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2,410,638

SELECTIVE SYSTEM FOR GUNFIRE CONTROL

Filed April 27, 1937

4 Sheets-Sheet 1

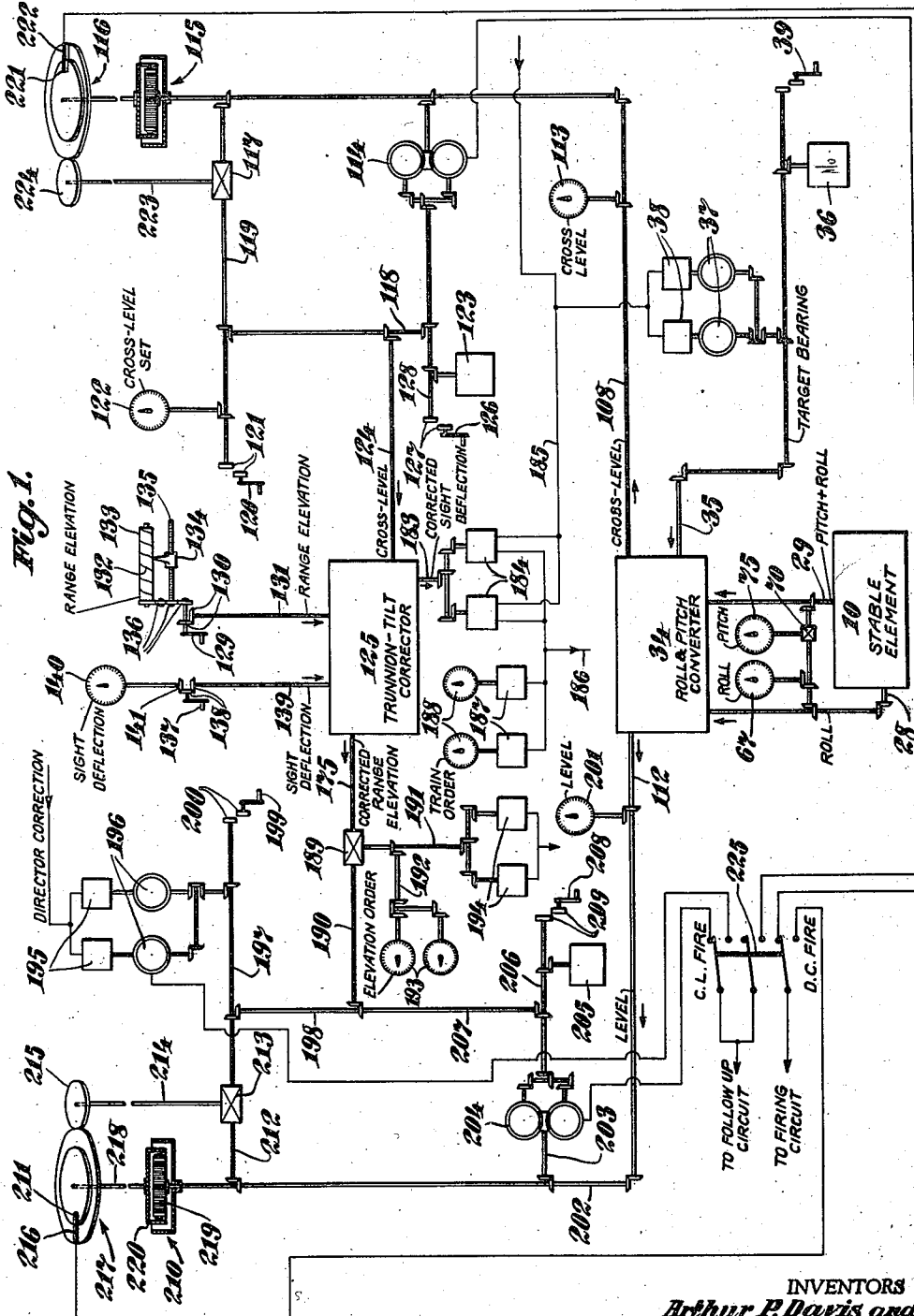


Fig. 1.

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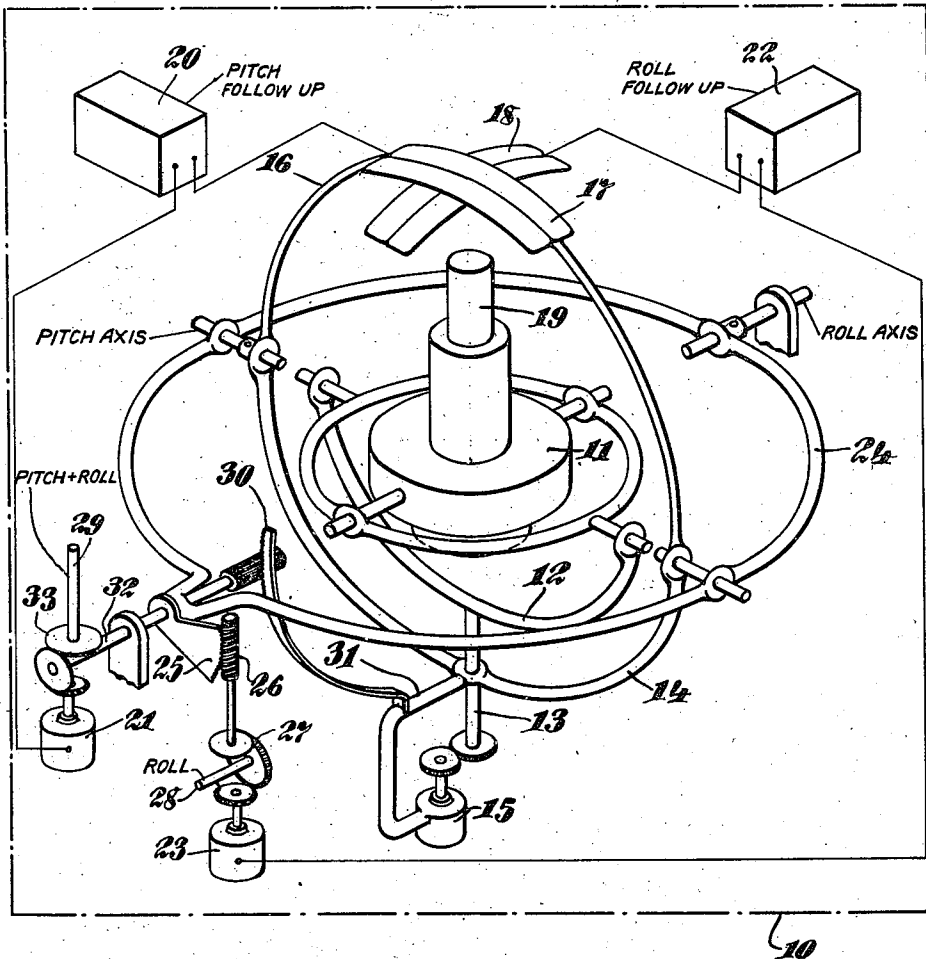
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4 Sheets-Sheet 2

