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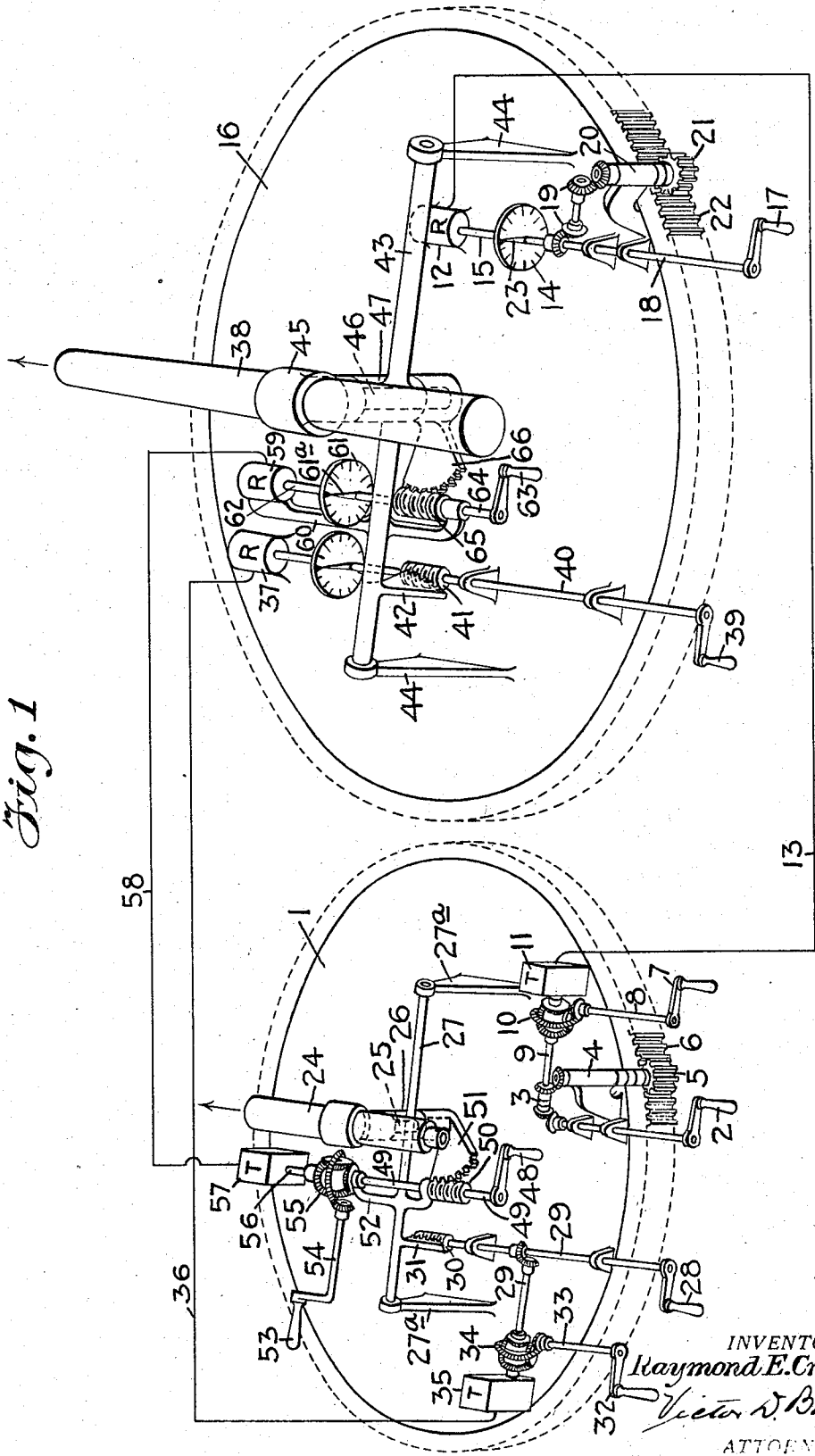
R. E. CROOKE

