Oct. 27, 1931. M. F. BATES 1,829,181

GUN FIRE CONTROL SYSTEM

Filed June 8, 1923 2 Sheets-Sheet 1

Fig. 1.

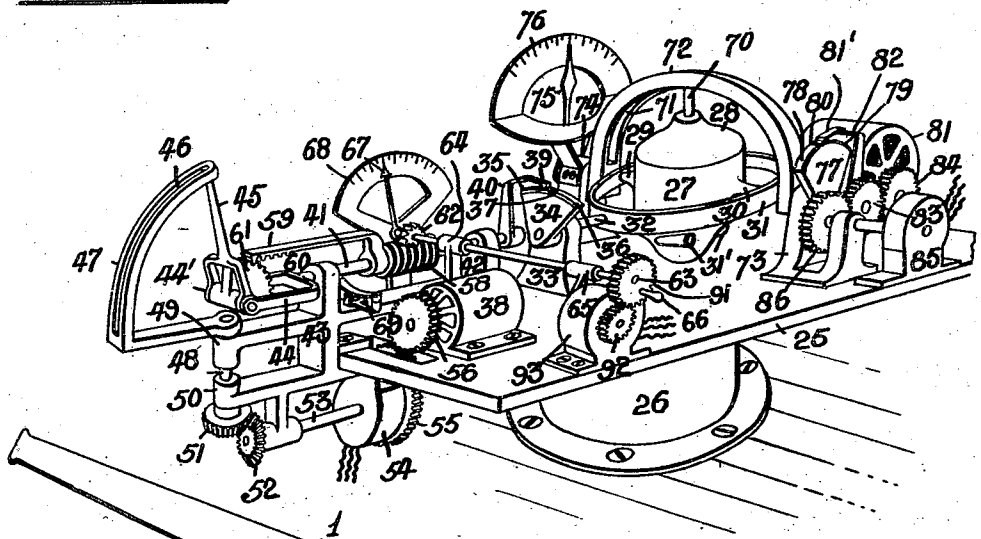

Fig. 2.

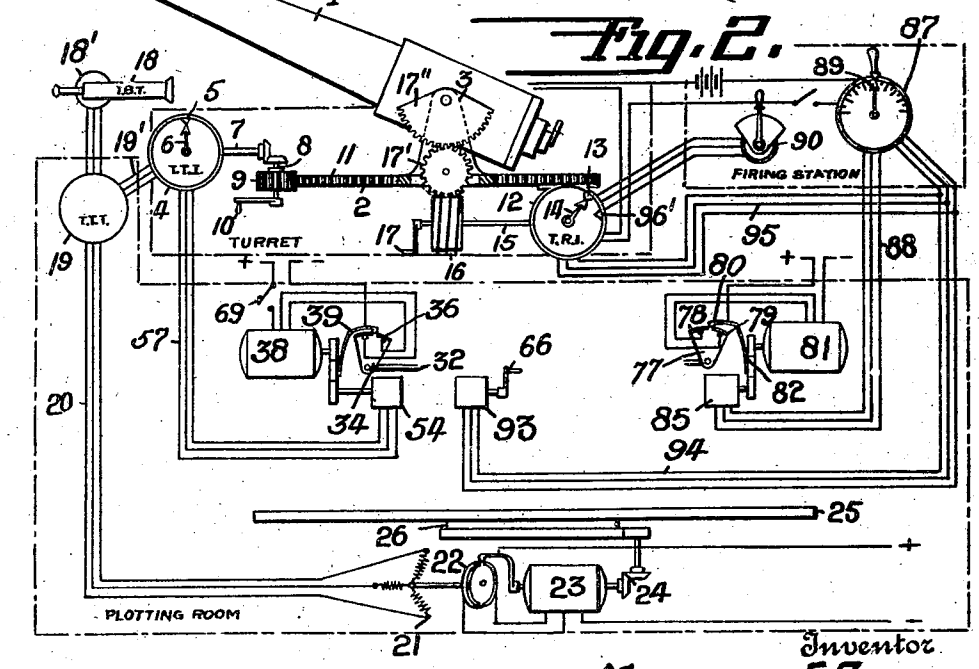

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Fig. 3.