Fig. 2



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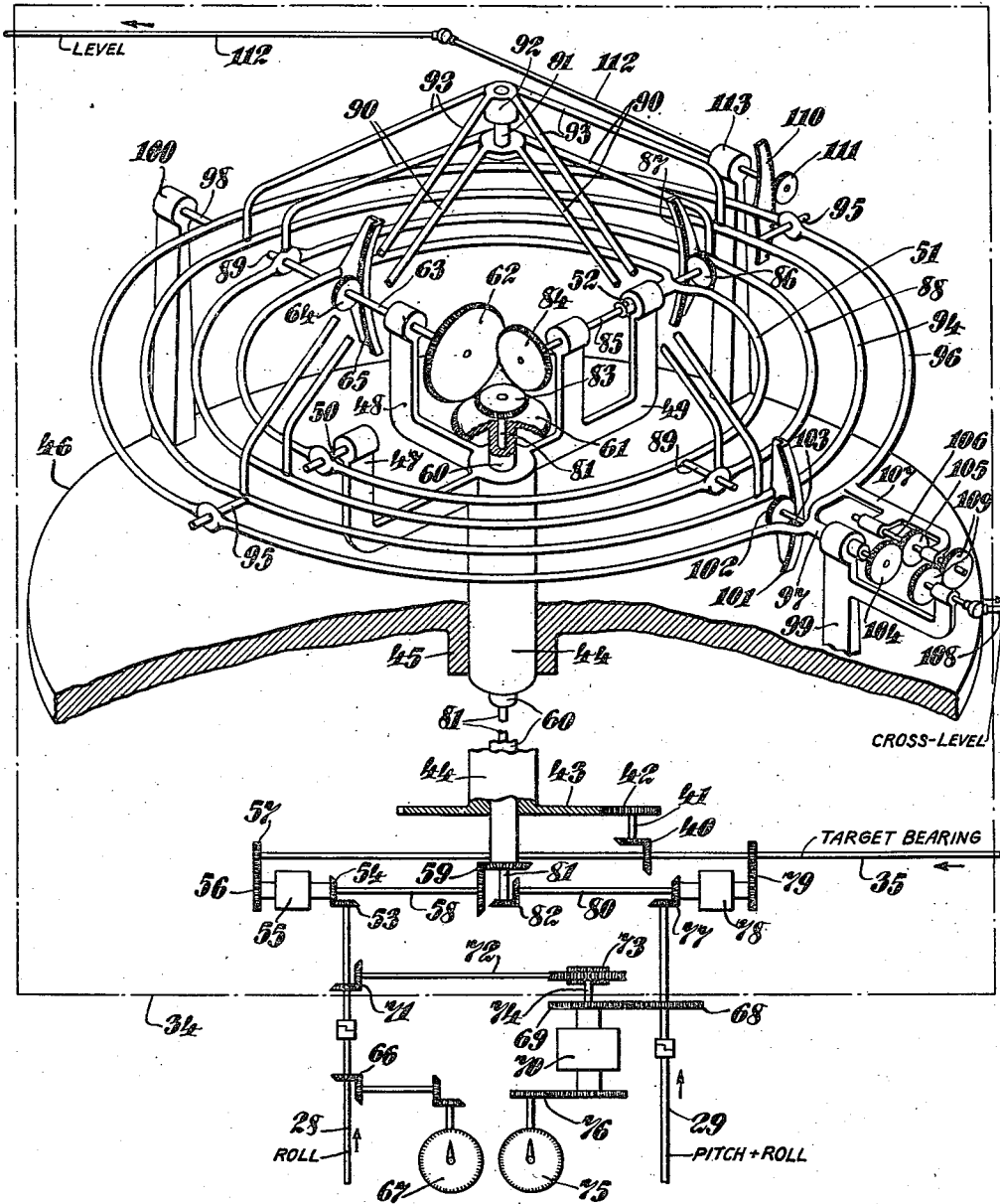
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4 Sheets-Sheet 3

Fig. 3



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UNITED STATES PATENT OFFICE

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SELECTIVE SYSTEM FOR GUNFIRE
CONTROL

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20 Claims. (Cl. 89—41)

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This invention relates to gun fire control systems and has particular reference to a system for controlling the firing of the main or other gun batteries on a ship at any selected point in the ship's motion in roll or pitch.

