33-236. OR 2,658,277 SR

SEARCH ROOM

Nov. 10, 1953 A. P. DAVIS ET AL 2,658,277

GUN FIRE CONTROL APPARATUS

Filed Dec. 19, 1938 2 Sheets-Sheet 1

Fig. 5

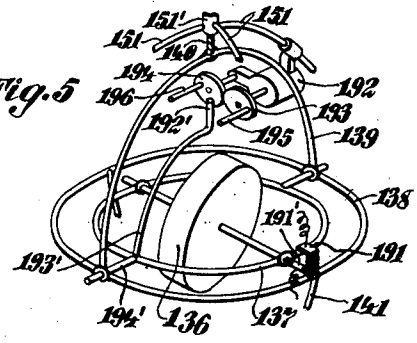


Fig. 2

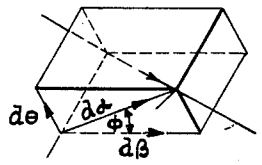


Fig. 3

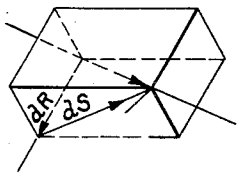


Fig. 1

Fig. 6

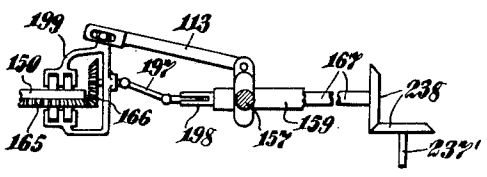


Fig. 7.