2,339,461

FIRE CONTROL SYSTEM

Filed May 15, 1940

3 Sheets-Sheet 1



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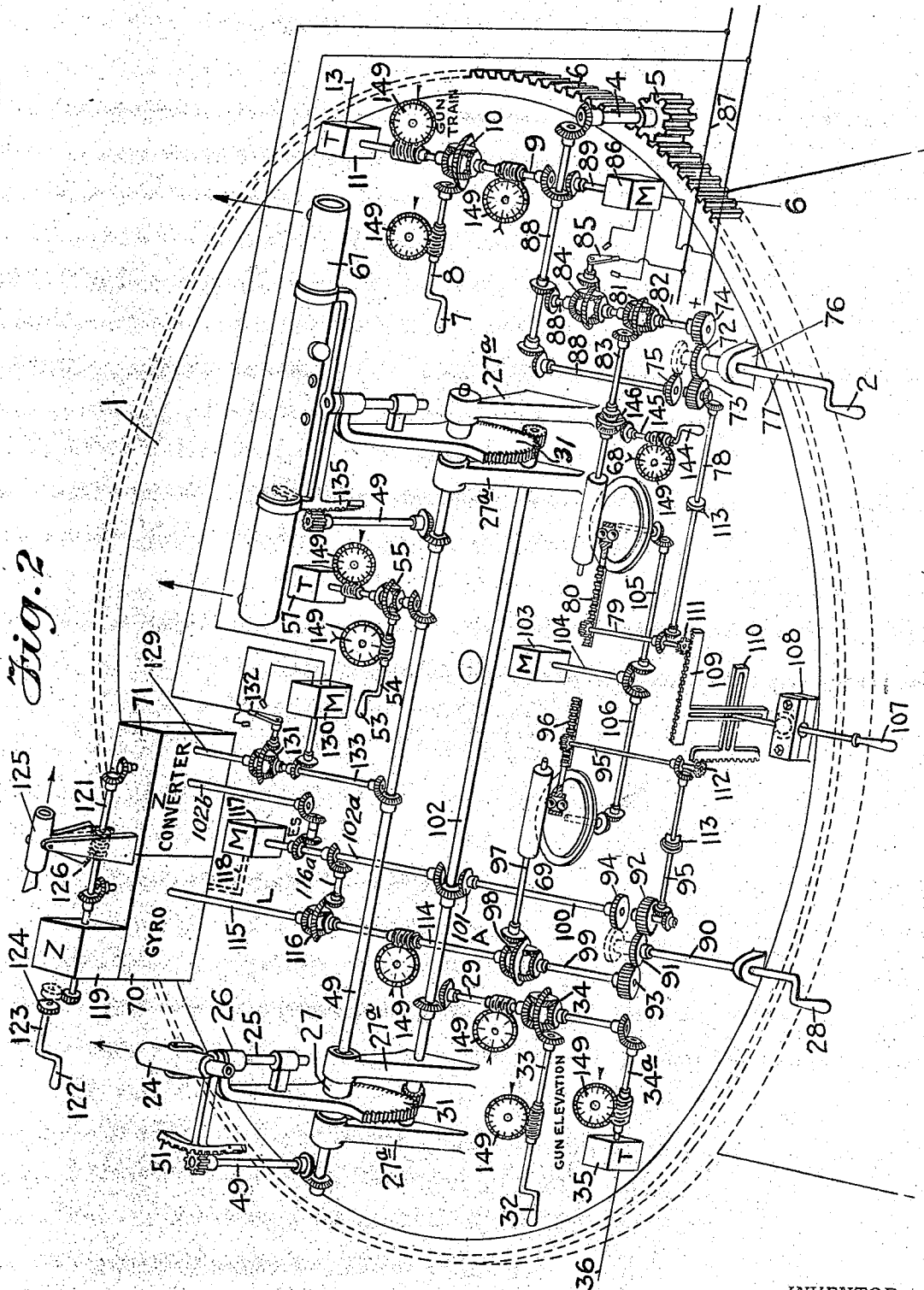
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3 Sheets-Sheet 2