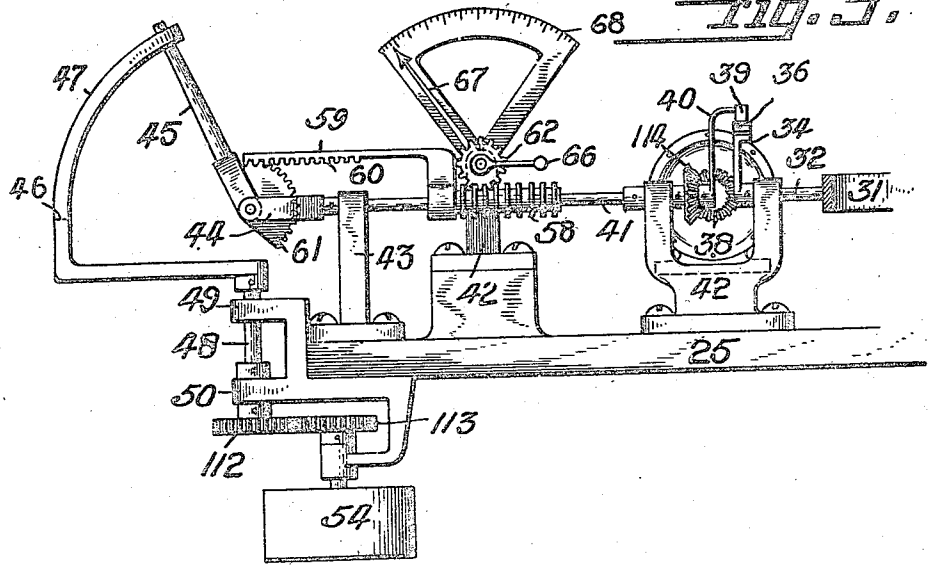
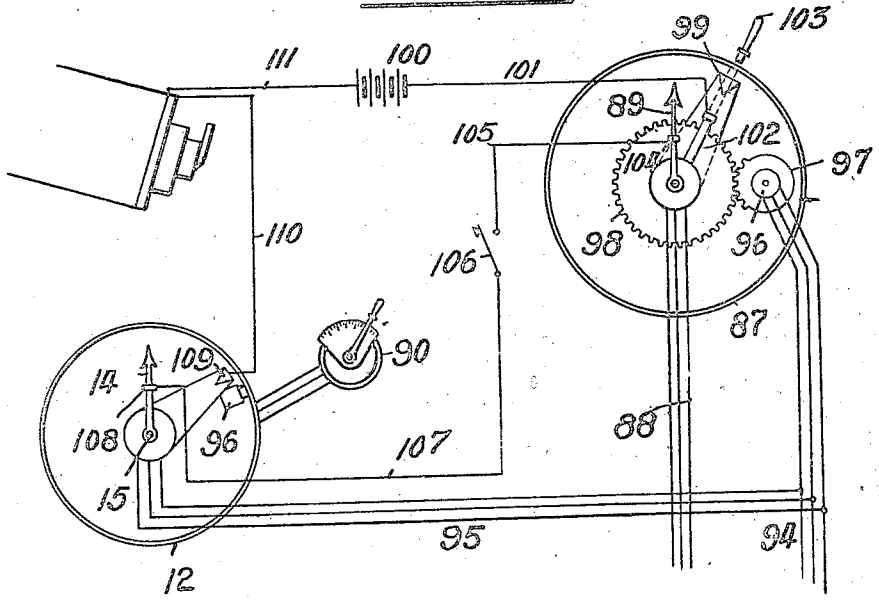


Fig. 4.



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Patented Oct. 27, 1931 1,829,181

UNITED STATES PATENT OFFICE

MORTIMER F. BATES, OF BROOKLYN, NEW YORK, ASSIGNOR, BY MESNE ASSIGNMENTS, TO SPERRY GYROSCOPE COMPANY, INC., A CORPORATION OF NEW YORK

GUN FIRE CONTROL SYSTEM

Application filed June 8, 1923. Serial No. 644,136.

This invention relates to gun fire control systems and has for its object the provision of an improved system of this character. More specifically, it relates to a correction system for errors due to trunnion tilting of ordnance on shipboard out of the plane of the horizontal occasioned by the rolling and pitching motions of the ship. The invention embraces azimuth or train correction due to said motions, which correction is preferably introduced automatically in the general azimuth training system either by indicators or the automatic operation of the gun mounting or turret. The device also extends to the automatic indication of the proper correction value which may be introduced into the range at will. These functions vary when the axis of the gun and its elevation is considered with respect to the longitudinal axis of the ship.

In carrying out my invention, I employ a universally supported pendulum for maintaining the vertical. This is preferably gyroscopic and compensated against acceleration pressures, being mounted on a base which may swivel about a vertical axis and be trained virtually with the gun directly or indirectly, and having indicating or actuating apparatus or contacts on either one or both of the axes of the gyroscopic pendulum, one of which axes may be considered as kept at all times parallel with the training of the gun and the other axis at right angles thereto. The contact about the first mentioned axis is employed to obtain the angle of tilt of the trunnions, thereby actuating intermediate computing or other apparatus which properly functions to develop the azimuth corrections of the gun as well as the location of these corrections in their proper amounts as they lie either to the right or left of the line of train. The contact about the last mentioned axis which is parallel with the gun trunnions controls the correction indicator for elevation or range of the gun located at the firing station. This latter correction can be introduced at will into the range of the gun as will appear hereinafter. Of course, it is understood that this final correction for elevation or range varies from moment to moment usually passing through zero. The range that is primarily transmitted to the range indicator located in the turret is the net range after all plotting room corrections have been made and is based on the assumption that firing will take place as the ship passes through the horizontal. When firing is to take place as the ship is heeled, the said final correction for range may be of some moment and it is therefore indicated as a plus or minus correction of the primary range. In this system, provision is made in the firing circuit for interlocking this circuit with the range indicator in the turret and an indicator at the firing station so that when a given amount of range correction has been introduced into the range indicator, the firing of the gun cannot take place except at that point of heel of the ship corresponding to this given correction. On the other hand, the correction for trunnion tilt which affects the train of the gun is constantly introduced automatically along with other well understood azimuth corrections, the algebraic sum of which reaches the target turret indicator.

I may also employ my invention in connection with the director firing system disclosed in the copending application of Ralph E. Kortepeter, Serial No. 653,445 filed July 24, 1923 which invention is assigned to the assignee of the present invention, reference to which is had for the preferred details of the indicators referred to herein.

My invention will be better understood from the following description taken in connection with the accompanying drawings and its scope will be pointed out in the appended claims.

In the drawings illustrating what I now consider the preferred form of my invention,

Fig. 1 is a perspective view of my controlling apparatus with auxiliary parts.

Fig. 2 is a diagram illustrating parts of the mechanism shown in Fig. 1 and their relation to other units in the system, with electrical connections.

Fig. 3 is a modification of part of my controlling mechanism, and

Fig. 4 is an enlarged detail of a portion of

Fig. 2 more clearly to illustrate the operation of the system.