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GUN FIRE CONTROL APPARATUS

Filed Dec. 19, 1938 2 Sheets-Sheet 2

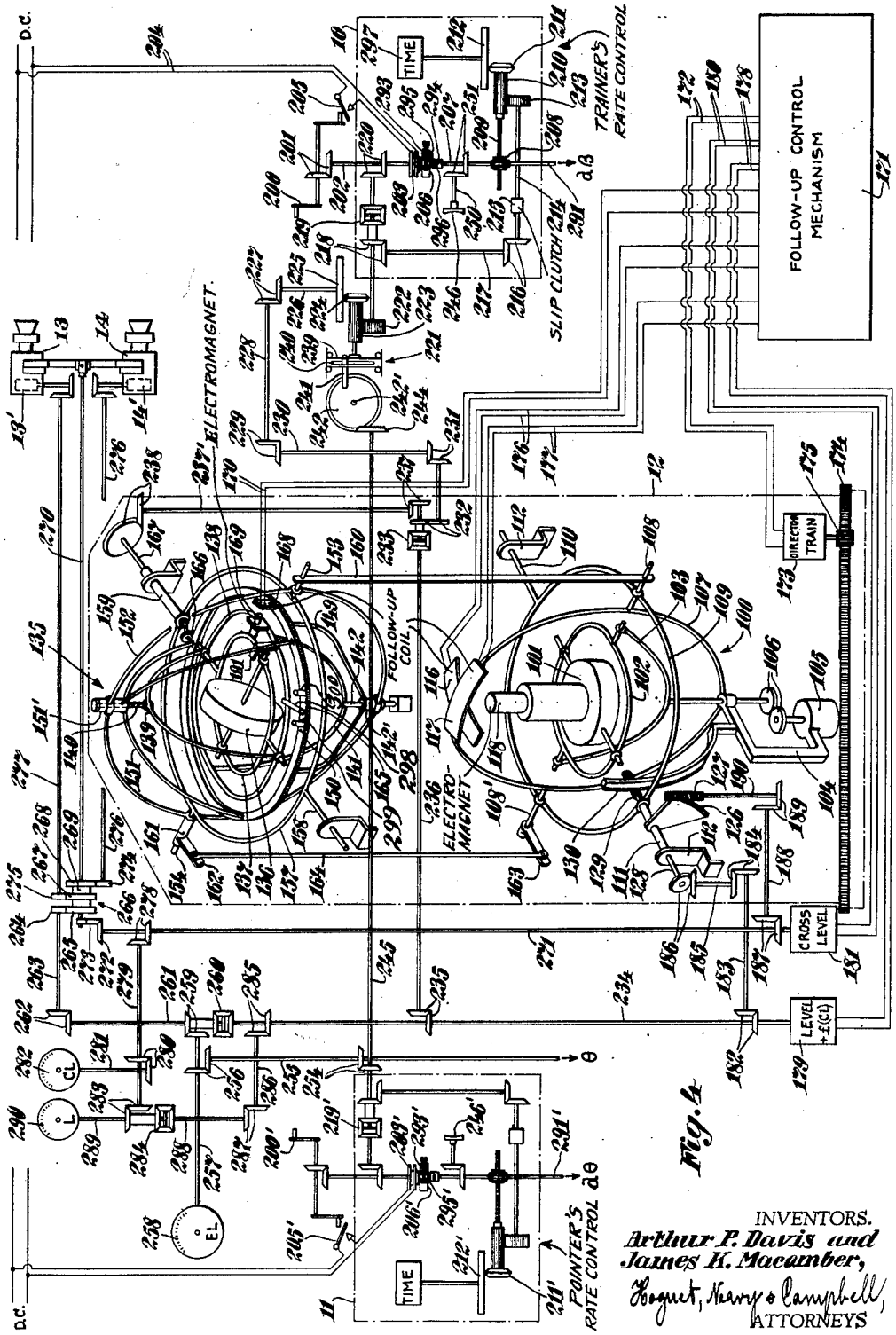


FIG. 4.

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GUN FIRE CONTROL APPARATUS

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Application December 19, 1938, Serial No. 246,680

10 Claims. (Cl. 33—49)

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This invention relates to gun fire control apparatus and has particular reference to angular rate control mechanism for following a moving target in train and/or elevation from a point on an unstable datum plane such as the deck of a ship.

Angular rate control mechanisms of this character may form part of gun fire control director apparatus, whose function it is to set up and solve the mathematical relations between a moving target and own ship in order that the gun or guns may be properly maintained directed on a moving target, such as aerial or surface craft, depending upon requirements.

The invention will be described in connection with a problem diagram upon which the design of one of such directors, including the angular rate control mechanism, is based, and this diagram and the apparatus are illustrated in the accompanying drawings, in which:

Figure 1 illustrates the aforementioned problem diagram;

Figure 2 is a reduced view of a portion of the problem diagram of Figure 1, showing the relations between the mutually perpendicular components of the angular rate of target movement;

Figure 3 is a reduced view, similar to Figure 2, illustrating the vector relations between the components of the relative linear rate of the target;

Figure 4 is a schematic diagram of the rate control mechanisms constructed in accordance with this invention, including a gyroscopic system;

Figure 5 is a partial view illustrating apparatus for erecting the azimuth gyroscope into the horizontal plane;

Figure 6 is a partial view illustrating a gear assembly for transmitting power to the azimuth gyroscope follow-up ring, and

Figure 7 is an enlarged fragmentary perspective view of a lost motion connection between aligned shafts.

Problem analysis

Referring to the problem diagram illustrated by Figure 1, T is the target which may be an aeroplane, for example, moving in a straight line at a uniform speed, and D represents the gun fire control director mounted on own ship. R is the present line of sight and its length also represents the present range from the director D to the target T. Vector dR in Figure 3 represents the instantaneous linear range rate, determined usually from the average trend of several immediately previous observations. The angle θ

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is the present position angle between a stabilized horizontal plane in the director and the present line of sight R.

The point T′ is the advance predicted target position, which also represents the intended projectile impact point. The target displacement ΔS is the component of the distance moved by the target T perpendicular to the present line of sight R in the α plane relative to own ship during the time of flight of the projectile. $A\theta$ is the advance position angle between the advance predicted line of sight AR and the stabilized horizontal plane in the director D. The length of AR also represents the advance predicted range from the director D to the advance predicted target position T′.

It is required to determine the angular values of lateral deflection LD and the vertical deflection VD through which the gun must be moved from the present line of sight R in order that a projectile fired when the target is in the present line of sight will strike the target at the advance predicted position T′. This discussion, of course, neglects for the purposes of the present problem the usual correction factors, and assumes that the trajectory of the shell is a straight line. On these premises and given the values of θ, α and ϕ; $A\theta$, LD and VD may be determined from the equations:

$$\text{Sin } A\theta = \sin\theta\cos\alpha + \cos\theta\sin\alpha\sin\phi$$

$$\text{Sin } LD = \frac{\sin\alpha\cos\phi\cos\theta}{\cos A\theta}$$

$$\text{Cos } VD = \frac{\cos\alpha}{\cos LD}$$

The present position angle θ may be determined by following the target in elevation. The dihedral angle ϕ between a plane containing all horizontal lines perpendicular to the line of sight, and a plane through R and AR, is determined by resolving the angular elevation rate $d\theta$ and the angular bearing rate $d\beta$ of the target into the resultant angular rate $d\alpha$ in the plane through R and AR as shown in Figure 2. The angle ϕ may then be obtained graphically or from the equation