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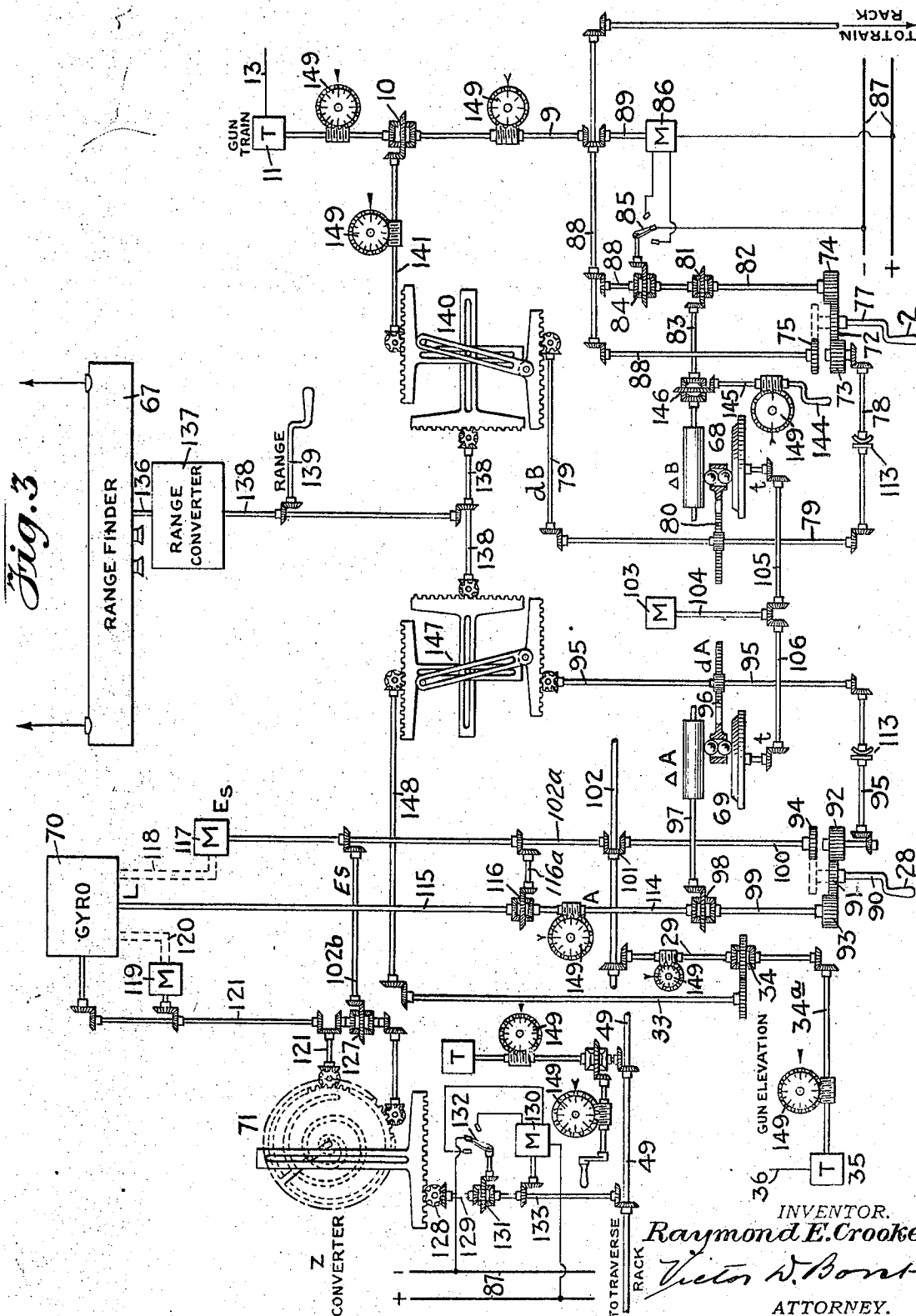
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UNITED STATES PATENT OFFICE

2,339,461

FIRE CONTROL SYSTEM

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3 Claims. (Cl. 89-41)

This invention relates to a fire control system and more particularly to a fire control system for a gun mounted for universal movement including traverse, that is, about an axis at right angles to the plane of elevation.

The principal object of the invention is to provide a director and a prediction computer particularly adapted to control the fire of universally mounted guns.