Range elevation and sight deflection are ordinarily computed with reference to a horizontal plane, so that the position of the guns is correct for firing only at the instant that the deck of the ship is in a true horizontal plane, i. e., at the midpoint of the roll or pitch. Accordingly, correction is required for so-called "trunnion-tilt," i. e., the displacement from the horizontal caused by the motion of the ship about the line of sight, or cross-level angle, and correction must also be made for motion of the ship in the plane of sight, or level angle. The roll and pitch angles, as measured by a stable element, such as a gyroscopic vertical, must be first converted into cross-level and level angles, as determined by relative target bearing.

In the system of the present invention, range elevation is automatically corrected for trunnion-tilt and combined with director correction or level angle to generate the gun elevation order, which indicates the corrected elevation at any instant so that the guns may be continuously corrected in elevation. The sight deflection is automatically corrected for trunnion-tilt and combined with relative target bearing to generate the gun train order, which indicates the correction at any instant so that the guns may be continuously corrected in train.

Also in accordance with the present invention, means are provided for introducing the angular correction to range elevation in order that the guns may be fired the maximum number of times in either level or cross-level, this correction being introduced either as "director correction" or "cross-level set." Furthermore, automatic means are provided whereby firing of the gun can be effected at the selected point in either level or cross-level with a high and consistent degree of accuracy, independently of the variable reaction rates of individual operators.

More particularly, the fire control system of this invention essentially comprises a stable element, preferably a gyroscopic vertical with associated means for measuring and transmitting the angle of roll and pitch of the ship, mechanical means for converting these angles into level and cross-level angles relative to the bearing of the target, mechanical means for correcting range elevation and sight deflection for trunnion-tilt in accordance with cross-level or cross-level set,

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a differential for combining the corrected range elevation with director correction or with level for gun elevation order, a differential for combining the corrected sight deflection with the relative target bearing for gun train order, automatic means for firing in accordance with these corrected and selected values, and switching means for selectively preparing the automatic firing means in accordance with firing procedure. For a more complete understanding of this invention, reference may be had to the accompanying drawings, in which:

Figure 1 is a schematic mechanical diagram of the selective gun fire control system of this invention;

Fig. 2 is a schematic illustration of the stable element and a portion of the electric follow-up of the system;

Fig. 3 illustrates partially in perspective and partially schematically, the roll and pitch converter; and

Fig. 4 illustrates, partially in perspective and partially schematically, the trunnion-tilt corrector.

Referring to Fig. 2 of the drawings, the stable element designated 10 in Fig. 1, preferably comprises a gyroscopic vertical, including the gyroscope 11, universally mounted on the gimbal support 12 having the normally vertical shaft 13 journaled in follow-up support 14 and constantly rotated by motor 15 carried by follow-up support 14. A bail 16 fixed on the support 14 extends over the gyroscope 11 and carries the respective pitch and roll follow-up coils 17 and 18, which are positioned to be inductively energized by the electro-magnet 19 mounted on the gyroscope 11 as the latter tilts relatively to the support 14.

The pitch follow-up coil 17 is part of the follow-up system 20 for energizing the motor 21 in response to relative movement of the gyroscope 11 to drive the support 14, by means of shaft 32 and toothed sector 30, which is secured to arm 31 of support 14 at right angles to the pitch axis, so that support 14 follows the movement of the ship in pitch and maintains the coil 17 in coincidence or alignment with the electro-magnet 19. Similarly, the roll follow-up coil 18 is part of the follow-up system 22 for energizing the motor 23 to drive the outer gimbal ring 24, by means of gears 27, worm 26, and toothed sector 25, which is secured to outer gimbal ring 24, so as to maintain coil 18 in alignment with the electro-magnet 19. Further details of the follow-up mechanism, which form no part of the present invention, are

illustrated and described in copending application Serial No. 53,736, filed December 10, 1935.

With the follow-up support 14 being stabilized in this manner, the degree of motion of the ship in pitch and roll is represented by the proportional movements of the follow-up systems 20 and 22. Accordingly, the angular motion in roll is measured and transmitted by roll output shaft 28. The angular motion in pitch is measured and transmitted, plus a function of the roll angle, to pitch and roll output shaft 29.

As is illustrated schematically in Fig. 1, the outputs of shafts 28 and 29 of stable element 10 are introduced into roll and pitch converter 34, to be described, which also receives relative target bearing through shaft 35 driven by motor 36 actuated by a conventional type of follow-up 37 driven by high and low speed self-synchronizing motors 38, which receive target bearing electrically from a suitable controlling director, not shown, and forming no part of the present invention. Hand crank 39 may be clutched to shaft 35 for manual follow-up, if desired. In the roll and pitch converter 34, illustrated in detail in Fig. 3, the target bearing shaft 35 is connected by bevel gears 40 to shaft 41 having pinion 42 driving gear 43 secured to the end of hollow shaft 44 journaled in hub 45 of main frame support 46 secured to the deck of the ship. The upper end of hollow shaft 44 is fitted with supporting arms 47, 48 and 49, which accordingly move with change in target bearing. Arm 47 carries one pivot 50 of roll ring 51, whose opposite pivot 52 is hollow and journaled in arm 49.

Roll angle shaft 28 is connected, in the roll and pitch converter 34, through bevel gear 53 to one gear 54 of the differential 55, the other gear 56 of which meshes with pinion 57 on relative target bearing shaft 35. Roll angle with relative target bearing thus added by differential 55 is transmitted by shaft 58 and bevel gears 59 to hollow shaft 60 journaled in shaft 44 and having at its upper end the gear 61 meshing with gear 62 fixed on shaft 63 journaled in arm 48 and having a pinion 64 meshing with rack 65 on roll ring 51. The addition of relative target bearing to roll angle by differential 55 is to prevent displacement of roll ring 51 by relative rotation of gear 62 when target bearing input shaft 44 is trained through relative target bearing. Gearing 66 transmits roll angle to indicating dial 67.