$$\text{Tan } \phi = \frac{d\theta}{d\beta}$$

In order to determine the angle α between R and AR, it is first necessary to determine the range base R_B and the target displacement ΔS in the α plane perpendicular to present line of sight. The target displacement ΔS is obtained

by multiplying the target displacement angular rate $d\alpha$ by the present range R to get target displacement linear rate ds, which is then multiplied by the projectile time of flight TF. The range base R_B is obtained by multiplying the range rate dR by the time of flight TF to give the line of sight projection of the target displacement ΔR and subtracting it from or adding it to present range R, as the case may be. The range base R_B and the target displacement ΔS are then composed to obtain the advance predicted range AR and the angle α. These values may be determined mathematically in accordance with the following equations:

$$\alpha=\tan^{-1}\frac{\Delta S}{R_B}$$

$$AR=\sqrt{\Delta S^2+R_B{}^2}$$

Having values for ϕ, θ, and α, the equations given above may be solved to give VD, LD, and $A\theta$. The solution is performed with facility by graphic mechanism forming no part of the present invention. VD and LD are then corrected for additional ballistic corrections before they are transmitted to the gun train and elevation controls. It is also necessary to correct for the angular movement of the unstable ship deck, which is preferably resolved into its two components, viz. level L, which is the vertical angle between the projection of the present line of sight R on the stabilized horizontal plane, and the plane of the deck, and cross level CL which is the angle measured perpendicular to the deck between the plane of the deck and a line in the horizontal plane perpendicular to the line of sight projection in the horizontal plane.

The angular rate control mechanisms of the present invention serve to measure the mutually perpendicular angular target rates in elevation and bearing $d\theta$ and $d\beta$ respectively, with reference to stabilized horizontal and vertical planes in the director, and to move the director automatically in train and elevation in response to the measured rates. Angular bearing rate $d\beta$ is measured in a slant plane from a vertical plane of reference in the director. These rates are obtained by following the target in train and elevation by the operation of the trainer's and pointer's handwheels as described below.

The angular rates $d\theta$ and $d\beta$ are mechanically integrated over elapsed time. The output of θ, corrected for the pitch and roll of the ship by inputs of level L and cross level CL from a stable element, is transmitted to the pointer's and trainer's telescopes mounted on the director.

Inasmuch as angular bearing rates $d\beta$ are measured in a slant plane containing all horizontal lines perpendicular to the line of sight, the integrated angular bearing rate must be divided by the cosine of the position angle θ in order to convert it to integrated horizontal bearing $\int dH\beta$ which is employed for training the director to follow the target. This conversion is expressed by the equation:

$$\int dH\beta=\int\frac{d\beta}{\cos\theta}=\frac{1}{\cos\theta}\int d\beta$$

The manual correction which is applied to bearing in the slant plane is added to $\int d\beta$ before the latter is divided by $\cos\theta$.

In accordance with the invention, the pointer or trainer brings his telescope on to the target and closes the rate control switch. He then continues to turn his handwheels to as to remain on the target, and by so doing he sets the angular rate into the director. The gearing constants are such that the rate may be set within a few seconds of time. After the rates are set in, the rate control mechanisms will cause the telescopes to automatically follow the target so long as the relative angular rate of the target with respect to the own ship remains constant. In general, the elevation and bearing rates will not remain constant and it will be necessary for the trainer and pointer to frequently correct the rates, keeping the crosshairs on the target, by small motions of the handwheels with the rate control switch closed.

Gyroscopic system

Referring to Figure 4, numeral **100** designates the level gyroscope assembly which establishes the horizontal reference plane in the director and which comprises a vertical axis gyroscope **101** mounted on a gimbal support **102** on bail **103** journalled in bracket **104** about a vertical axis and constantly rotated about that axis by a slow speed motor **105** through gears **106**. The rotation of the gyroscope and gimbal support **101**, **102** cooperating with a ballistic system provides an erecting torque tending to maintain the gyroscope **101** vertical under all conditions of operation, as is explained in greater detail in copending application Serial No. 95,722, filed August 12, 1936, by applicant Davis.