Another object of the invention is to provide a fire control system for a universally mounted gun that is mounted on a ship or a vehicle subject to rocking movements.

A further object of the invention is to provide a universally mounted sight on a ship or vehicle subjected to rocking movements, adapted, with other associated mechanisms, to control the fire of guns similarly mounted.

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

Fig. 1 is a perspective diagram of a director and gun mount of the invention in its simplest form;

Fig. 2 is a perspective diagram of the gun director in more detail and especially adapted to be used on an unstable platform; and

Fig. 3 is a schematic diagram of the arrangement shown in Fig. 2 and giving in detail the construction of the converter for determining the traverse correction.

The standard type of gun mounts developed for land and ship firing at surface targets and having only two axes of movement, viz., train and elevation, have been used at a disadvantage when firing at aerial targets and especially when these targets are at high angles of elevation. At these high angles of elevation it was impossible to follow a target as the training rate becomes excessively high when the target passes near the zenith.

To overcome these defects a third movement was provided as illustrated in the well known Scarff ring, which was mounted on a base movable in train and which carried a ball on which was mounted the gun. The gun was capable of movement in elevation and train relative to the ball.

Another form of so-called universal gun mount was devised and was disclosed in Henderson Patent No. 1,693,712 in which a third or cross level movement was provided between the train and elevation movements. However, the setting of the sights in this system was difficult

and complicated as the changes in the settings for train disturbed the setting for elevation and vice versa. It was also difficult to provide a remote sight or director control for mounts of this type.

There have been remote sights that were universally mounted, such as described in Willard Patent No. 1,936,442, but in that arrangement the transmissions to the gun were in terms of the conventional train and elevation, whereas the transmissions in the present invention are in terms of train, elevation and traverse, which is a change in the angular position about an axis at right angles to the plane of the sight.

In the form of gun mount and director shown herein a target may be followed at or near the zenith as readily as at any other elevation as it will be seen that a combination of elevation and traverse will permit the sight and the gun to follow a target in any direction across the zenith and thereby obviate the need for excessive train corrections at these high elevations. The inclusion of the traverse motion also makes it possible to readily move the sight and gun to compensate for rocking movement of the gun elevation trunnions, the angle which the said trunnions assume relative to the horizontal due to such movement being generally known as cross lever or trunnion tilt. With the standard form of gun mount the training correction necessary to correct for this trunnion tilt increases with the elevation and comes to exceed the amount of the trunnion tilt as the gun elevation becomes high. By making this correction as a movement in traverse, that is, a training movement in an inclined plane, substantially that of the line of sight, the correction never exceeds the amount of trunnion tilt and therefore no excessive rates of movement are introduced.

Referring particularly to Fig. 1 of the drawings, the director consists of a turntable 1 mounted on some solid part of the ship where a clear and unobstructed view of the target may be obtained. The table 1 is trained about its vertical axis by crank 2, gears 3, shaft 4 and gear 5 that meshes with teeth 6 of a ring gear surrounding the table. Corrections in train for offsetting the gun from the director may be made by turning hand crank 7 and shaft 8. Shaft 8 together with shaft 9, connected to gears 3, are connected to differential 10, the output of which is connected to transmitter 11. Transmitter 11 transmits to the gun receiver 12 the desired train angles or train orders by means of

cable 13. The values of train at the receiver is indicated by a dial 14 connected to shaft 15.

The gun mount is trained by crank 17 through shaft 18, gears 19, shaft 20 and gear 21, which meshes with teeth 22 of a ring gear surrounding the turntable 16. It is known that the table 16 is properly trained by matching the pointer 23 secured to shaft 18 with the dial 14.

The director sight 24 is moved in elevation by its being mounted on the shaft 25 which turns for traverse in bushing 26 which is rigidly secured to the trunnion 27 mounted in supports 27a. Trunnion 27 is rotated for elevating the sight about its axis by crank 28, shaft 29, worm 30, and toothed segment 31. Corrections for gun elevations relative to the sight are applied by crank 32 turning shaft 33, whose movement is combined with that of shaft 29 by differential 34, the output of which is connected to transmitter 35.

