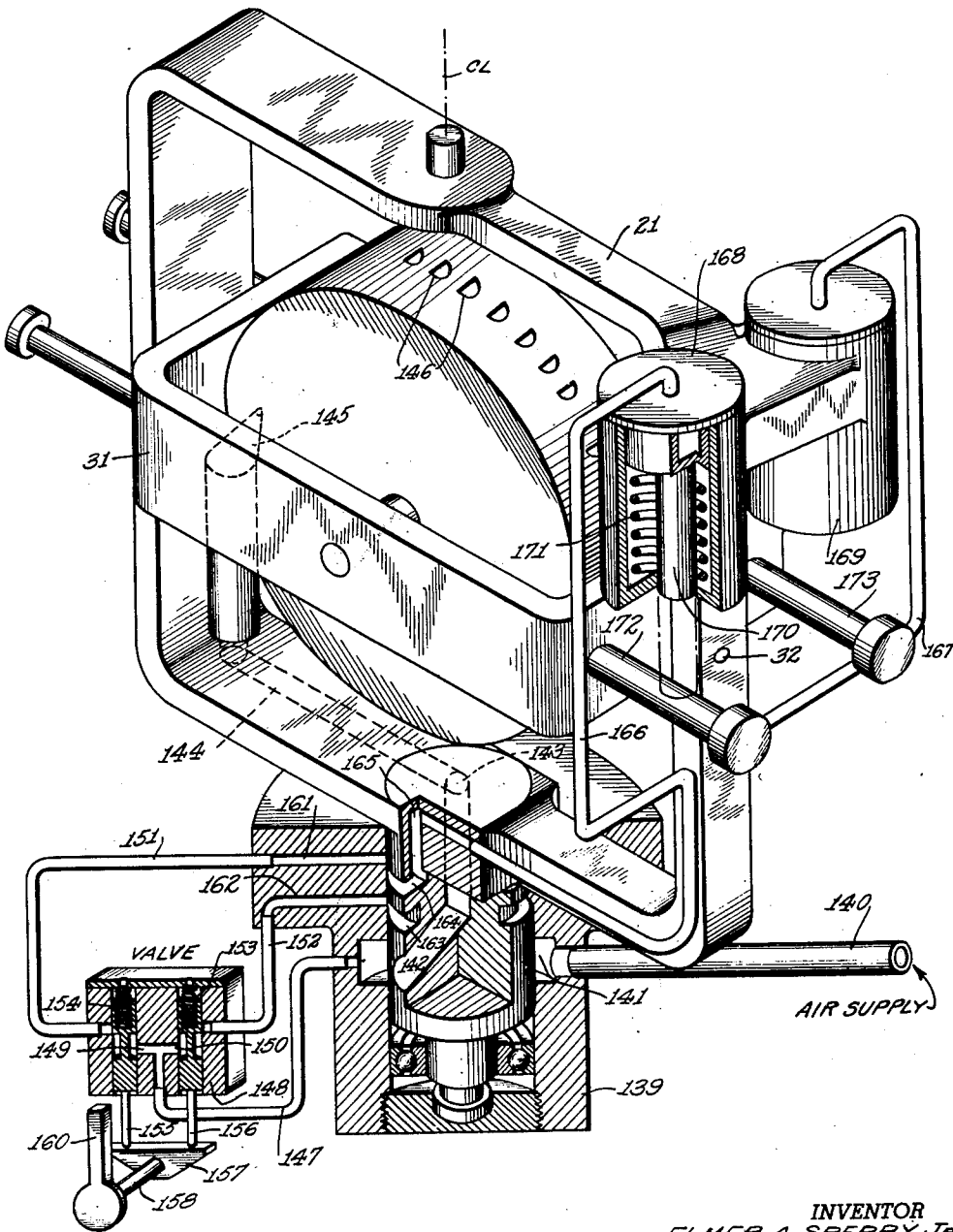
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FIG.2.



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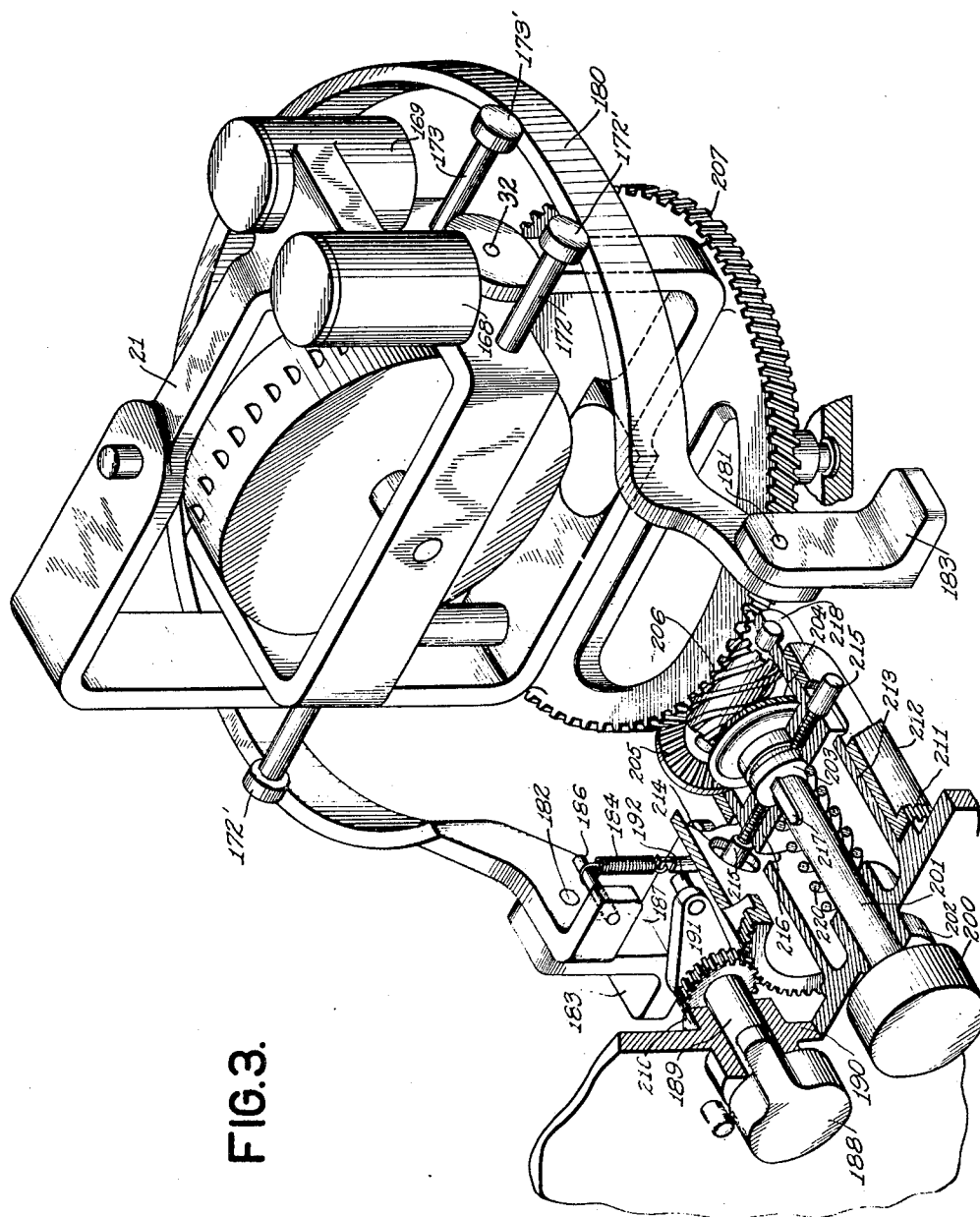


FIG. 3.