The bracket **104** is supported on a vertical ring **107** having opposite pivots **108** and **108'** journalled in horizontal outer gimbal ring **109** having opposite pivots **110** and **111** displaced 90° from ring **107**, pivots **108** and **108'**, and in turn journalled on brackets **112** fixed on the director casing **12**. At the upper end of the ring **107** are mounted the level and cross-level follow-up coils **116** and **117**, respectively, which are energized inductively by an electromagnet **118** on the casing of gyro **101**. The pivot **111** on outer gimbal ring **109** is hollow and is fitted with a toothed sector **126** driven by a worm wheel **127** for rotating the outer gimbal ring **109** about the cross-level axis **110**, **111**. Journalled in pivot **111** is a shaft **128** fitted with pinion **129** engaging a sector **130** secured to bracket **104** for rotating the latter about the level axis.

Directly above the level gyro **101** is the azimuth gyro assembly **135** which comprises a horizontal axis gyroscope **136** mounted on a gimbal support **137**. The gimbal support **137** is pivoted on outer ring **138**, which is secured to a supporting bail **139**. Secured to the outer gimbal ring **138** is a second vertical bail **141**, displaced horizontally 90° from the bail **139** and extending downwardly and provided with a vertical shaft **142** on which is journalled a hollow pivot **142'** to which the supporting arms **149** of a follow-up ring **150** are secured. The follow-up ring **150** is provided with upwardly-extending supporting arms **151** terminating in a hollow pivot **151'** from which the gyroscope supporting bail **139** is suspended on a suitable cable **140**.

Journalled on the pivot **151'** and the pivot **142'** is a vertical ring **152** which is supported on the pivots **153** and **154**, formed on outer gimbal ring **157**. The outer gimbal ring **157** is provided with opposite shafts **158** and **159**, displaced horizontally 90° from pivots **153** and **154**, by means of which it is supported within the director housing. The pivot **153** is connected by a link **160** to pivot **108** on outer gimbal ring **109** of the level gyro assembly **100**, so that the motion of the outer gimbal ring **109** about the cross-level axis

is transmitted to the outer gimbal ring 157 of the azimuth gyro. Similarly, the vertical ring 152 is provided with a hollow shaft 161 which is connected by means of an arm 162 and link 164 to an arm 163 on the pivot 108' on vertical ring 107 of the level gyro assembly 100, so that rotation of the vertical ring 107 about the level axis is transmitted to the vertical ring 152 of the azimuth gyro 135 assembly. By means of these linkages, the rings in the azimuth gyro are at all times maintained in the same horizontal plane by the level gyro assembly 100.

Where it is not desired or not practicable to connect the gimbal system of the azimuth gyro 135 with the gimbal system of the level gyro 100, follow-up mechanisms may be used in a known manner, so that the rings of the azimuth gyro assembly 135 are maintained level at all times.

Inasmuch as the azimuth gyro 136 is not fixed in space, it may tilt from the horizontal by as much as 15° in an hour, due to the rotation of the earth about its axis. It becomes necessary, therefore, to restore the azimuth gyro to the desired position in the horizontal plane at regular intervals and this may be accomplished by providing an electrical contact 191 on the gimbal ring 138, and insulated therefrom, which is adapted to engage contact 191' on the gyro shaft when the latter has tilted 15° from the horizontal. This closes a circuit to an erecting motor 192 mounted on one of the supporting arms 151 of the ring 150 as is illustrated in greater detail in Figure 5. When the erecting motor 192 is energized, the director train motor 173 is electrically disconnected by means of switching circuits, not shown, but which may be of any conventional disconnect type.

Under certain conditions it may be preferable to actuate the erecting motor manually, in which case the switch 191 may be made to operate a signal device (not shown) indicating to the operator that the azimuth gyro has tilted to a position where it may introduce errors in the results obtained by the apparatus. The operator may then, before the beginning of a run, actuate the erecting motor 192 to restore the azimuth gyro 136 to its proper position in the horizontal plane as indicated below.

A pin 298 on gimbal ring 138 engages either stop 299 or 300 on follow-up ring 150, when electromagnet 169 is angularly displaced approximately 15° from its neutral position of alignment with follow-up coil 168.