The pitch and roll shaft 29 is connected by gear 68 to gear 69 of differential 70, which also receives roll from shaft 28 through gears 71, shaft 72, worm gears 73 and shaft 74. The differential 70 subtracts the roll factor so that pitch angle is directly indicated by pitch dial 75 driven by differential 70 through gears 76.

Pitch and roll shaft 29 is connected by gears 77 to one side of differential 78, the other side of which is connected by gears 79 to relative target bearing shaft 35. Relative target bearing is thus added to pitch and roll angle by differential 78, whose output shaft 80 drives pitch input shaft 81 through gears 82. Pitch input shaft 81 is journaled in roll input shaft 60 and its upper end carries gear 83 driving gear 84 on shaft 85 journaled in arm 49 and hollow pivot 52 of roll ring 51. The shaft 85 carries the pinion 86 meshing with rack 87 on pitch ring 88, which is pivotally mounted in spaced relation to roll ring 51 on pivots 89 located 90° from pivots 50 and 52. Relative target bearing is added in this way by differential 78 to prevent displacement of pitch

ring 88 by relative rotation of gear 84 when target bearing input shaft 44 is trained through relative target bearing. Also, the factor of roll added to pitch by the stable element 10 prevents the motion of the roll ring 51 from affecting the position of the pitch ring 88 when pitch input shaft 81 is locked.

Integral with pitch ring 88 are four equally spaced arms 90 converging to a "conical" shaft 91 normally coaxial with pitch input shaft 81. Fitting over "conical" shaft 91 is a hollow shaft 92 centrally supported by four equally spaced arms 93 of cross level ring 94 positioned in spaced relation to pitch ring 88 and so supported by shafts 91 and 92 as to follow the motion of pitch ring 88. Cross level ring 94 is provided with pivot pins 95, spaced 180° apart, in which the outer or level ring 96 is pivoted, in spaced relation to cross level ring 94. Level ring 96 is in turn provided with hollow pivot 97 and opposite pivot pin 98 spaced 90° from pivots 95 and journaled in respective brackets 99 and 100 of main support frame 46.

The cross level ring 94 carries rack 101 engaging pinion 102 mounted on shaft 103 journaled in hollow pivot 97 of outer or level ring 96 and having the gear 104 at its outer end which meshes with pinion 105 on counter-shaft 106 journaled in bracket 107 of outer or level ring 96. This counter-shaft 106 is provided in order that relative motion between rings 94 and 96 is not imparted to cross-level output shaft 108 journaled in bracket 99 colinearly with shaft 103 and driven by the counter-shaft 106 by gears 109. Thus, shaft 108 mechanically transmits cross-level angle converted from roll, pitch and relative target bearing.

The outer or level ring 96 carries rack 110, spaced 90° from pivots 97 and 98, which meshes with pinion 111 mounted on level output shaft 112 journaled in a bracket 113 mounted on main frame 46. Thus shaft 112 mechanically transmits level angle, converted from roll, pitch and relative target bearing.

It will be seen that the roll and pitch converter 34 comprises two sets of mountings which are free to rotate with respect to each other about a common vertical axis. Each set, level and cross level, roll and pitch, comprises two rings each, 96 and 94, 51 and 88, respectively, pivoted at right angles to each other. One ring of each set 96 (level) and 51 (roll) is pivoted about an axis fixed with respect to the deck while the second ring of each set 94 (cross-level) and 88 (pitch) is mounted on the corresponding first ring 96 (level) and 51 (roll), respectively, so that it can be maintained in a horizontal plane. The outer set of rings 96 (level) and 94 (cross-level) is rotatably mounted with respect to the main frame 46 and the deck of the ship, whereas the inner set of rings 51 (roll) and 88 (pitch) is rotated, i. e. trained through relative target bearing, by means of support arms 47, 48 and 49 when shaft 44 carrying them is trained through relative target bearing by target bearing shaft 35.

Actually the roll and pitch axes are fixed with respect to the deck and the level and cross-level axes are trained. However, in order to simplify construction, the level and cross-level axes are made fixed and the roll and pitch axes are rotated through relative target bearing, but in the opposite direction to maintain the relative position of the two sets of axes.

As is illustrated in Fig. 1, cross-level angle is mechanically transmitted by shaft 108 to dial

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113, calibrated to indicate generated cross-level angle; also to a conventional form of follow-up 114, such as the contact type; also to firing delay compensator 115, to be described, and thus to automatic firing contacts 116 thereof; and also to mechanical differential 117. The other side of differential 117 also receives cross-level angle, either from follow-up 114 through shafts 118 and 119, or "cross-level set" introduced manually by hand-crank 120 clutched by gears 121 to shaft 119. Dial 122 is geared to hand crank 120 and indicates cross-level set. Follow-up 114 through its follow-up motor 123 and shafts 118 and 124 transmits cross-level angle to trunnion-tilt corrector 125. Cross-level set from hand crank 120 may also be used to introduce cross-level angle to the trunnion-tilt corrector 125 through shafts 118 and 124. Hand crank 126, gears 127, and shaft 128 are provided for manual follow-up.

Range elevation is introduced into trunnion-tilt corrector 125 by hand-crank 129, gears 130 and shaft 131 and is indicated on helical scale 132 of range drum 133 by index pointer 134 threaded on lead screw 135 driven by gears 136, which also drive range drum 133, as crank handle 129 is turned.

Sight deflection is introduced into trunnion-tilt corrector 125 by hand-crank 137, gears 138 and shaft 139, and is indicated on dial 140 driven by gear 141 connected to one of the gears 138.

The trunnion-tilt corrector 125, illustrated in detail in Fig. 4, corrects the range elevation input from shaft 131 and the sight deflection input from shaft 139 in terms of cross-level received from shaft 124, by mechanically solving the following equations:

$$A_c = 18/17 E \sin CL + d \cos CL$$

$$E_c = E \cos CL - d \sin CL$$

Where A_c =corrected sight deflection, E_c =corrected range elevation, E =range elevation, positive-up; d =deflection, positive-to right, CL =cross level, positive-down at left, the directions be considered positive when looking toward the target.