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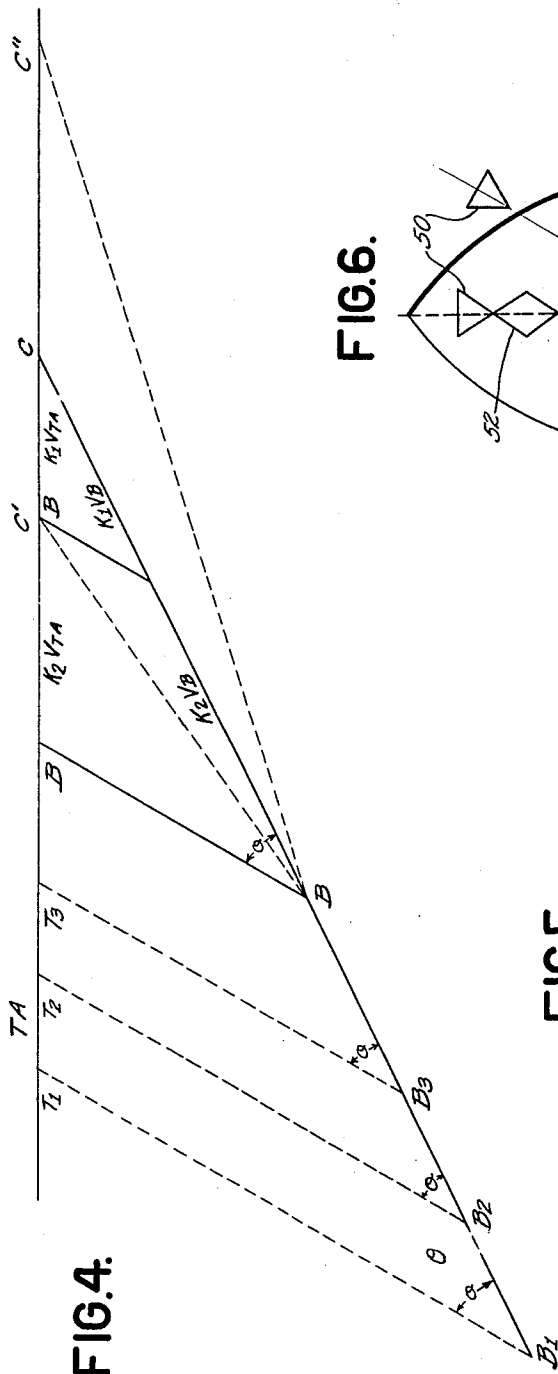


FIG. 4.

FIG. 6.

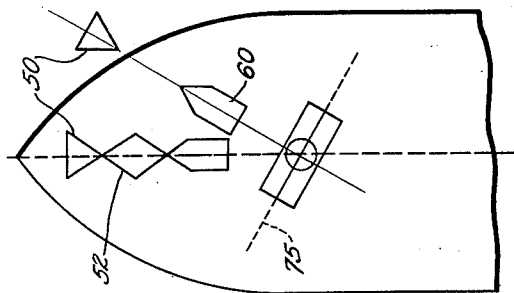
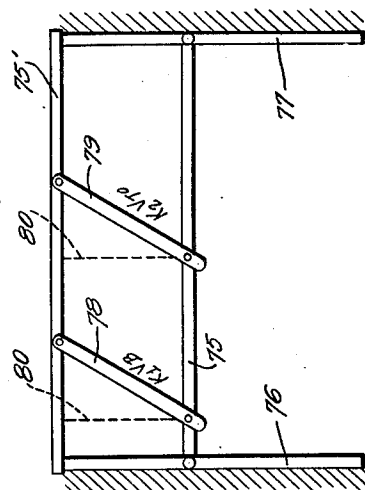


FIG. 5.



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UNITED STATES PATENT OFFICE

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TORPEDO DIRECTOR

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Application July 8, 1941, Serial No. 401,462

13 Claims. (Cl. 33—46)

This invention relates to an instrument commonly termed a torpedo director whose function it is to control the direction of firing of torpedoes from warships. While large, complicated and expensive directors are known and in use on battle-ships and destroyers, these devices would not be suitable for use upon the new class of small, high speed, motor torpedo boats which have recently been introduced. These boats operate at high speeds and are subject to rapid deviations from course. Furthermore, they are built so low on the water line that it would be impossible to estimate the speed and direction of the target ship—a condition precedent to the use of standard torpedo directors. Therefore this invention operates upon an entirely different principle, as disclosed in the co-pending patent application of Elmer A. Sperry, Jr., and John D. Peace, Jr., for Torpedo director, Serial No. 347,354, filed July 25, 1940. In this type of director it is not necessary to estimate the speed and direction of the target ship, but, instead, the firing ship is steered until it is operating on a collision course with the target ship. If a torpedo is released on this course and the torpedo travels at the same speed as the firing ship, the torpedo will collide with the target ship. If, however, the torpedo travels faster or slower than the firing ship, then the course of the torpedo must be varied by an angle to cause the torpedo to collide with the target ship sooner or later than the collision course of the firing ship. The utilization of this principle makes it possible to provide a small simplified torpedo director which will be accurate in operation at high speed in high seas, or when zig-zagging if battle conditions so require. As stated above, in this type of torpedo director, when the speed of the torpedo is different from the speed of the firing ship, the torpedo course will differ from the collision course by plus or minus a given angle calculated in accordance with the several factors involved. In the said Sperry and Peace patent application mentioned above, this correction for torpedo course was separately calculated and then run in by hand. It is one of the principal objects of this invention to provide means whereby the said torpedo angle correction will be automatically set in during the normal operation of sighting the director upon the target ship.

In this type of torpedo director the firing ship must be steered into a collision course, that is, a course which if maintained would cause the firing ship to collide with the target ship. When such collision course is obtained, a line of sight from the firing ship directed on the target ship main-

tains a constant angle with respect to a base line on the firing ship. If this angle varies, or, conversely, if the line of sight when maintained at a constant angle to its base-line moves ahead or behind the target ship, then the firing ship is not travelling a collision course and the course must be changed as directed by the observer. The present invention has for another of its objects the provision of means whereby the observer may not only direct the helmsman to change the course of the vessel in the desired direction to the predetermined degree, but, further, said observer may see, without removing his eye from the line of sight of the instrument, whether or not the helmsman has brought the ship into the newly designated course.

If the observer, after having placed his line of sight on the target ship, thereafter maintains the line of sight at a constant angle with respect to a base-line on the firing ship and notices that the line of sight moves rapidly ahead or behind the target sometimes sufficiently to lose the target from the field of observation, then the observer desires quickly to restore his line of sight to the target ship. If he proceeded in the manner heretofore employed he would be required to signal a large change of course of the firing ship, which, in order to bring the line of sight on the target, would over-correct and introduce a substantial error in the opposite direction. It is another of the objects of this invention to provide means whereby instead of changing the course of the firing ship through a large angle under these circumstances, the observer can rapidly bring his line of sight on the target ship by causing the line of sight to assume a new angular relation with respect to the base-line on the firing ship. This operation also can be effected by the observer without removing his eye from the sighting instrument.