The motor 192 drives a gear 193 meshed with gear 194 from which gears the pins 195 and 196, respectively, project. The rotation of the gears 193 and 194 moves the pins 195 and 196 toward each other until one of the pins 195 or 196 engages a vertical pin 192' which is mounted on an arm 193' secured perpendicularly to the inner gimbal ring 137 at the point where it is connected to pivot 194'. The resulting precession of the gyro 136 in azimuth is limited by the engagement of pin 288 with either stop 299 or 300, and as the director train motor 173 is electrically disconnected, the effect produced by limiting the precession of the gyro 136 in azimuth erects the axis of the gyro into the horizontal plane. The gears 193 and 194 rotate until the pin 192' is centered between the gear pins 195 and 196. In this position, the inner gimbal ring 137, and thus the axis of rotation of the azimuth gyro 136, lie in the horizontal plane. Connections to the coils and switches on the gyro gimbal rings are made through suitable brushes and slip rings (not shown).

On the outer periphery of the azimuth gyro ring 150 a ring gear 165 is formed which is driven by the gearing 166 from a shaft 167 concentric with hollow supporting shaft 159. Inasmuch as the ring 150 moves relatively to the outer gimbal ring 157 due to inputs of level to the azimuth gyro assembly 135, a special gearing assembly is required to rotate the ring 150. Any suitable flexible coupling may be used, such as is shown in Figure 6, for example, in which gear 166 is connected to shaft 167 through a universal coupling 197, and a cooperating slot and pin combination 198. The gear 166 is maintained engaged with ring gear 165 by a bracket and roller assembly 199, which is prevented from moving with ring 150 by the slotted arm 113. Ring 150 carries follow-up coil 168 energized inductively by an electromagnet 169 on the azimuth gyro gimbal ring 138. Follow-up coil 168 is connected by wires 170 to a follow-up control system 171 which may be of the electronic type, and which is connected by wires 172 to the director train motor 173. A follow-up system that is suitable for this purpose is disclosed in copending application Serial No. 53,736, filed December 10, 1935, by applicant Davis now Patent 2,421,247. The mechanical output of train motor 173 drives a ring gear 174 on the director housing through a pinion 175, causing the director to train right or left as may be required by the movement of the target.

The level and cross-level follow-up coils, 116 and 117, respectively, of the level gyro 100 are also connected to the follow-up control 171 by wires 176 and 177, respectively. The signals from the follow-up coils are amplified by follow-up control 171 and the amplified signals are transmitted through the wires 178 to operate the level motor 179, giving it a mechanical output of level L plus $f(CL)$.

Similarly, amplified signals are supplied through the leads 180 to the CL motor 181, providing a mechanical output of cross-level CL. The mechanical output of $L+f(CL)$ from the motor 179 is transmitted through the gearing 182, shaft 183, gearing 184, shaft 185, gearing 186, shaft 128, gear 129, sector 130, bracket 104 and bail 107, rotating the latter about the L axis in the proper direction to reduce the signal from the L follow-up coil 116 to zero. The function of CL designated $f(CL)$, is a correction which must be added to the L input to compensate for relative motion between the L input shaft and the CL gimbal element.

The mechanical output of CL from the motor 181 is transmitted through the gearing 187, shaft 188, gearing 189, shaft 190, worm 127 to worm segment 126 on outer gimbal ring 109 of level gyro 100. The ring is thereby rotated in the proper direction about the CL axis to restore the CL follow-up coil 117 to the zero signal position directly over the electromagnet 118. Further details of the construction of the lever gyroscope system 100 and its follow-up mechanism are illustrated and described in copending application Serial No. 53,736, filed December 10, 1935, by applicant Davis.

By means of the L and CL follow-ups, together with their motors and the linkages between the two gyro systems, the rings of both the level 100 and the azimuth 135 gyro systems are at all times maintained level regardless of the roll and pitch of the ship. The whole gyro system thus pro-

vides a stabilized horizontal reference plane and a vertical plane of reference in the director.

Angular rate control mechanism

The angular rates in elevation ($d\theta$) and bearing ($d\beta$) of the moving target are determined by direct measurement of the movements of the target with the pointers' and trainers' telescopes by means of their respective handwheels in conjunction with angular rate control mechanism.