Referring now to Figs. 1 and 2, the gun 1 to be controlled is shown as mounted on a rotatable platform 2 such as a turret for movement in azimuth and in trunnions 3 for elevation. In the turret is an instrument 4 of a standard type, an early form of which is shown in Letters Patent 1,296,439 to Elmer A. Sperry dated March 4, 1919, and a later form of which is shown in the pending application of the same inventor, now Patent No. 1,755,340, dated April 22, 1930, being assigned to the assignee of the present invention, known as the target bearing or target turret indicator (T. T. I.) to which is transmitted the azimuth readings with all corrections introduced, which will be more fully explained hereinafter. The instrument 4 has an index 5 to indicate the readings transmitted, and a pointer 6 rotatable with a shaft 7 which may be geared to a shaft 8 carrying a gear 9 and handle 10. The gear 9 meshes with a gear 11 on the periphery of platform 2. An attendant is stationed in the turret, who by means of the handle 10, keeps the pointer 6 and index 5 in coincidence, thereby moving the gun in azimuth to the position indicated by the index 5, in a manner readily understood. Since azimuth corrections are being continuously introduced, due to the motion of the ship or of the target, the attendant continuously keeps the pointer 6 and index 5 in coincidence.

In the turret is a second instrument 12, of a standard type and somewhat similar to the indicator 4, known as a target range indicator (T. R. I.) to which is transmitted the elevation of the gun, as will be later described. This instrument has an index 13 to indicate the elevation of the gun, and a pointer 14, rotatable with a shaft 15 having fixed thereto a gear 16 and handle 17. The gear 16 meshes with a gear 17′, which meshes with a gear segment 17″ fixed to gun 1. A second attendant in the turret keeps the pointer 14 and index 13 in coincidence, thereby moving the gun in elevation to the position indicated by the index 13, in a manner readily understood. The elevation at which the gun is to be fixed is predetermined, and consequently, after the gun is once trained in elevation, it need not be changed unless new conditions requiring correction arise, such as where it is desired to change the point or time with respect to the roll of the ship at which firing is to take place. The parts described are located in the turret, and the diagram is a conventional drawing to illustrate their relation, it being understood of course, that in practice the parts may assume other forms and be differently arranged to perform these functions.

In standard systems, a target bearing telescope 18 (T. B. T.) is employed, which is continuously kept upon the target. This is a standard instrument and need not here be described. It is provided with a transmitter 18′ which transmits its readings to an instrument 19 located in the plotting room known as a target bearing or target turret transmitter (T. T. T.). This is also a well-known standard type of instrument and need not be described in detail herein. In the plotting room, there are numerous corrections introduced, and the corrected reading is transmitted through conductors 19′ to the target turret indicator 4. These corrected readings are also transmitted through conductors 20 to a synchronous motor 21, which rotates contacts 22, which control a follow-up motor 23 in a manner well understood in the art. The motor 23 through suitable gear mechanism 24 rotates a table 25, on which as shown in Fig. 1, is supported my apparatus for correcting for error in angle of train due to trunnion tilt and motion about the trunnion axis, which will be described in detail hereinafter, although all of the mechanism shown in Fig. 1 need not necessarily be mounted on this table. Table 25, the mechanism supported thereby and motors 21 and 23 are also preferably located in the plotting room as indicated.

The table 25 is mounted in a horizontal plane on a suitable rotatable vertical support within a casing 26 containing collector rings and brushes for the various electric circuits of the apparatus, the details of which are not shown. On said table is mounted a universally supported pendulum for maintaining the vertical, which is shown as a gyroscope 27, which is preferably of the type shown in my Patent No. 1,518,892, dated December 9, 1924, which patent is assigned to the assignee of the present invention.

As shown in Fig. 1 the gyroscope 27 comprises a casing 28 in which is mounted on a vertical spinning axis a rotor of the usual type, not visible in the drawing which is driven by a suitable electrical source in the usual manner. The casing 28 is universally mounted in a cardan suspension, the casing being provided with pivots 29, 30 journaled within a gimbal ring 31, which ring is in turn similarly mounted for oscillation or rotation about normally horizontal pivots at right angles to the pivots 29, 30, one of which, 32, is visible in Fig. 1. These latter pivots of which 32 is visible, are suitably journaled in supporting brackets, one of which is shown at 33. I preferably employ a gyroscope compensated against acceleration pressures as described in the aforesaid application, in which the casing is provided with nozzles 31′, through which air under pressure flows, the openings of the nozzles being controlled by an auxiliary, universal pendulum. The apparent movement of the gyroscope about the two cardan axes of the gyroscopic suspension, due to the motion of the ship, is

used to control two separate sets of mechanism.