Mention has been made above of the fact that when the torpedo speed differs from the speed of the firing ship a correction of course for the torpedo differing from that of the firing ship must be made. In addition to this correction, still another correction may become necessary because the axes of the torpedo tubes may not be parallel to the axis of the firing ship. Under these circumstances the gyro control of the torpedo is sometimes set so that the torpedo, after being fired from its tube, is steered into the desired course parallel to the axis of the ship. However, if no such provision is made, then the angular difference between the firing ship's course and the torpedo course must be further corrected by the

angular displacement of the axis of the torpedo tube with respect to the axis of the firing ship. It is another object of this invention to provide means whereby the necessary correction for the displacement of the torpedo tube axis from the axis of the firing ship will be automatically indicated to the helmsman.

In the operation of this type of device the gyro stabilized line of sight is turned until the line of sight is placed upon the target ship. Obviously, during this movement of the gyro and its sight in azimuth, precession of the gyro would occur if it were not caged or locked with respect to the moving casing. It is another object of this invention, therefore, to provide novel caging or locking means.

Once the line of sight is positioned on the target ship the gyro is released and thereafter maintains its position fixed in azimuth regardless of the movements of the ship. After operation, the gyro will no longer be in the original centralized position with respect to the ship and it will be necessary to adjust the position of the gyro relative to the casing. Any attempt at rotating the gyro in azimuth would cause precession thereof unless the gyro were caged. It is a further object of this invention, therefore, not only to provide means for setting the gyro in azimuth relative to the supporting casing, but also to provide means whereby it is impossible to change the position of the gyro in azimuth without first caging said gyro against precession.

The theory of operation of this invention depends upon the firing ship maintaining a collision course and automatically determining the correction angle for torpedo course. Under certain conditions of speed of the firing ship or speed of the torpedo relative to the target ship it may be the case that an inoperative condition has arisen whereby the torpedo cannot collide with the target ship. It is therefore another object of this invention to provide means whereby the operator or observer will be given notice of the fact that such as inoperative condition exists.

Further objects and advantages of this invention will become apparent in the following detailed description thereof.

In the accompanying drawings,

Fig. 1 is an assembly partly sectioned vertically and partly shown in isometric projection disclosing the principal features of this invention.

Fig. 2 is an isometric view of the means for effecting precession of the gyroscope.

Fig. 3 is an isometric view of the means for caging and setting the gyro.

Fig. 4 is a diagram explaining the underlying theory of this invention.

Fig. 5 is a diagram explaining the theory underlying the operation of the torpedo angle correction mechanism.

Fig. 6 is another diagram illustrating still another theory underlying the operation of another portion of the invention.

Referring first to Fig. 4, the theory underlying the present invention is graphically illustrated. Let us assume that the target ship TA is travelling along a course $T_1T_2T_3$ and that a firing vessel B on which the torpedoes are carried and on which the torpedo director is mounted is travelling a course $B_1B_2B_3$. If the target ship and the firing ship are travelling at the proper speeds they will collide at point C, in which case it is said that the firing ship is travelling on a collision course. If a sight instrument on the firing ship is directed on the target ship it will make

an angle θ with the line of travel of the firing ship. If the firing ship is travelling a collision course, then obviously at every point along this course the sight instrument will remain trained on the target ship because the triangles CB_1T_1 , CB_2T_2 , CB_3T_3 , etc. are all similar triangles. If, however, the firing ship is travelling too slowly or too fast to meet the target ship at C there will be no collision and the firing ship will pass behind or in front of the target ship as their courses cross. When the sight instrument is trained on the target ship, the observer on the firing ship can see almost immediately whether he is travelling on a collision course, because from the above theory it becomes apparent that if he is on the collision course the sight instrument will remain trained on a fixed point on the target ship. If he is not on the collision course, the target ship will pass behind or in front of the line of sight. When this occurs it is necessary for the observer to change the course of the firing ship so as to increase or decrease the angle θ , as the case may be, or to alter the speed of the firing ship until he reaches the condition where the line of sight remains trained on the target ship.

Having thus achieved a collision course, the firing ship is ready for the next step, which is directing the ship into the torpedo course so that when the ship is in said course the torpedoes may be released along this course. It is apparent that if the torpedo is designed to travel at the same speed as the firing ship, or, conversely, if the firing ship is purposely operated at the known torpedo speed, then it is only necessary to discharge the torpedoes which then continue on the collision course previously determined and will collide with the target ship in the same manner as the firing ship would have collided with the target ship if it had continued on its course to a point C. Usually, however, the torpedo will have a different speed from that of the firing ship and under these conditions it will be seen that in order for the torpedoes to effect collision with the target ship it is necessary to turn the boat, before the torpedoes are fired, to a different angle from the collision course of the firing ship. The direction of the correction to be introduced in the course of the torpedoes depends upon whether the torpedoes travel faster or slower than the firing ship. If they travel faster, then a correction angle is introduced so that the torpedo may meet the target ship sooner at point C'; whereas, if the torpedoes travel slower than the firing ship, then the correction angle is in the opposite direction so that the torpedo will collide with the target ship later, as at point C''. The angle through which the ship must be turned has been indicated as $\pm\alpha$.

Summing up the operation of this type of torpedo director, therefore, it becomes apparent that the following operations are employed:

1. The observer must place his sight on the target ship.
2. The observer must indicate to the helmsman the changes in the course of the firing ship in order that the line of sight shall remain fixed relative to the target ship, in other words, in order that a collision course may be effected.
3. The helmsman must direct the ship promptly into the collision course.
4. The observer must satisfy himself that the indicated change in course of the firing ship has been made.

5. An indication must be given to the helmsman of the necessary change in course of the firing ship for proper torpedo course.

6. The helmsman must turn the ship into the torpedo course.

7. The torpedoes must be released while the ship is on the torpedo course.

The mechanism for effecting the above sequence of operations is disclosed mainly in Fig. 1. The observer has established for him a line of sight from his eye to a reticle image 10 focused at infinity so as to reduce parallax to a negligible quantity. This reticle image may be obtained by causing light rays from any suitable source, such as a lamp 11 mounted within housing 12, to send its rays through a slit 13 in a opaque tube 14, the said slit being positioned at the focus of a lens 15 at the other end of opaque tube 14. The image is thrown upon an inclined screen 16 having a partially mirrored surface 17 so that while the reflection of the image is visible on the surface of the screen, the observer nevertheless can look through the screen and sight the target ship at the same time. The screen 16 is carried at the upper end of a shaft 20 fixed to a vertical ring 21 supported for movement about a vertical axis on bearings 22 and 23 in horizontal plates 24 and 25 respectively, forming part of a casing 26. Said casing is supported for movement around a vertical axis on flange 27 integral with the fixed base 30 attached to the firing ship. Thus it will be seen that by rotating case 26 on flange 27 the vertical ring 21 and the screen 16 may be rotated in azimuth. In order that the screen 16 shall be stabilized in azimuth so that it shall not be subject to the yawing movements of the ship, there is mounted within the vertical ring 21 a horizontal ring 31 pivoted on horizontal trunnions 32 within the vertical ring and having supported therein for rotation on horizontal axis 33 a gyro rotor 34. The casing 26 may be rotated around a vertical axis by means such as a knob 40 which is geared to the casing by any suitable gearing such as the worm gearing 41, 42. A casing means (to be described hereinafter) is provided between the casing 26, vertical ring 21 and horizontal ring 31, so that the entire gyro mechanism may be locked against precession while permitting relative rotation of the vertical ring with respect to the casing.