Considering the trainers' rate control mechanism in trainer's handle box **10**, it comprises the double handwheel **200** connected through the gearing **201** and shaft **202** to an electromagnetic clutch **203**. The clutch **203** is supplied with power from the D. C. line through the wires **204** and a switch **205** which is conveniently located on the right handle of the trainer's hand wheel **200**. The driven disc **206** of the clutch **203** is connected through a limited lost motion mechanism to a shaft **207** on which a pinion **208** is secured. The lost motion mechanism may comprise any suitable means such as that disclosed in Fig. 7 in which a pin **294** on the driven shaft **295** moves in a narrow slot **296** formed in a lateral extension **207** on the end of the aligned shaft **207**, although obviously any other suitable mechanism may be used. The mechanism allows a few degrees play between the shaft **295** and the shaft **207**, so that the stabilization of the telescopes may be improved by small manual adjustments to eliminate the effects of lost motion, without affecting the rate set up in the rate control mechanism. The pinion **208** engages a rack **209** having an elongated gear **210** and roller **211** engaging a disc **212** rotated at a constant speed by a suitable source of power, which may be the mechanical time system of the director, generally indicated by the unit **297**. The time system may be of the type disclosed in copending application Serial No. 93,138, filed July 29, 1936, by Clifton T. Foss, now Patent No. 2,138,912, issued December 6, 1938. This assembly comprises the trainer's integrator which integrates change in lateral bearing $d\beta$ over elapsed time.

The rotation of the roller **211** which is integrated change in lateral bearing $d\beta$ is transmitted by gear **210** and pinion **213**, shaft **214**, slip clutch **215**, gearing **216**, shaft **217**, and gearing **218** to one gear of a differential **219**. The other gear of the differential **219** receives an input of change in lateral bearing from the shaft **202** through the gearing **220**. The output of the differential **219** is thus the sum of integrated lateral bearing from the shaft **217** and change in the lateral bearing from the shaft **202**. The slip clutch **215** prevents the integrator roller **211** from slipping on the disc **212** when the shaft **217** reaches its limit at the maximum value of $\int d\beta$.

The output of the differential **219**, which is the sum of integrated lateral bearing and change in lateral bearing, is transmitted through pinion **222**, connected to the output of the differential **219**, to a divider **221**, where it is divided by the cosine of the position angle θ. The cosine divider **221** includes gear **223** engaging pinion **222**, and carrying the roller **224** engaging a disc **225** mounted on a shaft **226**. The rotation of disc **225** is transmitted through gearing **227**, shaft **228**, gearing **229**, shaft **230**, gearing **231**, and gearing **232** to a differential **233**, the other input to which is $f(L)$ plus $f(CL)$, from the level motor **179** through the shaft **234**, gearing **235**, and shaft **236**.

The output of the differential **233** which is horizontal $\beta+f(L)+f(CL)$ is transmitted through the gearing **237**, shaft **237'** and the gearing **238** to shaft **167** which then actuates the gearing **166** and causes the ring gear **165** on the azimuth follow-up ring **150** to move in response to the rotation of the trainer's handwheel **200**. The movement of the azimuth follow-up ring **150** is opposite to the desired direction of train, so that the director will train in the proper direction to keep the telescope cross-hairs on the target.

Division of the quantity integrated lateral bearing plus change in lateral bearing is accomplished by changing the position of the roller **224** with respect to the disc **225**. Attached to the free end of the gear **223** is a vertical slide **239** which is formed with a slot **240** in which a pin **241** on gear **242** is adapted to slide. The gear **242** is rotated about its pivot **242'** in accordance with the magnitude of the position angle θ which is received from the pointer's rate control mechanism **11** through gear **244** and the shaft **245**.

It will be evident that as the gear **242** rotates through the angle θ, the slide **239** will be moved horizontally a distance proportional to cosine θ and the roller **224** will move a corresponding radial distance along the disc **225**. The output of the disc **225**, therefore, is the input of integrated lateral bearing plus change in bearing from the pinion **222** divided by cosine θ.

In case it is desired to return the trainer's rate control mechanism **10** to the zero position, such as for example, in directing the director on different target, the trainer's resetting device is actuated. This resetting device comprises a reset handle **246** on shaft **250** connected to shaft **207** through gearing **251**. By rotating handle **246**, the trainer's rate control mechanism may be accordingly reset.

The pointer's rate control mechanism **11** is substantially identical in construction to the trainer's rate control mechanism **10** so that it will not be necessary to repeat the description except to point out differences in construction. Thus, the integrated angular elevation plus the change in elevation, which is the output of the differential **219'**, is transmitted to the cosine divider **221** of the trainer's rate control mechanism **10** through the shaft **245** as described above. This output is also transmitted through the gearing **254**, shaft **255**, gearing **256**, and shaft **257** to an elevation dial **258**, which indicates elevation of the target T above the stabilized horizontal reference plane set up in the director by the level gyro assembly **100**.