First considering the oscillation about the horizontal axis of pivot 32. As shown in Fig. 1, the pivot 32 extends through bracket 33 and has suitably fixed thereto an element 34 having two contacts 35, 36, separated by a strip of insulation 37. The contacts 35, 36 are electrically connected to a follow-up motor 38, which connections are diagrammatically shown in Fig. 2. Said contacts are arranged to be engaged by a brush 39, carried by an arm 40. The brush 39 is connected to the opposite side of the electrical source for motor 38. It is therefore obvious that rotation about pivot 32 will close the circuit of motor 38 through either of the contacts 35, 36 and that the circuit is open when the brush is in its neutral position or on insulation 37. It is of course understood that the circuit through said contacts drives the motor in opposite directions. The arm 40 is fixed to a shaft 41 which is journaled in suitable supporting brackets 42, 43. Said shaft 41 being mounted on the platform 25 in line with the axis 32 of the gyroscope is obviously maintained in the line of sight of the target. At its opposite end, the shaft 41 is formed with a fork 44 within which is pivoted an arm 45, on axis 44′ which lies perpendicular to the shaft 41 and is maintained truly horizontal by the gyroscope by means of contacts 35, 36, 39, follow-up motor 38, and the linkage hereinafter described. The end of the arm 45 which is shown as in the form of a pilot gun fits into the slot 46 of an arc shaped member 47 which is secured to a shaft 48, suitably journaled in extensions 49, 50 of the bracket 43 at right angles to the axis 44′, i. e., shaft 48 lies perpendicular to the ship's deck. All three axes, i. e., of shafts 41, 44′ and 48, preferably intersect at a common point. At its opposite end, the shaft 48 is provided with a bevel gear 51 meshing with a bevel gear 52 on shaft 53 of a transmitter 54. The transmitter 54 is provided with a gear 55 meshing with a gear 56 on the follow-up motor 38. From the foregoing, it will be seen that when the circuit of motor 38 is closed through either of the contacts 35, 36, the transmitter 54 will be rotated turning its shaft 53 which in turn moves part 47 to the right or left through its bevel gear connection through an angle equal to the component of the angle of traverse of the gun resolved in the plane of the ship's deck. The movement of part 47 carries with it the arm 45 causing shaft 41 to turn until the brush 35 reaches its neutral position on insulation 37, when the motor circuit is opened. At the same time the transmitter 54 is actuated as before stated and the movement is transmitted to the target turret indicator 4 through conductors 57. A circumferentially grooved sleeve 58 is loosely mounted on shaft 41, and has fixed thereto an arm 59 provided with gear teeth 60 arranged to mesh with a gear segment 61 fixed to the arm 45. Consequently, and longitudinal movement of the sleeve 58 will cause the arm 45 to be elevated or lowered in the slot 46. The sleeve 58 may be moved longitudinally by means of a gear 62 on a shaft 63 journaled in brackets 64, 65. At one end, the shaft 63 is provided with a handle 66, and its opposite end with a pointer 67 cooperating with a graduated dial 68. It follows from this construction that the greater the elevation of element 45, the more movement for a given amount of follow-up on the contact sector 34 there will be of the motor 38 and transmitter 54. When the arm 45 is in its lowest position, no motion can be transmitted to shaft 41. Therefore, a circuit breaker is placed at 69 to render motor 38 inoperative except at such times as there is an appreciable elevation of arm 45. Having described the structural details, the operation and purpose of this apparatus will be readily understood.

As shown in Fig. 2, the table 25 supporting this mechanism is rotated by a motor 23 controlled by synchronous motor 21, which is driven from the target turret transmitter 19. When the apparatus therefore is in operation, the horizontal axis 32 of the gyroscope 27 is oriented with the gun 1, that is, it points in the same direction the gun should point after certain well-known corrections have been introduced at the target turret transmitter 19. This is done through the means just described. The next step is to move the arm 45 about its axis 44′ to the desired elevation or range. This is done by the attendant in the plotting room, who rotates the handle 66 until the pointer 67 coincides with the said elevation or range on the dial 68. This motion is transmitted to the arm 45 through gear 62, sleeve 58, arm 59 and gear 61.

As is well known, a gun pointed at a target is displaced with respect thereto in azimuth by trunnion tilt, due to the motion of the ship, and in order that the gun may be fired at any instant it is necessary to introduce a correction to compensate for this displacement in azimuth which correction must be determined in terms of angular movement of the turret about the axis thereof, which, of course, usually lies perpendicular to the ship, i. e., the angle of traverse of the gun must be determined in the plane of the ship's deck. The angular correction in train, made necessary by the tilt of the gun trunnion, is, of course, actually equal to the projection on a horizontal plane of the angle of elevation of the gun. These corrections are automatically and continuously introduced by the apparatus described in the following manner:

With the gyroscopic pendulum holding a true vertical, all motions of the ship will re-

solve themselves into motions about the cardan axes of the gyro; for example, movement about pivot 32, which is trunnion tilt, will bring contact 35 or 36 under the brush 39, starting motor 38 in the proper direction to restore the brush 39 to the neutral section between contacts 35 and 36.

In performing the above work, the motor also drives the transmitter 54. It is evident that the amount the transmitter turns is dependent upon the elevation of the arm 45, i. e., is a function of the sine of the angle of deviation of the gun, or is equal to the angle of traverse of the gun resolved in the plane of the ship. In this manner the two factors, trunnion tilt (measured by the angle between shaft 44′ and the plane of slot 46) and gun elevation are combined to give the correct azimuth or train correction wanted which is actually the deflection to the right or left of part 47 and it is the amount of this deflection that is transmitted by transmitter 54.

In operation, again referring to brush 39, it is seen that the brush supporting mechanism being virtually a part of the ship will be displaced when the ship rolls and pitches. Said brush is also caused to follow the contact sector neutral point as motions of the ship affect it, by its follow-up connection to shaft 41, with only a few minutes of arc lag existing at any time.

It will be observed that this correction is introduced into the target turret indicator 4 and not the target turret transmitter 19, into which the other corrections are introduced. This is for the reason that the apparatus is oriented from the target turret transmitter and with the latter correction introduced, the apparatus would not be properly oriented. It is obvious that only the gyroscope 27 need be supported on a table 25 to be oriented from the target turret transmitter to function properly, and that the other mechanism may be conveniently mounted elsewhere and properly connected.

I have provided means to render the apparatus inoperative when the arm 45 is in a horizontal position, because in this position, as previously indicated, there is no azimuth correction for trunnion tilt to be transmitted, which is accomplished by opening the circuit of motor 38. A switch 69 of any suitable type normally closed, is placed in the said motor circuit, and may be mounted on an extension of bracket 43 in the path of sleeve 58. When this sleeve has advanced to a position in which the arm 45 is horizontal, the switch 69 is opened by said sleeve.

As above indicated, the horizontal axis pivoted at 32, of the gyroscope, is oriented with the gun so that movement about this cardan axis is a direct measure of the trunnion tilt due to the motion of the ship which factor is introduced into the correction device by the shaft 41. The other cardan axis at 29, 30 is therefore paralled with the trunnion axis, and movement about this axis is a direct measure of the displacement of the gun in elevation due to the motion of the ship and is employed to indicate the varying range correction value due to said motion of the ship.