In operation, with the rings of the gyro locked to the casing 26, the observer turns the control knob 40 to rotate casing 26, gyro 34, screen 16 and slit 13 until the line of sight is on the target ship. With the gyro there turns an index 50 carried by a circumferential ring 51 fixed to the vertical ring 21. A cooperating index 52 is carried by a similar ring 53 adjustably mounted on the casing 26 by means such as a flange 54. As the knob 40 is turned to bring the line of sight on the target ship, the pointers 50 and 52, which were originally in coincidence when the line of sight was in the fore and aft axis of the ship, are still in coincidence after the line of sight has been turned through the angle to bring it on the target ship. At this point the observer uncages the gyro (by means to be described hereinafter) so that it remains fixed in azimuth, and notes whether the line of sight stays fixed with respect to the target ship. If it does, then he knows that the firing ship is on the collision course. If there is relative movement between the line of sight and the target ship so that the line of sight advances or falls behind the target ship, then it is necessary to change the course of the ship in order to bring

it to the collision course. The observer then operates knob 40 to turn casing 26 and pointer 52 in one direction or the other as the case may be to indicate to the helmsman that the ship's course must be changed as indicated by relative movement of pointer 52 away from pointer 50. The helmsman then changes the ship's course until the pointer 52 is again in coincidence with the pointer 50. If the correction of course has been sufficient to bring the ship into the collision course, then the observer will note that the line of sight remains fixed relative to some point on the target ship and no further correction will be necessary. If, however, there is still some movement of the line of sight with respect to the target ship, then the observer again operates knob 40 to move pointer 52 in one direction or the other to indicate a further correction to the helmsman.

The observer could, by taking his eye away from the line of sight and the target ship, discover whether the helmsman has complied with his transmitted signal to change the ship's course by looking at the pointers 50 and 52. This, however, would require taking his eye off the line of sight and the target ship. In order that the observer may note whether the helmsman has complied with his transmitted signal to change the ship's course, without removing his eye from the line of sight and the target ship, there may be provided in cooperative relation to the reticle image 10 an additional pair of reticle images 10', 10'' positioned normally to either side of the image 10. These auxiliary images may be formed in the same manner as image 10 by light rays from source 11 entering slits 13' and 13'' positioned at the focus of a lens 15' within an opaque cylinder 14' which, however, is carried by casing 26 whereas cylinder 14 is carried by the gyro system. The images are reflected through screen 16' having partly silvered surface 17'. When the pointers 50 and 52 are in alignment, the images 10' and 10'' are positioned symmetrically to either side of the image 10. When the observer rotates knob 40, and hence casing 26, to move pointer 52 with respect to pointer 50, he also moves the two images 10' and 10'' because cylinder 14' is carried by the casing in a suitable support to be described hereinafter. As the ship is turned to a new course to bring pointer 52 into coincidence with pointer 50, the images 10' and 10'' are brought into symmetrical relationship on either side of image 10, and the observer thus knows, without removing his eye from the line of sight and the target ship, that the firing ship has been turned to the indicated course. While the single line of sight has been described as carried by the gyro and the double lines by the casing, this arrangement may be reversed, or both may be single lines.

When the line of sight no longer moves relative to the target ship, the observer knows that the firing ship B is on its collision course. Travelling on this course, a torpedo could be released and would strike the target ship provided the speed of the torpedo was the same as that of the firing ship and that the torpedo was fired to run along ship's course. This, however, is usually not the case and therefore it is necessary to turn the ship through an angle $\pm\alpha$, depending upon whether the speed of the torpedo is less than or greater than the speed of the firing ship. Referring to the diagram in Fig. 4, the torpedo course is indicated by the dash lines from B to

C' and C''. From this diagram the following equations are obtained:

$$\frac{K_2 V_{TO}}{\sin \beta} = \frac{K_2 V_{TA}}{\sin (\theta \pm \alpha)} \quad (1)$$

$$\frac{K_1 V_{TA}}{\sin \theta} = \frac{K_1 V_B}{\sin \beta} \quad (2)$$

In the above equations, K_1 and K_2 are constants denoting time. V_{TA} is the velocity of the target ship, V_{TO} is the velocity of the torpedo, and V_B the velocity of the firing ship. Equations 1 and 2 yield the following equations:

$$V_{TO} \sin (\theta \pm \alpha) = V_{TA} \sin \beta \quad (3)$$

$$V_B \sin \theta = V_{TA} \sin \beta \quad (4)$$

$$V_{TO} \sin (\theta \pm \alpha) = V_B \sin \theta \quad (5)$$

$$\sin (\theta \pm \alpha) = \frac{V_B}{V_{TO}} \sin \theta \quad (6)$$

From the above equations it is to be seen that the addition or subtraction of the angle α is a function of the velocity of the firing ship V_B and the velocity of the torpedo V_{TO} . Since the angle θ is known and the velocities of the firing ship and torpedo are known, the angle α representing the correction of firing ship course necessary to effect torpedo course can be calculated. However, by this invention there is provided means for automatically indicating to the helmsman the correction angle α both as to quantity and sign.

In order to achieve the above result, namely, the automatic determination of the correction angle α I provide an additional pointer 60 carried by a circumferential ring 61, the said pointer cooperating with pointers 50 and 52 and the said ring being of the same diameter as rings 51 and 53. The ring 61 may be supported on the casing 26 by means of rollers 64 carried by brackets 65 on the casing 26. The ring 61 is provided with gear teeth 66 on its periphery with which meshes a gear 67 carried by a shaft 68 having a gear 69 forming one of a train of gears 69 to 74 inclusive, the said shaft 68 and the gears 67 and 69 to 74 inclusive being supported on the casing 26. Originally the pointers 50, 52 and 60 are in alignment when the line of sight is in the fore and aft axis of the ship and before sighting on the target ship has begun. With the caging mechanism locking the gyro against precession, the knob 40 is turned to bring the line of sight on the target ship. This rotates pointers 50 and 52 which move with the casing 26 through an angle θ , but the pointer 60 is moved through a different angle. In other words, while the line of sight and therefore the pointers 50 and 52 are being moved through the angle θ with respect to the fore-and-aft axis of the ship, the pointer 60 is designed to be moved through an angle $\theta \pm \alpha$, depending upon the torpedo speed, the firing ship speed and the angle θ . This is effected by way of the gearing 66, 67, shaft 68, gearing 69 to 74 inclusive, and a parallel motion mechanism about to be described.