Orders in elevation are transmitted from transmitter 35 by cable 36 to receiver 37. The gun 38 is brought to the proper elevation by crank 39, shaft 40, worm 41 and toothed segment 42, which is secured to trunnion 43 mounted by supports 44 on the revolving table 16.

The gun 38 is mounted in a sleeve 45 which is connected to a shaft 46 turning in bushing 47. Bushing 47 is secured to trunnion 43.

Traverse movement is given to the director sight 24 by crank 48, shaft 49, worm 50, and toothed segment 51 keyed to shaft 25. Shaft 49 turns in bearings in bracket 52 secured to trunnion 27. Corrections in traverse are made by crank 53 turning shaft 54. The movements of shafts 49 and 54 are combined in differential 55 the output of which, shaft 56, is fed into traverse transmitter 57.

Orders in traverse are transmitted by transmitter 57 through cable 58 to receiver 59, which is mounted on a bracket 60 secured to the trunnion 43. The traverse orders are made visually available to the traverse operator at the gun by dial 61 connected to the output shaft 62 of the receiver 59.

The gun 38 is moved in traverse by crank 63, shaft 64, worm 65 and toothed segment 66 which is keyed to shaft 46. Shaft 64 is journaled in a bearing in bracket 60 and carries pointer 61a which cooperates with dial 61. It is by keeping pointer 61a matched with dial 61 that the gun is kept in the desired traverse position.

Fig. 2 shows a director in more detail than in Fig. 1 and includes numerous aids for the operators such as a mount for a range finder 67, variable speed devices 68 and 69 for driving the mount in train and elevation with controls for setting the rates of the variable speed devices, and automatic mechanism for moving the director sight 24 in traverse. This mechanism consists essentially of a level gyroscope 70 and a converter or cross level corrector 71 for determining the traverse value. A connection from the level value of the level gyroscope continuously modifies the elevation value for level.

Referring particularly to Fig. 2, the orders in train are generated, corrected, spot corrections applied, and transmitted to the gun by transmitter 11 and cable 13 as follows:

Train hand crank 2 is connected by gear 72 (1) to gear 73 only, (2) to gears 73 and 74 (as shown), (3) to gear 74 only, or (4) to gear 75 only, according to the axial position in bearing 76 of shaft 77 to which gear 72 is secured.

Gear 72 in its outer position (1) is in contact

with gear 73, which is connected to shaft 78 geared to shaft 79. Shaft 79 is connected to the control element 80 of variable speed device 68 or other train generator.

In the position shown in the drawings, gear 72 is in mesh with gears 73 and 74. The movement of shaft 77 applies corrections to the rate of train generation dB as previously described and at the same time, as disclosed in Ford Patent No. 1,468,712, applies corrections to the generated values B by gear 74 being connected to differential 81 by shaft 82. The other input of differential 81 is shaft 83, which is the output of train generator 68.

The output of differential 81 is connected to shaft 9 by the conventional follow-up consisting of differential 84, switch 85, motor 86 connected to a source of electrical power 87, and shafts 88 and 89.

When shaft 77 is moved inwardly so that gear 72 engages gear 74 only, the value of train is changed without changing the rate of generation of train and when gear 72 is moved to the position indicated by dotted lines, it meshes with gear 75 only and direct manual control is had through shaft 88, shaft 4, gear 5, and teeth 6.

As described in connection with Fig. 1, shaft 9 is connected to transmitter 11 through differential 10, the other input of which is shaft 8 by which deflection spots in train may be added in the conventional manner.

For the generation of elevation values, shaft 90, to which crank 28 is attached at one end, has connected to its other end the gear 91 which is adapted to be shifted to any one of four positions: (1) to mesh with gear 92 only, (2) to mesh with gears 92 and 93, (3) to mesh with gear 93 only, or (4) to mesh with gear 94 only. In the first position gear 91 drives gear 92 and shaft 95 which is connected to the control element 96 of variable speed device 69. The output of the variable speed gear 69 is shaft 97 which is connected to one input side of differential 98. In the second position, gear 91 engages gears 92 and 93, which latter gear is connected by shaft 99 to the other input side of differential 98. It will be seen that in this position shaft 90 applies corrections to the rate of generation of elevation dA as well as applies corrections to the values of elevation A.