As shown in Fig. 1, the gyroscope 27 is provided with an upwardly extending pin 70 which fits into a groove 71 of an arched member 72 pivoted in brackets 73, 74 on an axis coincident with the gyroscope horizontal axis pivoted at 29, 30. By this arrangement, the gyroscope is free to tilt about its axis 32 and tilting about the axis 29—30 is transmitted to member 72. The bearing at one end of the member 72 may extend through bracket 74 and have fixed thereto a pointer 75 to cooperate with a dial 76 to indicate the angle of tilt of the member 72. At its opposite end, the bearing of the member 72 may extend through the bracket 73 and have fixed thereto an element 77, having two contacts 78, 79 separated by a strip of insulation 80. These contacts are electrically connected to a follow-up motor 81, as shown diagrammatically in Fig. 2. Said contacts are arranged to be engaged by a brush 81′ carried by an arm 82. Said brush 81′ is connected to the opposite side of the electrical source for motor 81, and the control of this motor by the tilting of member 72 is similar to that described above with respect to motor 38. In this case however, the arm 82 is fixed to a gear 83 which meshes with a gear 84 driven by the motor 81. The tilting of the member 72 is imparted to a transmitter 85, through a gear 86 in mesh with gear 83, which transmits the angle of tilt to the firing station indicator 87 through conductors 88, which reading is indicated by the pointer 89. It should be understood that more than one transmitter may be geared in series for coarse and fine readings, if desired. This correction is introduced at will into the range indicator 12 by means of a range correction transmitter 90 located at the firing station which may be of any standard type, and is well known in the art.

As shown in Fig. 1, the handle 66, for putting the desired elevation or range of the gear into the corrector is fixed on a gear 91, which meshes with a gear 92 of a transmitter 93 which transmits the elevation to the range indicator 12 through conductors 94, 95. As stated above, the range indicator 12 is a standard type of instrument, but in addition, it is provided with a stop 96′, or other means, so located that the pointer 14 cannot move beyond the maximum elevation of the gun. There obviously would be no need for readings beyond the maximum elevation in the turret since the attendant could not elevate the gun beyond its maximum. To fire the gun at a greater range than its maximum elevation requires a consideration of the roll

of the ship, which is done at the firing station. The conductors 94 are therefore continued to the firing station 87 as shown in Fig. 2. The firing station is not concerned with the elevation of the gun until its maximum elevation is reached, its function at other times being to introduce the correction in elevation due to the motions of the ship through transmitter 90 as described. The conductors 94 lead to a transmitter 96 at the firing station as shown in Fig. 4. This transmitter rotates a segmental gear 97 which is arranged to introduce no reading to the firing station indicator 87 until the maximum elevation of the gun is reached, that is, when pointer 14 strikes stop 96′ in the range indicator 12. At this time, however, the segmental gear 97 meshes with a gear 98 carrying an index 99. It is of course understood that the handle 66, pointer 67 and arm 45 have a movement beyond the maximum elevation obtainable at the gun. The index 99 now indicates the range at which the gun must be fired, which can only take place when the pointer 89 and index 99 coincide.

The firing circuit comprises a suitable electrical source 100, conductor 101, contact 102 on a handle 103, contact 104 on pointer 89, conductor 105, firing switch 106, conductor 107, contact 108 on pointer 14, contact 109 on pointer 13, conductor 110 to the gun, and conductor 111 to the source 100.

Regardless of the elevation at which the gun is to be fired, the same conditions must exist. The handle 103 is moved to coincide with index 99 at the firing station, contacts 104 and 102 must close the circuit, the control switch 106 must be closed, and contacts 108 and 109 at the range indicator must engage, that is, the gun must have been moved in elevation until the pointer 14 coincides with index 109. It is therefore clear that no firing can take place until the gun has been elevated in accordance with the turret range indicator 12, nor until the motion of the ship has brought the indicator pointer 89 in contact with 102 when the circuit is closed by switch 106. For illustrating purposes, the handle operating the transmitter 90 and handle 103 are shown separately, but in practice I prefer that handle 103 shall also operate transmitter 90 as their positions always coincide.

Any given range setting at the target range indicator 12 which is within the limits of the gun mounting can be corrected at will from the firing station by movement of transmitter 90 to coincide with any setting of lever 103. The movement of the ship effecting range and the amount of it is shown by pointer 89 as before described, therefore, lever 103 can be set at any point that under prevailing conditions will be passed over by the pointer 89.

In Fig. 3 is shown a modification of Fig. 1, the similar parts having similar reference numerals. Herein, instead of rotating the member 47 in azimuth and transmitter 54 from motor 38 as shown Fig. 1, the transmitter 54 is rotated through gears 112, 113 from shaft 48 and the shaft 41 is directly rotated by motor 38 through a gear 114 on the shaft 41 adjacent the arm 40.

With this construction the transmitter drive is by means of the arm 45, and varies as in the first construction with a function of the elevation set in the arm 45. When the arm is horizontal its axis is in line with shaft 41 and no movement of the transmitter takes place, but motor 38 need not be rendered inoperative by a circuit breaker because shaft 41 is still free to rotate.

In accordance with the provisions of the patent statutes, I have herein described the principle of operation of my invention, together with the apparatus, which I now consider to represent the best embodiment thereof, but I desire to have it understood that the apparatus shown is only illustrative and that the invention can be carried out by other 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 herein described my invention, what I claim and desire to secure by Letters Patent is:

1. In a system of gun fire control, a target bearing transmitter, a target indicator connected therewith, a universally supported gyroscope for maintaining the vertical, means for maintaining the same with one of its axes in a constant relation to the target bearing transmitter, means positioned according to the angle of tilt about said gyroscope due to motions of the ship, means positioned in accordance with range cooperating with said means, and means for automatically introducing a correction which is a function of the angle of said tilt and range into the target indicator.