Referring to the diagram, Fig. 5, it will be seen that if a Scotch yoke device is employed with a yoke member 75 movable in parallel guides 76, 77 by links 78 and 79, then these links, being of different lengths, will subtend different angles. Thus if the link 78 is made equal in length to a value $K_1 V_B$ (a constant multiplied by the speed of the firing ship) it is found that there is subtended an angle θ . Similarly, if another link 79 having a length representing a value $K_2 V_{TO}$

(a constant multiplied by the speed of the torpedo) this link will subtend an angle ϕ . It is, however, apparent that the distance 80 in each of these angles is the same and therefore we get the equations—

$$V_B \sin \theta = V_{TO} \sin \phi \quad (7)$$

$$\sin \phi = \frac{V_B}{V_{TO}} \sin \theta \quad (8)$$

But since

$$\frac{V_B}{V_{TO}} \sin \theta = \sin (\theta \pm \alpha) \quad (9)$$

therefore

$$\sin \phi = \sin (\theta \pm \alpha) \quad (10)$$

and

$$\phi = \theta \pm \alpha \quad (11)$$

In other words, if we employ a parallel motion mechanism wherein an element 75 moves parallel to a base-line 75' and two pivoted links have lengths which are functions of the velocity of the firing ship and the velocity of the torpedo, and the link representing the velocity of the firing ship makes with the base 75' an angle θ , then the link 79 representing the velocity of the torpedo will make with the base 75' an angle equal to $\theta \pm \alpha$ the correction angle α . Since the line of sight has been moved through θ , this movement can be transmitted to a link 78 and by causing this link to operate a Scotch yoke member 75, another link 79 whose length is a function of the torpedo speed will be caused to make an angle $\theta \pm \alpha$. The pointers 50 and 52 are caused to move through the angle θ by the mechanism and connections already described. If now, the pointer 60 is caused to move through the angle $\theta \pm \alpha$, the difference between the two will indicate the correction angle α . In other words, the pointer 60 will be displaced from the pointers 50 and 52 when the firing ship is on its collision course by an angle equal to the correction which must be made in the ship's course to bring the firing ship into the torpedo course. All that the helmsman need do, therefore, to bring the firing ship on its torpedo course is to turn the ship until pointer 50 coincides with pointer 60.

The Scotch yoke mechanism which is here employed may consist of a bar 75 having slots 81 and 82 therein within which slide blocks 83 and 84 having pins 85 and 86 fixed thereto and carrying blocks 87 and 88 at their upper ends. Said blocks operate in slots 89 and 90 formed in yoke members 91 and 92. The yoke 91 is fixed to a bracket 93 carried by casing 26 so that as the casing is rotated (by knob 40, gearing 41, 42) the yoke 91 will be rotated about the vertical central axis C.L. The link 78 is thus formed from the center line C.L. to the center of pin 85. In order that the arm 78 shall be a function of the firing ship speed V_B , means are provided for positioning the block 87 within slot 89 nearer or further from the center line C.L. a distance which is proportional to the firing ship speed. For this purpose there may be provided a knob 100 operating through gearing 101, 102, shaft 103, gearing 104, 105, shaft 106 which extends through bracket 93 and through yoke 91 and is provided with a screw-threaded portion 107 screw-threaded through the block 87 so that as shaft 106 is rotated in one direction or the other, block 87 is moved toward or away from the center line C.L. to increase or decrease the length of link 78. The shaft 103 may also be provided with gearing 108, 109 to operate an indi-

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cator 110 calibrated in terms of firing ship speed V_b . The yoke 75 is constrained to parallel movement by means of a pair of parallel links 112, 113 pivoted at one end 114, 115 to the yoke 75 and at the other end at 116, 117 to gears 118, 119 which mesh with a center gear 120 so that gears 118 and 119 will rotate in the same direction and through the same angular distances. The said gears 118, 119, 120 are pivoted in the fixed casing 30 to prevent out of parallelism of arms 112 and 113 when said arms are swung past their dead center positions.

In order that the movement of yoke 75 transmitted to it by arm 78 shall actuate an arm 79, the block 88 is caused to rotate about a center line $C'L'$ so that the distance from $C'L'$ to the center of pin 86 corresponds to the link 79 of the diagram Fig. 5. In order that this arm shall be proportional to torpedo speed, means are provided whereby block 88 may be positioned in the yoke 92 a distance from the center line $C'L'$ such that it is a function of torpedo speed. For this purpose there extends through the block a screw 125 on a shaft 126 which carries a gear 127 meshing with gears 128, 129, the last-named gear being carried on a shaft 130 having a knob 131. Rotation of knob 131 will rotate screw 125 in one direction or the other to move block 88 toward or away from center line $C'L'$, so that the distance from the center line to the center line of pin 86 is proportional to the torpedo speed and therefore corresponds to the link 79. At the same time that knob 131 positions block 88 in accordance with torpedo speed, it may, by means such as gearing 132, 133, operate an indicator 134 calibrated in terms of torpedo speed.

With the links 78 and 79 now set as a function of the firing ship speed and torpedo speed respectively, it will be seen that as the casing 26 is rotated through angle θ to bring the line of sight on the target ship, the movement of yoke 75 rotates link 79 through the angle ϕ by way of block 88 yoke 92 and gear 74. The angle ϕ equals $\theta \pm$ the torpedo firing correction α . This angle is transmitted to pointer 60 through the gearing 74, 73, 72, 71, 70, 69, shaft 68, gears 67 and 66, so that whereas pointers 50 and 52 have been moved through the angle θ , pointer 60 is moved through the angle $\theta \pm \alpha$. Pointer 60 will thus be offset from pointers 50 and 52 by the angle α and therefore the helmsman need only bring pointer 50 into coincidence with pointer 60 in order to put the firing ship on the torpedo course.

As pointed out in the introduction hereto, the observer places his line of sight on the target ship and notes whether the line of sight moves relative to the latter ship. If there is no movement, then he knows that his ship is travelling a collision course, but if there is movement of the line of sight relative to the target ship, then some correction will be necessary. The rate of such movement is an index to the degree of correction which will be required. It frequently happens that the firing ship is travelling so far off the collision course that very shortly after the observer has placed his line of sight on the target ship and before the correction can be transmitted to the helmsman and the helmsman in turn can change the course of the vessel, the line of sight has completely moved off the target ship. Under these conditions, even if the firing ship is brought into collision course, the line of sight will still be off the target ship and the only way in which it can be brought on the target ship would be to over-correct the firing ship, in which case the latter

ship will again not be travelling a collision course, and after the line of sight has reached the target ship another correction in the opposite direction will be necessary. In other words, a large hunting movement will be incorporated due to the fact that the line of sight has left the target ship. In order to avoid the necessity for such over-correction there is provided means whereby the line of sight may be quickly restored to the target ship while the correction is being transmitted to the helmsman and the helmsman is effecting the necessary correction. In this manner, when the ship has been brought to the collision course, the line of sight will be on the target ship and it will not be necessary to over-correct in order to bring the line of sight on the target ship and then introduce another correction in the opposite direction. For effecting such quick movement of the line of sight on the target ship there may be provided the precessing means shown in Fig. 2. Here it will be seen that air is supplied under pressure from any suitable source, such as an air pump, and enters a main inlet 140 which communicates with a circumferential air passage 141 which in turn communicates with passage 142, 143 extending through the journal of the vertical ring 21 and thence by passage 144 in the ring frame to a nozzle 145 which delivers the air under pressure against the buckets 146 formed in the periphery of the gyro rotor 34. Communicating with said circumferential passage 141 is also a pipe line 147 leading to a valve box 148 which communicates with the two valve passages 149 and 150. These passages are connected to pipe lines 151 and 152 by way of valves 153 and 154 normally spring pressed downwardly so as to shut off communication between passages 149, 150 and pipes 151 and 152. The said valves may be provided with stems 155, 156 engaging opposite sides of a bell crank 157 pivoted at 158 so that it may be rotated in one direction or the other by means such as a handle 160. If the handle is operated in one direction, valve 153 will be raised to allow communication between the air supply port 149 and pipe 151; while if the handle 160 is rotated in the other direction it will lift valve 154 to allow communication between supply port 150 and pipe 152. The pipes 151 and 152 lead into ports 161 and 162 in the valve housing 139, and said ports communicate with circumferential ports 163, 164 in the circumference of the vertical frame journal. The latter peripheral ports 163 and 164 communicate with vertical passages 165 and a similar passage (cut away), which vertical ports communicate with pipes 166 and 167 respectively, which lead into the upper end of cylinders 168 and 169 carried by the vertical ring. Within each of said cylinders is a vertically operating piston 170 normally spring pressed into the cylinder by spring 171, but when handle 160 is turned in a direction to allow air under pressure to flow into pipe 166 or 167 the respective piston 170 is depressed to cause it to engage a projecting pin 172, 173 fixed to the horizontal ring 31 on opposite sides and equidistant from the axis 32. Whichever piston 170 engages pin 172 or pin 173, respectively, will cause a torque to be applied around the horizontal axis 32 of the gyro which will cause precession around the vertical axis $C'L$ and thus carry the line of sight quickly onto the target ship. This will displace pointer 50 with respect to ship and pointer 52, thus indicating to the helmsman a course change in the proper direction to bring the ship toward collision course. Thus, as soon as the helmsman has made the correction designed to