The elevation output is also transmitted from the shaft **257** through the gearing **259** to one of the gears of a differential **260** whose other input is $L+f(CL)$ from the level motor **179** through the shaft **234**. The output of the differential **260** is thus the position angle $\theta+L+f(CL)$ which is then transmitted through shaft **261**, gearing **262**, shaft **263**, to a pinion **264** in the system of the pointer's and trainer's telescopes **13** and **14**. The pinion **264** engages the drive gear **265** of a triple gear assembly **266** which includes the gears **265**, **267** and **268**, mounted on a hub **269**. Within the hub **269** is a shaft **270** which receives a mechanical input of CL from the cross-level motor **181** through shaft **271**, gear **272** and gear sector **273**. This input of CL causes the telescopes **13** and **14** to rotate about the shaft **270** to keep the telescope cross-hairs on the target as the ship pitches and rolls.

The gears **268** and **267** which provide an output of $\theta+L+f(CL)$ are engaged by the pinions

274 and 275, respectively, which are mounted on the shafts 276 and 277, respectively. Inasmuch as the shafts 276 and 277 rotate about the triple gear in response to the CL input to the shaft 270, it will be evident that a differential action takes place which removes $f(CL)$ from the input so that the input to the movable prisms 13' and 14' of respective telescopes 13 and 14 and open sight is $\theta+L$. The telescopes 13 and 14 and open sight accordingly are elevated and depressed by the L input in order to compensate for the roll of the ship so that the telescope cross-hairs may be maintained on the target.

A mechanical input of CL is also transmitted through the gearing 278, shaft 279, gearing 280 and shaft 281, to a cross-level indicator 282 which, indicates the magnitude of the cross-level angle due to pitch and roll of the ship. The same CL input is also transmitted from the shaft 279 through the gearing 283 to one side of a differential 284, whose other input is $L+f(CL)$ from the level motor 179 through the shaft 234, gearing 285, shaft 286, gearing 287 and shaft 288. As a result of the differential action, the mechanical input of CL from the shaft 279 is subtracted from the mechanical input of $L+f(CL)$ from the shaft 288. Hence, the output of the differential 284 is L alone, which is then transmitted through a shaft 289 to a level indicator 290.

Operation

In operation, the trainer rotates his handwheel 200, displacing the azimuth gyro 135 follow-up ring 150 and causing the director to train in a direction opposite to the direction of displacement of the follow-up ring 150 to restore the follow-up coil 168 to its neutral position with respect to the electromagnet 169. This operation continues smoothly until the cross-hairs of the trainer's telescope 13 are centered on the target. Thereupon the trainer closes the switch 205, thus energizing the electromagnetic clutch 203 and transmitting an input of lateral bearing rate to the trainer's rate control mechanism 10. By continuously following the target with the switch 205 closed, the roller 211 is moved radially along the integrator disc 212 until it rotates at a speed corresponding to the lateral bearing rate $d\beta$. The rotation of the roller 211 is transmitted to differential 219 where it is added to the change in lateral bearing as transmitted through gearing 201, shaft 202, and gearing 220 to differential 219. The sum is transmitted to the cosine divider 221 and the output of the divider is transmitted through shaft 226, gearing 227, shaft 228, gearing 229, shaft 230, gearing 231 and 232 to differential 233 where level$+f$(CL) is added to it. The sum is transmitted through gearing 237 and 238, shaft 167 and gear 166 to the follow-up ring 150 of the azimuth gyro system 135 to displace it at a rate equal to the bearing rate of the target with respect to the ship. This causes the director to train automatically so that only slight rotation of the handwheel 200 is necessary to correct the lateral bearing rate should the telescope cross-hairs go off the target.

The pointer meanwhile, likewise rotates his handwheel 200', elevating the telescopes 13 and 14 and open sights until the crosshairs are centered on the target. The switch 205' is then closed, energizing the electromagnetic clutch 203', and causing the roller 211' to move radially along the integrator disc 212' until it rotates at a speed corresponding to the angular rate of elevation $d\theta$. Further rotation of the handwheel 200' is necessary only to correct the elevation rate should the telescope crosshairs go off the target.

The driven discs 206 and 206' of the clutches 203 and 203', respectively, are both provided with suitable brakes 293 and 293' which are continually maintained under tension. These brakes prevent the driven shafts 291 and 291' of the $d\beta$ and $d\theta$ angular rate control mechanisms from being driven to zero under the influence of the biasing springs on the follow-up heads of the $(\phi-da)$ solver disclosed in application Serial No. 246,681 filed December 19, 1938, when the switches 205 and 205' are opened. The elevation rate $d\theta$ and the bearing rate $d\beta$ are introduced as inputs into the computer of the director by shafts 291' and 291, respectively, and are received as instantaneous angular rates determined by following the target T in elevation and bearing with the respective director sights 13 and 14 by rotation of the trainer's and pointer's handles as described. Suitable indicators driven by shafts 291 and 291' may also be provided.