2. In a system of gun fire control, a target bearing transmitter, a target indicator connected therewith, a universally supported gyroscope for maintaining the vertical oriented by the target transmitter, means positioned according to the angle of tilt of said gyroscope due to motions of the ship, means positioned in accordance with range cooperating with said means, and means for automatically introducing a correction which is a function of the angle of said tilt and range into the target indicator.

3. In a system of gun fire control, a target bearing transmitter, an indicator connected therewith, a universally supported gyroscope for maintaining the vertical, means for orienting the same from said transmitter to

naintain one of its axes parallel with the runnion axis of the gun, means actuated by elative angular motion of the ship and gyrocope about said axis, means positioned in ccordance with range cooperating with said neans, a member positioned in different lanes by said two means and means actuated rom said member for introducing a correcion which is the component in the plane of he ship of the actual instantaneous angle of raverse of the gun.

4. In a system of fire control for naval uns, a transmitter for sending the azimuth ngle at which the gun is to be aimed, an inicator connected therewith located near the un, a gyroscope automatically oriented from aid transmitter to indicate the trunnion tilt f the gun due to ship motions, means posiioned in accordance with the range or gun levation, a member positioned in different lanes by said two means and means for inroducing a correction which is the compoent of the angle of traverse of the gun in the lane of the ship.

5. In a system of gun fire control, a target ansmitter, a target indicator connected ierewith, a universally supported gyro penlum for maintaining the vertical, means for easuring the trunnion tilt of the gun with spect to said pendulum due to motions of ie ship, means for orienting said pendulum om said transmitter, means positioned in ccordance with range cooperating with said rst named means, and means for introducing correction which is a function of the angle said tilt and range into the target indicator.

6. In a gun fire control system, means for dicating the motion about the trunnion axis ie to ship motion comprising a universally pported gyroscope for maintaining the vercal, means for continuously orienting said roscope with one of its axes parallel with e normal gun trunnion axis, and indicating eans operating about both axes of the gyrope for measuring trunnion tilt and the anlar motion of the gun about the trunnion is due to the ship's rolling and pitching.

7. In a system of gun fire control, a target ansmitter, an indicator connected therelth, a universally supported gyroscopic penlum for maintaining the vertical, means r positioning said gyroscope with one of its es parallel with the trunnion axis of the n, means actuated by said gyroscope in acrdance with the trunnion tilt of the gun due motions of the ship, means positioned in cordance with range cooperating with said eans, means for transmitting to said indiitor from said last two means a correction, d means for compensating said gyroscope ainst acceleration pressures.

8. In a gun fire control system, a universalsupported gyroscope for maintaining the rtical, means for maintaining one of its es parallel with the train of the gun, a follow-up system responsive to tilting about said axis comprising a motor, an element driven thereby in one plane, a second element pivoted at right angles to said element adjustable to positions corresponding to the elevation of the gun engaging said element, the relative position of said two elements controlling the relation between the gyroscope and said motor, and a transmitter driven by said motor connected with a target bearing indicator.

9. In a gun fire control system, a universally supported gyroscope for maintaining the vertical, means for maintaining one of its axes parallel with the train of the gun, a follow-up system connected with said axis having a motor, an adjustable element positioned at the angle of elevation of the gun arranged to form a variable connecting link between the gyroscope and the motor according to the elevation of the gun, and a transmitter driven by said motor for indicating at a remote point an angular correction.

10. In a gun fire control system, a universally supported gyroscope for maintaining the vertical, means for automatically maintaining one of its axes parallel with the train of the gun, a follow-up system connected with said axis having a motor, an adjustable element positioned at the angle of elevation of the gun arranged to form a variable connecting link between the gyroscope and the motor according to the elevation of the gun, and a transmitter driven by said motor for indicating at a remote point an angular correction.

11. In a gun fire control system, a universally supported gyroscope for maintaining a horizontal reference plane, means for maintaining one of its axes parallel with the train of the gun, a follow-up system controlled by said axis, means for adjusting said system for the gun elevation, and indicating means connected with said system.

12. In a gun fire control system, a universally supported gyroscope for maintaining a reference plane, means for automatically maintaining one of its axes parallel with the train of the gun, a follow-up system controlled by said axis, means for adjusting said system for the gun elevation, and indicating means actuated by the ship's motions as modified by said adjusting means.

13. In a system of gun fire control, a target transmitter, a target indicator, a universally supported gyroscope for maintaining a reference plane, means for maintaining one of its axes parallel with the train of the gun controlled by said transmitter, a follow-up system controlled by said axis, means for adjusting said system for range, and means connected with said system for introducing a correction which is a function of the angle of tilt about said axis and range into said indicator.

14. In a system of gun fire control, a target

bearing transmitter, a target bearing indicator, a universally supported gyroscope for maintaining the vertical, means for maintaining one of its axes parallel with the train of the gun controlled by said transmitter, a follow-up system controlled by said axis, means for adjusting said system for range, and means connected with said system for introducing a correction which is a function of the angle of tilt about said axis and range into said indicator.

15. In a system of gun fire control, a target transmitter, a target indicator, a universally supported gyroscopic pendulum, means for maintaining one of its axes parallel with the train of the gun controlled by said transmitter, a follow-up system controlled by said axis, means for adjusting said system for range, and means connected with said system for introducing a correction which is a function of the angle of tilt about said axis and range into said indicator.

16. In a system of gun fire control, a target transmitter, a target indicator, a universally supported gyroscope for maintaining the vertical, means for maintaining one of its axes parallel with the train of the gun controlled by said transmitter, a follow-up system controlled by said axis, means for adjusting said system for range, and means connected with said system for introducing a correction which is a function of the angle of tilt about said axis and range into said indicator.