bring the ship into collision course, the line of sight will be somewhere on the target ship ready for the observer to note whether there is any relative movement between the line of sight and the target, and it will not be necessary to over-correct and then correct again in the opposite direction.

The operation described hereinbefore of causing pointers 52 and 60 to be brought into line in order to effect the torpedo course is correct provided the axes of the torpedo tubes are parallel to the fore-and-aft axis of the firing ship. If, as sometimes is the case, these tubes are positioned at an angle with respect to the fore-and-aft axis of the firing ship, then it will be seen that alignment of pointers 52 and 60 will not result in the torpedo course. In that case, the gyro control of the torpedo is sometimes set so that the torpedo after being fired from its tube is steered into the desired course parallel to the axis of the ship. However, if no such provision is made, then it will be seen that in addition to the angular correction α calculated above, a further correction equal to the angle between the fore-and-aft axis of the firing ship and the axes of the torpedo tubes must be introduced. This further correction will be added to or subtracted from the position of pointer 60, depending upon which side of the fore-and-aft axis of the firing ship the torpedo tubes are located. Since this angular relationship is fixed and known, there is provided means on the ring 61 whereby additional pointers 60' and 60'' are located on opposite sides of pointer 60 and coact with a scale 61' on the ring 61. The said pointers 60' and 60'' may be mounted on a shaft 220 having opposite threads so that rotation of said shaft will cause the pointers 60' and 60'' to move together or apart simultaneously and to the same degree. The pointers are, of course, held against rotation with said shaft by any suitable means. The adjustment may be effected by means of a small knob 221 on the shaft 220 so that operation of said knob in one direction or the other will move the pointers 60' and 60'' toward or away from the pointer 60 by an angular distance which may be read on scale 61'. Thus, if there is a 10° angle between the fore and aft axis of the firing ship and the torpedo tube axes, the pointers 60' and 60'' are moved 10° to either side of pointer 60. The helmsman will now maneuver the ship until pointer 52 is in alignment, not with pointer 60, but with pointer 60' or 60'', depending upon which tube is to be fired.

During the original movement of the line of sight toward the target ship, the gyro is locked against precession, for otherwise movement around the vertical axis would cause precession around axis 32. The locking or caging mechanism serves to maintain the gyro in its fixed relation to the vertical ring until the line of sight is on the target ship, whereupon the gyro is released and thereafter maintains the line of sight independent of the ship's movement. The caging and setting mechanism which is here employed is as follows: A ring shaped bail 180 substantially enclosing the gyro and its supporting rings is pivoted at its open ends at 181, 182 on brackets 183 fixed to the floor 25 of the casing 26. The bail in its upward position is adapted to engage the ends 172', 173' of projections 172 and 173 fixed to the inner, horizontal gyro ring at both ends of pivotal axis 32 and on opposite sides thereof. When the bail engages the end members of said pins it locks the horizontal ring

in the horizontal plane and therefore locks the gyro and said ring against precessional rotation around the axis 32. The case 26 and the gyro mechanism may now be rotated around the vertical axis C.L. without causing precessional movements of the gyro and its horizontal ring around the said axis 32.

The bail 180 is normally in its raised position for locking the gyro against precession by reason of the fact that a spring 184 is connected at one end to a pin 186 and bell crank arm 187 formed as an extension on said bail, the other end of the spring being attached to the base of the fixed bracket 183. The spring therefore normally tends to rock the bail around the pivot 182 in a direction to force the bail upwardly into caging position. After the line of sight has been placed on the target ship it is desired to release the gyro so that thereafter the line of sight shall not be affected by the yawing movements of the firing ship, and therefore it becomes necessary to release the gyro from the caging bail 180. For this purpose there is provided an operating handle 188 fixed to a shaft 189 pivoted for movement within bearing 190 and carrying at its other end a bell crank 191 having at its outer end a pin 192. When the handle 188 is thrown (to the left in Fig. 3) the pin 192 will engage underneath the extension 187 of the bail and raise said end to rock the bail 180 around pivot 182 in such direction as to move the bail upwardly and thus unlock the gyro. After the bell crank 191 is swung past the central vertical position the operator may release handle 188 and the mechanism will remain in operated position by reason of the fact that bell crank 191 has moved past the center position and spring 185 will prevent its return unless actuated by handle 188.

It has been stated hereinbefore that the indices 50, 52 and 60 are normally in vertical alignment when the line of sight is in the fore-and-aft axis of the ship, that is to say, in the position which the parts occupy before the mechanism is operated. After operation, the gyro which has maintained its position fixed in a given direction while the ship has been maneuvered to various positions, will no longer be in the relative position where index 50 carried by the gyro will coincide with the index 52. In order that the gyro may be actuated within the casing 26 so as to adjust the position of the gyro relative to said casing, setting mechanism is provided which may take the form of a knob 200 on a shaft 201 journaled in bearings 202, 203 and carrying at its inner end a bevel gear 204 meshing with a bevel gear 205 on the same shaft with a worm 206 which is in engagement with the worm gear 207 fixed to the vertical ring 21 and positioned symmetrically with respect to the center line C.L. This rotation of knob 200 will rotate the gyro with respect to casing 26.

Since the rotation of the gyro by knob 200 within casing 26 would cause precession of the gyro unless the gyro mounting were caged, the said setting mechanism is interconnected with the caging mechanism so that the setting mechanism is effective only when the caging mechanism is effective. For this purpose the shaft 189 may carry a gear 210 meshing with a gear 211 carried by a cylinder 212 which rotates on a sleeve 213 integral with bearing 202. The said cylinder 212 is provided with cam slots 214 in which engage studs 215 threaded into a hub 216 slideable on a key-way 217 on the shaft 201. The said hub 216 is provided with a forward extension 218 and

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the entire gearing 204, 205, 206 is supported in said hub and said extension. A spring 220 normally presses the hub 216 in a direction to cause engagement of worm 206 with worm gear 207.