In the third position gear 91 engages gear 93 only and applies corrections to the values of elevation. In the fourth position gear 91 engages gear 94 and provides a direct manual control of the director sight in elevation through shaft 100, gears 101, shaft 102 and toothed segment 31.

The power for turning the driving plates of the variable speed devices 68 and 69 is furnished by constant speed motor 103 through shafts 104, 105 and 106, the rotation of which represents time t.

Provision is also made to change the rate of generation of train and elevation by movement of the single control shaft 107 which is mounted for universal movement in a ball and socket bearing 108. The inner end of shaft 107 is connected to two racked slides 109 and 110. The rack on slide 109 is connected to shaft 79 by gear 111 and the rack on side 110 is connected to shaft 95 by gear 112. Slip connections 113 are provided on shafts 78 and 95 to prevent damage to the unit from any excessive movement of the hand cranks when connected thereto by the axial position of shafts 77 and 90, respectively.

In explaining the generation of the traverse

values, reference is made also to Fig. 3 which is a schematic diagram of Fig. 2 showing the details of the converter 71 and its cooperation with other mechanisms. For simplicity, certain structures have been omitted from Fig. 3 such as the mechanism for turning the director turntable, the mechanism for controlling the rates of elevation and train by a single shaft, the mechanical mounting of the director sight and the range finder, etc.

The output of differential 98 is the corrected generated elevation from the horizontal A and is represented by the rotation of shaft 114. When there is relative motion between the platform on which the director sight is mounted and the horizontal, the elevation of the sight plane above the deck (Es) is equal to the elevation angle A plus the level angle L. The level angle L is the angle between the horizontal and the plane of the deck in the elevation plane. The generation of the level angle L by a gyroscope is well known in the art. The level angle L, represented by the rotation of shaft 115, is combined with the elevation angle A by differential 116, the output of which, shaft 116a, represents (Es) and is connected to shaft 102 by shaft 102a. For power to drive shaft 102 when gears 91 and 94 are disconnected, a motor 117 is connected to drive shaft 102a, motor 117 is connected by cables 118 to the level gyro 70 such that when the output (Es) of the motor 117 is combined with the elevation angle A in differential 116, the rotation of shaft 115 is compared with the actual level value to operate a control which actuates the motor 117 until the level values are equal. Shaft 102 is connected to the elevating segments 31, which are mounted for rotation on the supports 27a. The sight 24 and the range finder 67 are thereby automatically elevated to the angle Es.

Shaft 102 is connected to shaft 29 which as described in connection with Fig. 1 is the equivalent of shaft 102 of Figs. 2 and 3. The motion of shaft 29 and therefore of shaft 102 is combined in differential 34 with the motion of shaft 33, representing corrections to gun elevation. The output of differential 34 is connected to the transmitter 35 by a shaft 34a.

It will be recognized by those skilled in the art of correcting for trunnion tilt or cross level, that the correction (Tz) necessary to be applied as traverse may be expressed in the equation

$$\tan Tz = \tan Z \sin Es \quad (1)$$

and since both Tz and Z are small angles the approximation

$$Tz = Z \sin Es \quad (2)$$

is satisfactory for all practical purposes, in which both Tz and Z may be expressed in degrees or in any other unit of that measure. Cross level Z is the angular tilt of the deck about a line lying in the deck and perpendicular to the elevation trunnions 27.

The value of Z is obtained from a conventional cross-level motor 119 controlled by the gyro 70 mechanically or by cables 120 (Fig. 3). The value of Z is represented by the rotation of shaft 121. Provision is also made to generate the value of Z by crank 122 connected to shaft 123 which may be connected to shaft 121 by gears 124. The shaft 121 is thereby turned until the cross-level sight 125 connected to shaft 121 by worm and gear 126 is on the horizon and is kept there.