Referring to Fig. 4, in the trunnion-tilt corrector 125, the range elevation input shaft 131 is connected by universal joint 142 to one end of shaft 143 connected at its other end by gears 144 to a parallel threaded shaft 145 mounted on toothed disc 146, which is rotated through cross-level angle by meshing worm 147 on cross-level input shaft 124, and whose axis of rotation is the axis $X-X$, which coincides with the center of the universal joint 142. A nut 148 threaded on shaft 145 moves along shaft 145 as range input shaft 131 rotates it. The position of the nut 148 vertically below axis $X-X$, in the plane of the drawings, is proportional to $E \cos CL$, while the position of nut horizontally from axis $Y-Y$ is proportional to $E \sin CL$. Axis $Y-Y$ is the line of travel of nut 148 for zero cross-level and is a vertical axis intersecting axis $X-X$ in a point corresponding to zero range elevation.

The sight deflection input shaft 139 is connected by a second universal joint 149, positioned on the rear side of disc 146 and coinciding with axis $X-X$, to one end of shaft 150, the other end of which is connected by gears 151 to threaded shaft 152 mounted on the rear surface of disc 146. A nut 153 moves along shaft 152 when the latter is rotated by sight deflection input shaft 139, and the position of nut 153 along shaft 152 vertically with respect to axis $X-X$ is proportional to $d \cos CL$. The position of nut 153

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along shaft 152 horizontally from axis $Y-Y$ is proportional to $d \sin CL$. Axis $Z-Z$ is the line of travel of nut 153 for zero cross-level and is a vertical axis intersecting axis $X-X$ in a point corresponding to zero sight deflection.

A lateral pin 154 on nut 148 fits slidably into a horizontal slot 155 of slide 156, which is constrained by rollers 157 to move in a vertical direction as the vertical component of movement of nut 148. Pin 154 on nut 148 also fits slidably into a vertical slot 158 of slide 159, which is constrained by rollers 160 to movement in a horizontal direction as the horizontal component of movement of nut 148.

Similarly, a lateral pin 161 on nut 153 fits slidably into a horizontal slot 162 of slide 163, which is constrained by rollers 164 to move in a vertical direction as nut 153 moves along shaft 152. Pin 161 also fits into vertical slot 165 of slide 166, which is constrained by rollers 167 to move in a horizontal direction as nut 153 moves along shaft 152.

The vertical displacement of slide 156 proportional to $E \cos CL$ is transmitted by rack 168 and meshing pinion 169 to one side of corrected range elevation (E_c) differential 170, the other side of which is connected by pinion 171 to rack 172 of horizontal slide 166 and receives an input therefrom proportional to $d \sin CL$. The resultant output of differential 170 is the sum of these two inputs and is equal to $E \cos CL - d \sin CL$, which is the corrected range elevation, E_c . The output gear 173 of differential 170 is connected by gear 174 to corrected range elevation or E_c output shaft 175.

The horizontal displacement of slide 159 proportional to $E \sin CL$ is transmitted by rack 176 and meshing pinion 177 to one side of corrected sight deflection (A_c) differential 178, the other side of which is connected by pinion 179 to rack 180 of vertical slide 163 and receives an input therefrom proportional to $d \cos CL$. The resultant output of differential 178 is the addition of these two inputs and is equal to

$$18/17 E \sin CL + d \cos CL$$

which is the corrected sight deflection, A_c . The output gear 181 of differential 178 is connected by gear 182 to corrected sight deflection or A_c output shaft 183. The empirical factor 18/17 is introduced by selecting pinion 177 to give the desired ratio between $E \sin CL$ input from rack 176 and the speed of differential output gear 182.

Referring to Fig. 1, the corrected sight deflection (A_c) output shaft 183 from the trunnion-tilt corrector 125 is geared to the rotors of high and low speed differential transmitters 184, preferably of the self-synchronizing type, the stators of which through connections 185 electrically receive relative target bearing from the controlling director, not shown. The resultant electrical output, which is gun train order O_t , is transmitted by connections 186 to any desired remote firing point, and is also transmitted to high and low speed electrical receiver motors 187, preferably of the self-synchronizing type, which drive indicating dials 188.

The corrected range elevation (E_c) output shaft 175 from trunnion-tilt corrector 125 is connected to one side of mechanical differential 189, to the other side of which is connected shaft 190 introducing director correction or level, from sources to be described. The resultant output of differential 189, which is gun elevation order, O_e , is transmitted by respective shafts 191 and 192 and

suitable gearing to high and low speed indicating dials 193 and to the rotors of high and low speed electrical transmitters 194, preferably of the self-synchronous type, from which the elevation order (O_e) may be transmitted to any desired firing point.

The aforementioned director correction applied to differential 189, is received electrically from the controlling director, not shown, by high and low speed receiver motors 195, preferably of the self-synchronizing type, and transmitted mechanically to the contact follow-up 196, which transmits it by shafts 197, 198 and suitable gearing to the input shaft 190 of the differential 189. Hand-crank 199 and gears 200 are provided on shaft 197 for manual follow-up.

The aforementioned alternative level input to differential 189 is received from level output shaft 112 of roll and pitch converter 34. Shaft 112 is connected to level indicating dial 201, and to shaft 202, which is connected by shaft 203 and suitable gearing to level follow-up 204, which is preferably of the contact type similar to cross-level follow-up 114. The follow-up motor 205 of follow-up 204 is connected by shafts 206 and 207 to input shaft 190 of differential 189. Hand-crank 208 and gears 209 are connected to shaft 206 for manual follow-up.