The interconnection of the caging mechanism and the hand-setting mechanism is such that when the bail is in its raised position as shown in Fig. 3, worm 206 is in engagement with worm 207. Therefore, when the knob 200 is rotated to rotate gear 207, the gyro is rotated around the vertical axis C.L. but precession is not permitted because the caging bail 180 is in its raised, effective position in engagement with pins 172', 173'. However, when handle 188 is operated (to the left in Fig. 3) to move the bail to inoperative position, gear 210 rotates gear 211 and hence rotates cylinder 212 to cause cam slots 214 to push the pins 215 rearwardly in said slots and thus move hub 216 and its gears 204, 205, and 206 to the left so that gear 206 is out of mesh with gear 207. Therefore, as long as the bail is in its lowered position, ineffective to cage the gyro, it is not possible to set the gyro by turning it around its vertical axis of support. When the handle 188 is moved to the right to permit spring 185 to raise the bail to effective caging position to lock the gyro against precession, gear 210 rotates gear 211 to rotate cylinder 212 while spring 220 pushes the hub 216 to the right, allowing pins 215 to move to the right in slots 214 until worm 206 again engages worm gear 207. The parts are so designed that the bail 180 will engage pins 172, 172' or 173, 173' just before worm 206 engages worm wheel 207. This will cause the gyro to start precessing and will facilitate meshing of the worm and worm wheel.

When the mechanism is assembled, the lines of sight 10' and 10'' should be positioned equidistant with respect to the line of sight 10, and the pointers 52 and 50 should coincide when the line of sight is in the fore-and-aft axis of the firing ship. The assembly may be such that these four elements do not line up in the manner described, for example, the images 10' and 10'' may not be symmetrically positioned with respect to the image 10. Therefore means are provided for changing the relationship of the images 10' and 10'' with respect to the image 10 by changing the position of the cylinder 14' which carries the slits 13' and 13'', with respect to the casing 26. For this purpose the cylinder 14' and its associated image producing mechanism is carried on a plate 226 which is supported on a plate 229 fixed to the casing 26, and said plate 226 is connected to plate 229 through a worm gearing connection 227, 228. The worm 228 may be provided with a slit end 231 so that an adjusting tool may rotate said worm 228 to rotate plate 226 on plate 229 around the center line C.L. until the images 10' and 10'' are brought into symmetrical relation with respect to the image 10.

When such adjustment of the images 10' and 10'' with respect to image 10 has been made and the image 10 is in the fore-and-aft axis of the ship, the pointers 50 and 52 should coincide. If, however the assembly has been such that these pointers do not coincide, then means are provided whereby the pointer 52 may be changed with respect to the casing 26 so that pointer 52 does coincide with pointer 50. For this purpose, a flanged plate 233 which carries the ring 53 may be provided with a slot 223 in which engages a pin 222 carried by an eccentric 224 at the lower end of a shaft 225 supported at its other end in the plate 226. The shaft 225 is provided with a screw

threaded upper end 230 whereby the shaft 225 may be rotated by means of a tool engaging the upper end and rotated to rotate eccentric 224 and cause pin 222 to rotate ring 53 in one direction or the other until the pointer 52 is in alignment with pointer 50.

The casing 26' may be provided with an index 240 cooperating with an index 241 on the base 30 so that when said indices coincide the line of sight is in the fore-and-aft axis of the firing ship, and the pointer 60 should be in alignment with pointers 52 and 50. This is true because since the line of sight has not been turned out of the fore-and-aft axis of the ship, the pointer 60 cannot have any angle α introduced therein which would bring it to any different position from that occupied by pointers 50 and 52. By the adjustments described above, the pointers 50 and 52 are in alignment when the line of sight is in the fore-and-aft axis of the firing ship. However, if the base 30 with its enclosed mechanism is not originally positioned so that what corresponds to the base-line 75' in Fig. 5 is not exactly perpendicular to the fore-and-aft axis, then it will be seen that pointer 60 will have an initial error when the line of sight is in the fore-and-aft axis of the firing ship. This becomes apparent from Fig. 6. In order that the pointer 60 may be in alignment with the pointers 50 and 52 when the line of sight is in the fore-and-aft axis, regardless of whether or not the base-line 75' is exactly athwartship, means are provided for adjusting the position of pointer 60 with respect to the mechanism in the base 30. In other words, there is a means for changing the relationship between pointer 60 and the remainder of the correction calculating mechanism in the base 30. For this purpose the shaft 68 may consist of two portions, 68' and 68'', one of said portions carrying a block 250 in which is journaled a worm 251 which meshes with a worm gear 252 carried by the other portion of said shaft. Thus by rotating the worm 251, by means of a tool inserted in the slit end 253 thereof, the gear 252 may be rotated to rotate ring 61 relative to base 30 and thus bring the pointer 60 into alignment with pointers 50 and 52 when the line of sight is in the fore-and-aft axis.

Referring to Equation 6 hereinbefore, it will be noted that the correction angle α is determined by the formula

$$\sin (\theta \pm \alpha) = \frac{V_B}{V_{TO}} \sin \theta$$

and from this equation it becomes apparent that there is a limiting condition beyond which the device becomes inoperative. This condition is the one wherein $\sin (\theta \pm \alpha)$ equals or exceeds 1. Thus, if the firing ship speed or the torpedo speed is insufficient, this condition will be obtained. Another way of visualizing this condition is to assume that the arm K_2V_{ro} in Fig. 5 is insufficiently long to bridge the distance between 75' and 75. In other words, the arm 78 in Fig. 1 is moved through such angle that the distance 80 exceeds the length of arm 79, in Fig. 1. Arm 79 would thus tend to stop the movement of the bar 75 unless arm 79 in some way were made to yield. Provision for this contingency is made by having the block 88 formed by two relatively movable portions, such as the dove-tailing portions 85' and 85'' such that when the pin 86 moves a distance beyond the length of arm 79, the upper portion will remain fixed but the lower portion will yield by reason of the fact that it will

move out from under upper portion 85' against the action of restraining spring 260 fixed at one end to the portion 85' and at the other end to the yoke 92.

When such inoperative condition prevails as described in the preceding paragraph, it is desirable that the observer shall be made aware of this condition. Obviously, this condition means that the arm 79 has been turned through 90° with respect to base 75'. A warning signal is therefore generated by this device when the rotation of the arm 79 approaches the 90° limiting position. While any margin of safety may be employed, the present embodiment of the invention operates the signal when the arm 79 is turned through 80° with respect to the base 75'. For this purpose the gear 74 which is rotated by the rotation of yoke 92 is caused to mesh with a gear 255 supported for rotation on bracket 256 fixed to the base 30 and having thereon cam blocks 257, 258 positioned corresponding to approximately 80° to either side of the center line C'.L. when the arm 79 is in its zero angle displacement. When the yoke 92 has been rotated through approximately 80°, one cam block or the other will engage a member 259 depending from a block 260', also mounted on casing 30, to lift said member 259 and close the circuit through any suitable blinking mechanism which will cause the light source 11 to set up a continuous blinking which will warn the operator that the limiting position is approaching.

The amount of light which lamp 11 must generate in order that the slits 13, 13' and 13'' shall provide a sufficiently clear image will vary with the time of day and the amount of atmospheric light present. Thus, at night a very small amount of light will be sufficient and the lamp may be turned low; while during the day, especially during sunlight hours, the maximum amount of light should be obtained from the lamp 11. Adjustment of the amount of light corresponding to the amount of light in the atmosphere may be made by any suitable rheostat 270 controlled from the outside of the casing by a knob 271.