The unit for solving Equation 2 is a conven-

tional single component solver with its conventional differential 127 in which the length of the vector, representing $\sin Es$, is determined from a spiral cam, which is turned in proportion to the angle Es represented by the rotation of shaft 102 to which it is connected by shafts 102a and 102b. The vector is turned in accordance with the value of Z, represented by the rotation of shaft 121. The output of this solver is represented by motion of the gear 128 by which it is transmitted to shaft 129. Associated with shaft 129 are the conventional follow-up motor 130, differential 131, switch 132 and driven shaft 133, whose motion is identical with that of shaft 129. Shaft 133 is connected to shaft 49 which is geared to the traverse segment 51 of the director sight 24 and the traverse segment 135 of range finder 67, which is mounted in position identical with director sight 24.

In Fig. 3 are shown the details for generating and applying corrections to train and elevation for the time of flight of the projectiles. The range as connected to the variable scale of the range finder is represented by the rotation of shaft 136. To obtain the motion of shaft 136 from a motion that will be in direct proportion to the range, a range converter 137, such as described in Ford Patent No. 1,526,538, is connected to shaft 136. The motion of the input of the range converter, shaft 138, is in direct proportion to the range or may be made in direct proportion to the time of flight. Provision is made to crank in the range or time of flight mechanically by shaft 139.

The computed correction in deflection is obtained by the conventional computer 140 whose inputs are the rate of change of deflection, shaft 79, and range or time of flight, shaft 138. The output of the computer 140, represented by the rotation of shaft 141, is combined with the rotation of shaft 9 by differential 10 previously referred to.

Spot corrections in train may be added by turning crank 144 and shaft 145, connected to differential 146 inserted in shaft 83. The compass course of the ship may also be added by this or similar mechanism to convert the angles of train from true to relative bearings.

The computed correction in elevation is obtained by the conventional computer 147 whose inputs are the rate of change of elevation, represented by the rotation of shaft 95, and the range or time of flight, represented by the rotation of shaft 138. The output of this computer, shaft 148, is connected to shaft 33 and is thereby combined with the rotation of shaft 29 by differential 34, previously described.

Instantaneous values of the various factors represented by the rotation of various shafts may be obtained by a worm gear in mesh with teeth on a dial cooperating with a reference line. These mechanisms are indicated generally throughout the drawings by the numeral 149.

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

I claim:

1. An anti-aircraft gun control system comprising, in combination with a gun mounted for angular adjustment about train and elevation axes with respect to an angularly movable reference plane, said gun being also mounted for

angular adjustment about a traverse axis, a director including a sighting device mounted for angular movement in train about an axis perpendicular to said plane and in elevation about an axis parallel to said plane and in transverse about an axis perpendicular to a second plane including the elevation axis and the line of sight, means to apply corrections to the sighting device about the traverse axis to compensate for angular movement of the elevation axis due to angular movement of the reference plane, and means to transmit to the gun the angular positions of the sighting device about the three axes to direct the adjustment of the gun about its corresponding axes.

2. An anti-aircraft gun control system comprising, in combination with a gun mounted for angular adjustment about train and elevation axes with respect to an angularly movable reference plane, said gun being also mounted for angular adjustment about a traverse axis, a director including a sighting device mounted for angular movement in train about an axis perpendicular to said plane and in elevation about an axis parallel to said plane and in traverse about an axis perpendicular to a second plane including the elevation axis and the line of sight, means for measuring the angular movement of the elevation axis relative to the horizontal,

means actuated by the measuring means for adjusting the position of the sighting device in traverse, and means to transmit to the gun the angular positions of the sighting device about the three axes to direct the adjustment of the gun about its corresponding axes.

3. An anti-aircraft gun control system comprising, in combination with a gun mounted for angular adjustment about train and elevation axes with respect to an angularly movable reference plane, said gun being also mounted for angular adjustment about a traverse axis, a director including a sighting device mounted for angular movement in train about an axis perpendicular to said plane and in elevation about an axis parallel to said plane and in traverse about an axis perpendicular to a second plane including the elevation axis and the line of sight, means for measuring the angular movement of the elevation axis relative to the horizontal, means actuated by the measuring means and in accordance with the position of the sighting device in elevation for adjusting the position of the sighting device in traverse, and means to transmit to the guns the angular positions of the sighting device about the three axes to direct the adjustment of the gun about its corresponding axes.

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