Level is also transmitted from roll and pitch converter 34 by shafts 112 and 202 to firing delay compensator 210, to be described, for actuating inner firing contact 211. Level is also transmitted by shaft 212, geared to shaft 202, to one side of mechanical differential 213, the other side of which is locked, because when cross-level fire is in use, director correction follow-up 196 is inoperative, as will be explained. Thus shaft 214 is driven by differential 213 through the level angle and, through its gear 215, drives the outer firing contact 216 of automatic firing device 217. Where director fire is employed, differential 213 adds the input from level shafts 202 and 212 and from director correction shaft 197 and the output shaft 214 and outer firing contact 216 are driven accordingly.

The firing delay compensators 115 and 210 automatically compensate for the time delay between the closing of the firing switch and the passage of the projectile out of the gun, so that the gun is actually fired ahead of the usual firing time. In the form shown, the compensator 210 essentially comprises a drag coupling interposed between the ends of aligned shafts 202 and 218 leading to inner firing contact 211, the former carrying electro-magnet 219 and the latter carrying a copper ring 220. As the electro-magnet 219 is rotated by level shaft 202, eddy currents induced in copper ring 220 cause it to follow the magnet 219, so that the inner firing contact 211 is displaced by an amount depending upon the speed of rotation of the magnet 219, which speed is a function of the roll or pitch of the ship, so that outer firing contact 216 engages inner contact 211 at an earlier time. Copending application Serial No. 98,877, filed September 1, 1936, discloses further details of construction of the firing delay compensators 115 and 210.

The electric follow-up and firing circuits are selected by a master selector switch 225 (Fig. 1), having two positions marked "Director correction fire" and "Cross-level fire." When this master switch is in position for director correction fire of the guns, cross-level follow-up 114 and director correction follow-up 196 are energized, whereas level follow-up 204 is deenergized.

Then the firing circuits to the guns are automatically completed at the proper time through the firing contacts 211 and 216 of the director correction firing device 217.

When the master selector switch is in "Cross-level fire" position, only level follow-up 204 is energized, whereas cross-level follow-up 114 and director correction follow-up 196 are deenergized, and the firing circuits to the guns are automatically completed at the proper time through the firing contacts 221 and 222 of the cross-level firing device 116, the inner contact 221 of which is driven by firing delay compensator 115, and the outer contact 222 of which is driven by the differential 117 through shaft 223 and gear 224.

The single follow-up motor 205, employed for both follow-ups 204 and 196 remains energized for both positions of the master switch, as in one position thereof follow-up 196 is energized, while in the other position, follow-up 204 is energized. Where manual follow-ups 39, 126, or 208 are employed, cut-out switches are provided for the follow-up motors which they substitute, namely, 36, 123 and 205, respectively.

Director correction fire is used when the motion of the ship is in the plane of sight, or when level angle, as indicated on generated level dial 201, is greater than cross-level angle, as indicated on generated cross-level dial 113. Cross-level fire is selected when the motion of the ship is across the plane of sight, or when cross-level angle, as indicated on generated cross-level dial 113, is greater than level angle, as indicated on generated level dial 201.

In operation of the selective gun fire control system of this invention, with director correction fire selected, the roll and pitch converter 34 receives roll and pitch plus roll angles mechanically from stable element 10 by means of respective shafts 28 and 29, and also receives relative target bearing by means of shaft 35, from follow-up 37, the motors 38 of which receive it electrically from the controlling director. These inputs are combined in the roll and pitch converter in the manner described into level and cross-level angles, which are transmitted by means of respective output shafts 112 and 108.

Cross-level angle is transmitted from shaft 108 through follow-up 114, follow-up motor 123 and shafts 118 and 124 into trunnion-tilt corrector 125, where it is combined with range elevation, introduced by hand-crank 129, gears 130 and shaft 131, and with sight deflection, introduced by hand-crank 137, gears 138 and shaft 139 to give corrected elevation (E_c) output by shaft 175 and corrected sight deflection (A_c) output by shaft 183.

Corrected elevation (E_c) is combined in mechanical differential 189 with the director correction from shaft 190 to give the gun elevation order (O_e) which is transmitted to indicating dials 193 located at the instrument, and also to electrical transmitter 194, from which it is electrically transmitted to suitable receiving motors with dials or conventional automatic follow-up mechanism, not shown, located at the battery, so that the position of the guns in elevation may be continuously corrected in accordance with the gun elevation order (O_e).

Corrected sight deflection (A_c) is combined in electrical differential transmitters 184 with relative target bearing received electrically through connections 185 from the controlling director to give gun train order (O_t), which is transmitted electrically to receiver motors 187 operating in-

dicating dials 188 located at the instrument, and also to receiving motors with indicating dials or automatic follow-up mechanism, not shown, located at the battery, so that the position of the guns in train may be continuously corrected in accordance with gun train order (O_t).

The roll and pitch converter 34 transmits level to dial 201, to firing delay compensator 210, and to mechanical differential 213, where it is combined with the director correction angle from follow-up 196 and shaft 197, its output shaft 214 being connected to gear 215 driving outer contact 216 of automatic firing device 217. Thus, outer firing contact 216 is made to move in synchronism with the motion of the ship in level, corrected for director correction, that is, with inner firing contact 211 locked on zero, the contacts 211 and 216 will engage, thus closing the gun firing circuit at the instant the ship is in a position corresponding to the director correction input. The inner contact 211 is carried by one member 220 of firing delay compensator 210, which causes the inner contact 211 to be advanced an amount proportional to the firing delay and varied automatically with the speed of the ship in level motion. Thus the battery is fired automatically when contacts 211 and 216 engage, in accordance with generated level, director correction and firing delay compensation.