17. In a gun fire control system, a universally supported gyroscope for maintaining the vertical, means for maintaining one of its axes parallel with the train of the gun, a follow-up system connected with said axis having a motor, an adjustable element positioned at the angle of elevation of the gun arranged to form a variable connecting link between the gyroscope and the motor according to the elevation of the gun, and means connected with said system for introducing a correction which is a function of the angle of tilt about said axis and given elevation into a target indicator.

18. In a system of gun fire control, a target bearing transmitter, a target bearing indicator connected therewith, and means for introducing azimuth correction into said indicator due to gun trunnion tilt resulting from motions of the ship comprising a universally supported gyro pendulum for maintaining the vertical, means for orienting said pendulum with one of its axes parallel with the training of the gun, electrical contacts carried by said axis, a follow-up motor electrically connected with said contacts, a vertical element driven by said motor, a second element positioned at the angle of elevation of the gun engaging the vertical element, means supporting said second element having a brush engaging said contacts constituting a follow-up for said motor and a transmitter connected with said motor for sending the angle of rotation of said vertical element to the target indicator.

19. In a system of gun fire control, a target bearing transmitter, a target bearing indicator connected thereto, and means for introducing azimuth correction into said indicator due to gun trunnion tilt comprising apparatus as specified in claim 18, in combination with means for positioning said second element in accordance with the elevation of the gun.

20. In a gun fire control system, means for indicating the trunnion tilt of the gun due to ship motion comprising a universally supported gyroscope for maintaining the vertical, means for continuously orienting said gyroscope with one of its axes parallel with the train of the gun, a follow-up system controlled by said axis comprising a follow-up motor, adjustable means intermediate said motor and said gyroscope for varying their relation and means for positioning said adjustable means at predetermined points for the different elevations of the gun.

21. In a system of gun fire control, a structure as specified in claim 20 in combination with a target bearing transmitter for continuously orienting the gyroscope as described, a target bearing indicator connected with said transmitter, and means connected with the follow-up system of said structure for automatically introducing a correction which is a function of the angle of trunnion tilt and gun elevation into said transmitter.

22. In a gun fire control system for naval guns, the combination comprising a target bearing transmitter, a target bearing indicator connected therewith, a range indicator, a firing station, a universally supported gyroscope for maintaining the vertical, means for continuously orienting said gyroscope with one of its axes parallel with the train of the gun and its other axis parallel with the trunnion axis, means for introducing the angle of trunnion tilt into the target bearing indicator comprising a follow-up system connected with said first mentioned gyroscope axis having an adjustable element arranged to change the relation of the follow-up system with respect to the gyroscope, means for positioning said adjustable element according to the elevation of the gun, a transmitter connected with said system leading to the target bearing indicator, means for indicating the angle of motion about the trunnion axis of the gun comprising a follow-up system connected with the latter gyroscope axis, and a transmitter connected therewith leading to the firing station indicator.

23. In a gun fire control system, means for indicating the motion about the trunnion axis due to ship motion comprising a universally supported gyroscope for maintaining the vertical, means for continuously orienting

said gyroscope with one of its axes parallel with the normal gun trunnion axis, and indicating means operating about an axis of the gyroscope.

24. In a gun fire control system, the combination with a gun and a sighting device, of a firing station located at a distance from said sighting device and gun, a range indicator, means for indicating the angle of motion about the trunnion axis of the gun due to ship motion located at the firing station, and means located at the firing station for introducing the said angle of motion into the range indicator.

25. In a gun fire control system, the combination with a gun and a sighting device, of a firing station located at a distance from said sighting device and gun, a range indicator, means for indicating the angle of motion about the trunnion axis of the gun due to ship motion located at the firing station, and means located at the firing station for introducing the said angle of motion or fractions thereof into the turret range indicator.

26. In a gun fire control system, a range indicator, a firing station having a range indicator, means for simultaneously transmitting the range to both of said indicators, means for rendering the range indicator inoperative when the transmitted range exceeds the maximum elevation of the gun, and means rendering the firing station range indicator operative only when the transmitted range exceeds the maximum elevation of the gun.

27. In a gun fire control system, a range indicator, a firing station range indicator, means for transmitting ranges to both indicators, means automatically limiting the indications of the range indicator to the maximum elevation of the gun and means automatically rendering the firing station range indicator inoperative when the range indicator is operative.

28. In a gun fire control system, a firing station having means for indicating the angle of motion about the trunnion axis of the gun due to ship motion, and means for indicating the range of the gun when it exceeds the maximum elevating angle of the gun about its trunnion axis.

29. In a gun fire control system, the combination comprising a turret range indicator, a firing station range indicator, means for simultaneously transmitting ranges to both indicators, means automatically limiting the turret range indicator to the maximum elevating angle of the gun, means for indicating at the firing station indicator the angle of motion about the gun trunnion axis due to motion of the ship, and means for automatically limiting the range indications at the firing station to ranges beyond the maximum elevating angle of the gun.

30. In a gun fire control system, a turret range indicator, a firing station indicator, means for compensating the same for trunnion tilt of the gun due to rolling and pitching of the ship and a firing circuit comprising a switch controlled by the position of the turret range indicator and a switch controlled by the firing station indicator.

31. In a gun fire control system, a turret range indicator having two elements to indicate the transmitted range and position of the gun respectively, contacts carried by said elements to form an electrical switch, a firing station indicator having a pointer to indicate the angle of motion about the gun trunnion axis due to ship motion carrying a contact and a movable member positionable to the range also carrying a contact, said latter two contacts forming an electrical switch, and a firing circuit controlled by said two switches and a firing switch.

32. In a gun fire control system for ships, a correction mechanism for errors due to rolling and pitching, comprising a member normally positioned in line with the target and pivoted about an axis perpendicular to the ship, a second member pivoted about an axis in line with the target and about a horizontal axis at right angles to said second axis, all of said axes intersecting at a common point, means for positioning said second member about said third axis at an angle equal to the gun elevation, a slidable connection between said members about said common point as a center, and means for positioning said first member about said perpendicular axis so as to maintain said third axis of said second member horizontal.