Under certain operating conditions, the fore-and-aft axis of the ship may be traveling at an angle to the ship's course. This would introduce an error in the indicated torpedo firing course while the ship was traveling on a collision course by an amount equal to the angle between the ship's keel and the ship's course. This yawing may be compensated for by turning worm 228 and worm gear 227 to cause case index 52 and reference collimator 10'-10'' to be rotated by an amount equal to the yaw. If desired, a dial calibrated in degrees could be applied at a point on the casing where the shaft of worm 228 enters to enable the operator to set the compensation in degrees of yaw.

In accordance with the provisions of the patent statutes, we have herein described the principle and operation of our invention, together with the apparatus which we now consider to represent the best embodiment thereof, but we desire to have it understood that the apparatus shown is only illustrative and that the invention can be carried out by other equivalent means. Also, while it is designed to use the various features and elements in the combination and relations described, some of these may be altered and others omitted without interfering with the more general results outlined, and the invention extends to such use.

Having described our invention, what we claim and desire to secure by Letters Patent is:

1. In a torpedo director adapted to be mounted on a ship, in combination, a line of sight device for sighting on a target, a torpedo course determining device, means whereby said second device is actuated in accordance with the ship's speed, the torpedo speed, and the angle through which the first device is actuated, and means whereby the operation of said first device actuates said second device.

2. In a torpedo director adapted to be mounted on a ship, in combination, a line of sight device for sighting on a target, a torpedo course determining device, means whereby said second device is actuated through an angular distance $\theta \pm \alpha$ in accordance with the formula:

$$\sin(\theta + \alpha) = \frac{V_B}{V_{To}} \sin \theta$$

where θ is the angle through which the first device is operated, V_B is the ship's speed, V_{To} is the torpedo speed, and α is the torpedo course correction, and means whereby operation of said first device actuates said second device.

3. In a torpedo director adapted to be mounted on a ship, in combination, a line of sight device for sighting on a target, a torpedo course determining device, means whereby said second device is actuated in accordance with the ship's speed, torpedo speed, and the angle through which the first device is actuated, said second device comprising a Scotch yoke arrangement including a member constrained to move parallel to a predetermined base, links pivoted to said base and connecting said base and said member, means whereby the length of one of said links is made a function of the ship's speed, means whereby the other of said links is made a function of the torpedo speed, and means whereby said line of sight controls the angular movement of said first link to actuate said member and determine the angular movement of said second link.

4. In a torpedo director adapted to be mounted on a firing ship, in combination, a line of sight device adapted to remain trained on a target ship when the firing ship is on a collision course, a torpedo course determining device to indicate collision course between the torpedo and the target ship, means whereby said torpedo course determining device is actuated as a function of the ship's speed, torpedo speed and the angle through which said first device is actuated, said torpedo collision course being impossible under certain conditions of torpedo speed and angular actuation of said first device, signal means, and means whereby said signal means is actuated when said torpedo collision course becomes impossible.

5. In a torpedo director adapted to be mounted on a firing ship, in combination, a line of sight device adapted to remain trained on a target ship when the firing ship is on a collision course, a torpedo course determining device to indicate collision course between the torpedo and the target ship, means whereby said torpedo course determining device is actuated through an angular distance $\theta \pm \alpha$ in accordance with the formula:

$$\sin(\theta \pm \alpha) = \frac{V_B}{V_{To}} \sin \theta$$

where θ is the angle through which the first device is operated, V_B is the ship's speed, V_{To} is the torpedo speed, and α is the torpedo course correction, said torpedo collision course being impossible when $\theta \pm \alpha$ is equal to or exceeds 1, signal

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means, and means whereby said signal means is actuated when $\theta \pm \alpha$ equals or exceeds 1.

6. In a torpedo director adapted to be mounted on a firing ship having torpedo tubes offset from the fore and aft axis of the ship, in combination, a line of sight device adapted to remain trained on the target ship when the firing ship is on a collision course, a torpedo course determining device including an indicator, means whereby said indicator is actuated in accordance with the ship's speed, the torpedo speed, and the angle through which the first device is actuated, and an auxiliary indicator offset from said first indicator by an amount equal to the displacement of said torpedo tube from the fore-and-aft axis of the ship.

7. In a torpedo director adapted to be mounted on a firing ship having torpedo tubes offset from the fore and aft axis of the ship, in combination, a line of sight device adapted to remain trained on the target ship when the firing ship is on a collision course, a torpedo course determining device including an indicator, means whereby said indicator is actuated in accordance with the ship's speed, the torpedo speed, and the angle through which the first device is actuated, and an auxiliary indicator movable with said first indicator and means for offsetting said auxiliary indicator from said first indicator by an amount equal to the displacement of said torpedo tube from the fore-and-aft axis of the ship.

8. In a torpedo director adapted to be mounted on a ship, in combination, a line of sight device, means for stabilizing said line of sight device in any position in azimuth in which it is placed independent of the ship's movements, and a second line of sight device adapted to move with the ship and positioned in cooperative relation to said first line of sight device so that an observer can observe along both lines of sight continuously.

9. In a torpedo director adapted to be mounted on a ship, in combination, a line of sight device, a second line of sight device comprising a pair of lines of sight, and means for stabilizing one of said devices in any position in azimuth in which it is placed independent of the ship's movements, the other of said devices being adapted to move with the ship, said pair of lines of sight being positioned in cooperative relation with respect to the other line of sight on either side thereof so that an observer can observe along all of said lines of sight continuously.

10. In a torpedo director adapted to be mounted on a ship, in combination, a line of sight device, means for stabilizing said line of sight device in any position in azimuth in which it is placed independent of the ship's movements,

a second line of sight device adapted to move with the ship and positioned in cooperative relation to said first line of sight device so that an observer can observe along both lines of sight continuously, and means for changing the relationship of said second line of sight device with respect to the ship.

11. In a torpedo director adapted to be mounted on a ship, in combination, a line of sight device, means for stabilizing said line of sight device in any position in azimuth in which it is placed independent of the ship's movements, a second line of sight device adapted to move with the ship and positioned in cooperative relation to said first line of sight device so that an observer can observe along both lines of sight continuously, means for changing the relationship of said second line of sight device with respect to the ship, a pointer movable with said first device, a second pointer movable with said second device, and means for changing the relationship of said second pointer relative to said first pointer without changing the relationship of said devices.

12. In a torpedo director adapted to be mounted on a ship, in combination, a line of sight device for sighting on a target, a torpedo course determining device, means whereby said second device is actuated in accordance with the ship's speed, the torpedo speed, and the angle through which the first device is actuated, an indicator for indicating torpedo course, means whereby said torpedo course determining device actuates said indicator, and means for changing the relationship between said indicator and said torpedo course determining device.

13. In a torpedo director adapted to be mounted on a ship and having a line of sight device adapted to be trained on a target, means for stabilizing said device in azimuth, said means including a gyroscope, means for mounting said gyroscope with three degrees of freedom for pivotal movement about a horizontal axis and a vertical axis, whereby said gyroscope will maintain its position in azimuth independent of the movements of the ship, and means whereby said gyroscope may be locked against precession, said last named means comprising a bail movable in azimuth with said ship and pivotally mounted thereon, said bail substantially surrounding the gyroscope and its mounting, and means whereby said bail may be swung into engagement with said gyroscope mounting to lock the same against pivotal movement.

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