The roll and pitch converter 34 transmits the cross-level angle by means of shaft 108 to dial 113, to firing delay compensator 115, to one member of mechanical differential 117, and to follow-up 114. Through the latter and corresponding follow-up motor 123, the second input member of differential 117 receives cross-level angle, so the resultant output of differential 117 is zero. Therefore, outer contact 222 of automatic firing device 116, driven by gear 224 on differential output shaft 223, remains stationary. Firing contacts 221 and 222 were cut out of the firing circuit by the master selector switch when director correction fire was selected.

With the master selector switch set in "Cross level fire" position, operation of, and inputs to, the roll and pitch converter 34 are the same as for director correction fire. Roll and pitch converter 34 thus transmits level angle to dial 201, to firing delay compensator 210, to one side of differential 213, and to follow-up 204, which in turn transmits level to the other side of differential 213, so that its resultant output to shaft 214 and gear 215 is zero. Outer contact 216 of automatic firing device 217 accordingly remains stationary. Firing contacts 211 and 216 of automatic firing device 217 were cut out of the firing circuit by the master selector switch when cross-level fire was selected.

Follow-up 204 also transmits level angle to one side of differential 189 which combines it with the corrected range elevation (E_c) received through shaft 175 from trunnion-tilt corrector 125, to give resultant gun elevation order (O_e), which is transmitted mechanically to dials 193 located at the instrument, and also is transmitted electrically by transmitters 194 to receiving motors with dials or automatic follow-up mechanism, not shown, located at the battery, so the position of the guns in elevation may be continuously corrected in accordance with the elevation order (O_e).

As before, the roll and pitch converter 34 transmits cross-level angle to dial 113, to firing delay compensator 115, and to one side of mechanical differential 117, the output shaft 223 of which

drives through gear 224 outer contact 222 of automatic firing device 116. The other side of differential 117 receives a selected value of cross-level as set in by hand crank 120 and indicated on cross-level set dial 122. This cross-level set is similar to setting of director correction and is made by observing the concentric dials of the firing contacts 221 and 222 of firing device 116 to ascertain the maximum number of opportunities to fire the gun battery. Outer contact 222 thus moves in synchronism with motion of the ship in cross-level, corrected for the selected cross level set at which the battery is to be fired. Inner contact 221 is carried by firing delay compensator 115, so that inner contact 221 is advanced by an angle which is proportional to the firing delay and which is automatically varied in accordance with the speed of the ship in cross-level motion. For automatic fire, the battery is fired when contacts 221 and 222 engage.

Cross-level set from hand crank 120 is transmitted by shafts 118 and 124 to the trunnion-tilt corrector 125. Follow-up motor 123 is not energized during cross-level firing so that follow-up 114 is inoperative.

The corrected sight deflection (A_c) from shaft 183 is combined, as in the case of director correction fire, with relative target bearing in electrical differentials 184 and is electrically transmitted to dials 188 at the instrument, and also to receiving motors with dials or automatic follow-up mechanism, not shown, located at the battery, so the position of guns in train may be continuously corrected in accordance with the gun train order (O_t).

It will be seen that a highly flexible selective system of gun fire control is provided by this invention, whereby the main battery or other guns may be automatically fired with a high and consistent degree of accuracy at any selected position, irrespective of the ship's motion in roll and pitch.

While a preferred embodiment of the invention is illustrated and described herein, it is to be understood that the invention is not limited thereby, but is susceptible of changes in form and detail within the scope of the appended claims.

We claim:

1. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship, means actuated in accordance with target bearing, mechanism jointly actuated by said two means for converting said angle into level angle, means responsive to the "trunnion-tilt" displacement of the ship from the horizontal about the line of sight to the target, mechanism actuated in accordance with range elevation, operative connections between said trunnion-tilt means and said range elevation mechanism for modifying the movement of the latter, means for combining the output of said two mechanisms, and means actuated by said last-named means for indicating corrected elevation.

2. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship, means actuated in accordance with target bearing, mechanism jointly actuated by said two means for converting said angle into cross-level angle, means actuated by said mechanism for determining "trunnion-tilt" displacement of the ship from the horizontal about the line of sight to the target, means actuated in accordance with sight deflection, operative connections be-

tween said trunnion-tilt means and said sight deflection means for modifying the movement of the latter, and means actuated by said last-named means for indicating corrected train.

3. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship, means actuated in accordance with target bearing, mechanism jointly actuated by said two means for converting said angle into cross-level angle, means actuated by said mechanism for determining "trunnion-tilt" displacement of the ship from the horizontal about the line of sight to the target, means actuated in accordance with range elevation, operative connections between said trunnion-tilt means and said range elevation means for modifying the output of the latter, means actuated in accordance with "director correction," means for combining the outputs of said range elevation means and said director correction means, and means actuated by said last-named means for indicating corrected elevation.

4. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship, means actuated in accordance with target bearing, mechanism jointly actuated by said two means for converting said angle into cross-level angle, means actuated by said mechanism for determining "trunnion-tilt" displacement of the ship from the horizontal about the line of sight to the target, means actuated in accordance with range elevation, operative connections between said trunnion-tilt means and said range elevation means for modifying the output of the latter, means for modifying the output of said range elevation means in accordance with a predetermined angular correction, and means actuated by the output of said range elevation means for indicating corrected elevation.

5. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship, means actuated in accordance with target bearing, mechanism jointly actuated by said two means for converting said angle into level and cross-level angles, means actuated by said mechanism for determining "trunnion-tilt" displacement of the ship from the horizontal about the line of sight to the target, means actuated in accordance with sight deflection, operative connection between said trunnion-tilt means and said sight deflection means for modifying the output of the latter, means for combining the output of the last-named means with the output of said target bearing means, and means actuated by said last-named means for indicating corrected sight deflection.

6. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship, means actuated in accordance with target bearing, mechanism jointly actuated by said two means for converting said angle into level and cross-level angles, means actuated by said mechanism for determining "trunnion-tilt" displacement of the ship from the horizontal about the line of sight to the target, means actuated in accordance with sight deflection, operative connections between said trunnion-tilt means and said sight deflection means for modifying the output of the latter, means for combining the output of the last-named means with the output of said target bearing means, means actuated

in accordance with range elevation, operative connections between said trunnion-tilt means and said range elevation means for modifying the output of the latter, means for modifying the output of said range elevation means in accordance with a predetermined angular correction, means actuated by the output of said range elevation means for indicating corrected elevation, and means actuated by said combining means for indicating corrected sight deflection.

7. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship, means actuated in accordance with target bearing, mechanism jointly actuated by said two means for converting said angle into cross-level angle, electrical contacts for firing the gun upon engagement, and means actuated by said mechanism for effecting engagement of said contacts.

8. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship, means actuated in accordance with target bearing, mechanism jointly actuated by said two means for converting said angle into level angle, electrical contacts for firing the gun upon engagement, means actuated by said mechanism for effecting engagement of said contacts, and means for modifying the actuation of said last-named means in accordance with "director correction."

9. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship, means actuated in accordance with target bearing, mechanism jointly actuated by said two means for converting said angle into level angle, electrical contacts for firing the gun upon engagement, means actuated by said mechanism for effecting engagement of said contacts, and means for modifying the actuation of said last-named means in accordance with a predetermined angular correction.

10. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship, means actuated in accordance with target bearing, mechanism jointly actuated by said two means for converting said angle into cross-level angle, electrical contacts for firing the gun upon engagement, means actuated by said mechanism for effecting engagement of said contacts, and manual means for modifying the actuation of said last-named means in accordance with "cross-level set."

11. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship, means actuated in accordance with target bearing, mechanism jointly actuated by said two means for converting said angle into level angle, mechanism jointly actuated by said two means for converting said ship angle into cross-level angle, two sets of electrical contacts for alternatively firing said gun upon engagement, operative connections between one set of said firing contacts and said level angle mechanism, operative connections between said other set of contacts and said cross-level mechanism, and selective means controlling said connections for rendering either of said contacts operative to fire the gun.

12. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship,

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means actuated in accordance with target bearing, mechanism jointly actuated by said two means for converting said angle into level angle, mechanism jointly actuated by said two means for converting said ship angle into cross-level angle, two sets of electrical contacts for alternatively firing said gun upon engagement, operative connections between one set of said firing contacts and said level angle mechanism, operative connections between said other set of contacts and said cross-level mechanism, selective means controlling said connections for rendering either of said contacts operative to fire the gun, and means for modifying the level connections to said corresponding contacts in accordance with "director correction."

13. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship, means actuated in accordance with target bearing, mechanism jointly actuated by said two means for converting said angle into level angle, mechanism jointly actuated by said two means for converting said ship angle into cross-level angle, two sets of electrical contacts for alternatively firing said gun upon engagement, operative connections between one set of said firing contacts and said level angle mechanism, operative connections between said other set of contacts and said cross-level mechanism, selective means controlling said connections for rendering either of said contacts operative to fire the gun, and means for modifying the cross-level connections to said corresponding contacts in accordance with a predetermined angular correction.

14. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship, means actuated in accordance with target bearing, mechanism jointly actuated by said two means for converting said angle into level angle, mechanism jointly actuated by said two means for converting said ship angle into cross-level angle, two sets of electrical contacts for alternatively firing said gun upon engagement, operative connections between one set of said firing contacts and said level angle mechanism, operative connections between said other set of contacts and said cross-level mechanism, selective means controlling said connections for rendering either of said contacts operative to fire the gun, and means for modifying the level connections to said corresponding contacts in accordance with a predetermined angular correction.

15. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship, means actuated in accordance with target bearing, mechanism jointly actuated by said two means for converting said ship angle into cross-level angle, means actuated in accordance with range elevation, means jointly actuated by said mechanism and range elevation means in accordance with the hereinbefore defined factor

$$E \cos CL - d \sin CL$$

and means for indicating the output of said last means as corrected range elevation.

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16. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship, means actuated in accordance with target bearing, mechanism jointly actuated by said two means for converting said ship angle into cross-level angle, means actuated in accordance with sight deflection, means jointly actuated by said mechanism and sight deflection means in accordance with the hereinbefore-defined factor

$$E \sin CL + d \cos CL$$

and means for indicating the output of said last-named means as corrected sight deflection.

17. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship, means for indicating said angle of unstable movement, means actuated in accordance with target bearing, mechanism jointly actuated by said stable means and said target bearing actuated means for converting said angle of unstable movement into level angle, and means actuated by said mechanism for indicating the said level angle existing simultaneously with the said indicated unstable movement angle.

18. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship, means for indicating said angle of unstable movement, means actuated in accordance with target bearing, mechanism jointly actuated by said stable means and said target bearing actuated means for converting said angle of unstable movement into cross-level angle, and means actuated by said mechanism for indicating the said cross-level angle existing simultaneously with the said unstable movement angle.

19. In a system for controlling ship gun fire, the combination of stable means for determining the angles of pitch and roll of the ship, means for indicating said angles of pitch and roll, means actuated in accordance with target bearing, mechanism jointly actuated by said stable means and said target bearing actuated means for converting said angles of pitch and roll into level and cross-level angles, and means actuated by said mechanism for indicating the said level and cross-level angles existing simultaneously with the said angles of pitch and roll.

20. In a system for controlling ship gun fire, the combination of stable means for determining the angle of unstable movement of the ship, means for indicating said angle of unstable movement, means actuated in accordance with target bearing, mechanism jointly actuated by said stable means and said target bearing actuated means for converting said angle of unstable movement into level angle, means actuated by said mechanism for indicating the said level angle existing simultaneously with the said indicated unstable movement angle, electrical contacts for firing the gun upon engagement, and means actuated by said mechanism for effecting engagement of said contacts.

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