33. In a gun fire control system for ships, a correction mechanism for errors due to rolling and pitching, comprising a member normally positioned in line with the target and pivoted about an axis perpendicular to the ship, a second member pivoted about an axis in line with the target, and about a horizontal axis at right angles to said second axis, all of said axes intersecting at a common point, means for maintaining the horizontality of said third axis, means for positioning said second member about said third axis at an angle to the gun elevation, and a slidable connection between said members about said common point as a center, whereby said first member is rotated through an angle, equal to the error due to said rolling and pitching.

34. In a gun fire control system for ships, a correction mechanism for errors due to rolling and pitching, comprising a member mounted for turning about a longitudinal axis and for turning about a horizontal axis perpendicular to said first named axis, means for positioning said member about said last named axis at the angle of gun elevation, means for maintaining said first named axis in line with the target, means for mechani-

cally resolving the relative angular movement of the ship and said member into a component which is in the plane of the ship's deck, and means for transmitting the resolved movement to the guns.

35. In a system of gun fire control, a target transmitter, a target indicator connected therewith, a gyroscope for maintaining the vertical oriented with the gun, means positioned according to the angle of tilt about said gyroscope due to motions of the ship, means positioned in accordance with range cooperating with said means, means controlled thereby for correcting the train of the gun for errors due to trunnion tilt, and means also controlled by said gyroscope for correcting the gun elevation.

36. In a gun fire control system, means for indicating the motion about the trunnion axis due to ship motion comprising a universally supported gyroscope for maintaining the vertical, means for continuously orienting said gyroscope to maintain one of its axes parallel with the normal gun trunnion axis, and means operating about said last named axis for correcting the gun elevation.

37. In a gun fire control system, means for indicating the motion about the trunnion axis due to ship motion comprising a universally supported gyroscope for maintaining the vertical, means for continuously orienting said gyroscope to maintain one of its axes parallel with the normal gun trunnion axis, means operating about said last named axis for correcting the gun elevation, and means operating about the horizontal axis of the gyroscope perpendicular to said other axis for correcting the train of the gun.

38. The combination with a sight and a gun, of a trunnion tilt correction device comprising a member mounted for rotation about a vertical axis and for oscillation about mutually perpendicular horizontal axes, a transmitter operated by said sight, a repeater motor connected to said member to orient the same with the sight so as to maintain one of the aforesaid horizontal axes of support in line with the trunnion axis of the gun, a gyroscopic stabilizing means on said member, a pilot gun mounted for adjustment about horizontal axes on said member, automatic means for stabilizing the trunnion axis thereof from said stabilizing means, means for setting said pilot gun in elevation in accordance with the range angle, and a non-stabilized member mounted for free turning about a vertical axis on said first-named member and cooperating with said pilot gun whereby a train correction is imparted to said member on rolling of the ship, and means for transmitting said correction to the gun.

39. A system of gun fire control comprising a combination with a sighting device and a gun mounted on a common moving support and each adjustable in elevation and train planes, a coacting correction device and pilot gun mounted on said support, the former being adjustable in train and the latter adjustable in elevation and train, automatic means actuated from said sight for maintaining the vertical plane of the pilot gun parallel to the sighting device, means for giving said pilot gun an elevation adjustment, automatic stabilizing means for maintaining the pilot gun in the vertical plane passing through the line of sight regardless of the oscillatory motions of the support whereby a train correction is imparted to said correction device, and means for transmitting such correction to the gun.

40. An unstable platform, a sight rotatable on said platform about an axis perpendicular thereto, a support rotatable on said platform about another axis perpendicular thereto, a stabilizing pendulum rotatable on said support about mutually perpendicular axes, one of which is parallel to said platform, and means connecting the sight to said support to rotate the support in synchronism with the sight and maintain the pendulum with one of its said axes parallel to a vertical plane containing the line of sight of the sight.

41. A gun, a mount on which the gun is adjustable about a set of axes varying in angular position with variations in the angular position of said mount, and means, settable with reference to a fixed set of planes to control the adjustments of the gun about at least one of said axes, for automatically generating corrections in the movements of the gun about said axis in its various positions.

42. A gun, a mount therefor on which the gun is adjustable about elevation and train axes which vary in angular position with variations in the angular position of said mount, and means, settable with reference to a vertical and a horizontal plane to control the movements of the gun about said train axis, for automatically generating corrections in the movements of the gun about said axis in its various positions.

43. A gun, an angularly movable mount on which the gun is adjustable about a set of relatively fixed mutually perpendicular axes which vary in angular position with variations in the angular position of said mount, and means, adapted to have corrections applied thereto with reference to horizontal and vertical planes, for automatically generating, from said applied corrections, corrections in the movements of the gun about at least one of said axes, and for subsequently varying said generated corrections to compensate the movements of the gun about said last named axis for changes in the angular position of the axes due to angular movements of said mount.

44. A movable support, a sighting device and a gun, each rotatable on said support

about elevation and train axes, and means adapted to have corrections applied thereto with reference to vertical and horizontal planes and operated by and in accordance with the movements of said sighting device, for automatically generating corrections in the movements of the gun about said train axis and subsequently varying said generated corrections upon changes in the angular position of said axes due to movement of the support.

45. A movable support, a gun adjustable on said support about elevation and train axes varying in angular position with variations in the angular position of said support, and means, settable with reference to vertical and horizontal planes, to correct the movements of the gun about said train axis, and for automatically generating the set corrections in terms of movements of the gun about said axis in its various positions, and for subsequently varying said generated corrections in response to and in proportion to changes in the angular position of said axes due to movement of said support.

In testimony whereof I have affixed my signature.

MORTIMER F. BATES.