It will be evident that the trainer's and pointer's angular rate control mechanisms 10 and 11 will keep the crosshairs of the telescopes 13 and 14 continually on the moving target T with a minimum operation of the trainer's or pointer's handwheels 200 and 200', respectively. It is assumed, of course, that the target meanwhile is moving in a straight line at a constant speed. Any changes in target course or speed, however, may be instantly corrected for by operation of either the trainer's or pointer's handles as may be required.

In the event that the target direction changes, or a new target is designated, the appropriate angular rate control mechanism may be instantly brought to zero by operation of either of the rate reset handles 246 or 246' and reset by operation of the trainer's or pointer's handles.

The embodiment described above is presented merely as being illustrative of the invention, and the latter is not intended to be in any way limited thereby except as defined in the appended claims.

We claim:

1. In gun fire control apparatus mounted on an unstable platform, the combination of a movable sight thereon, means responsive to the deviation of the platform from a horizontal plane for moving said sight to compensate for said deviation, means for measuring the rate of movement in bearing of a moving target, means for integrating the measured rate over elapsed time, means for modifying the integrated rate in accordance with a function of the angle of elevation to the target, and means responsive to the modified integrated rate for moving the sight in train independently of said stabilizing movement thereof, whereby the sight will follow the moving target as if mounted on a stable platform.

2. In gun fire control apparatus mounted on an unstable platform, the combination of a movable sight thereon, means responsive to the deviation of said platform from a horizontal plane for moving said sight to compensate for said deviation, means for measuring in a slant plane to the target the rate of movement in bearing of the target, means for integrating the measured rate over elapsed time, means for dividing the integrated rate by the cosine of angle of elevation of the target, and means actuated in

accordance with the divided integrated rate for moving the sight in train independently of said stabilizing movement thereof, whereby the sight will follow the moving target as if mounted on a stable platform.

3. In gun fire control apparatus mounted on an unstable platform, the combination of a movable sight thereon, means responsive to the deviation of said platform from a horizontal plane for moving said sight to compensate for said deviation, means for measuring the rate of movement in elevation of a moving target, means for integrating the measured rate over elapsed time, means responsive to the integrated rate for moving the sight in elevation independently of said stabilizing movement thereof, means for measuring in a slant plane to the target the rate of movement in bearing of the target, means for integrating the measured rate over elapsed time, means for dividing the integrated rate by the cosine of the angle of elevation of the target, and means actuated by the divided integrated rate for moving the sight in train independently of said stabilizing movement thereof, whereby the sight is moved in train and elevation to follow the target as if mounted on a stable platform.

4. In gun fire control apparatus mounted on an unstable platform, the combination of a movable sight thereon, means responsive to the deviation of the unstable platform from a horizontal plane for moving the sight to compensate for said deviation, means for measuring the rate of movement in elevation of a moving target, means for integrating the measured rate over elapsed time, and means responsive to the integrated rate for moving the sight in elevation independently of said stabilizing movement thereof, whereby the sight will follow the target as if mounted on a stable platform.

5. In gun fire control apparatus mounted on an unstable platform, the combination of a movable sight thereon, means responsive to the deviation of the unstable platform from a horizontal plane for moving the sight to compensate for said deviation, means for measuring the rate of movement in elevation of a moving target, means for integrating the measured rate over elapsed time, means responsive to the integrated rate for moving the sight in elevation, means for measuring in a slant plane to the target the rate of movement in bearing of the target, means for integrating the measured rate over elapsed time, means for dividing the integrated rate by the cosine of the angle of elevation of the target, and means actuated by the divided integrated rate for moving the sight in train, whereby the optical sight may be moved in train and in elevation independently of said stabilizing movement thereof to follow the target as if mounted on a stable horizontal platform.

6. In gun fire control apparatus for use on an unstable platform, the combination of a movable sight therefor, a gyroscopic system for maintaining a vertical reference plane relatively to the movement of the platform, a gimbal support therefor, a second gyroscopic system for maintaining a horizontal reference plane relatively to the movement of the platform, operative connections between said second gyroscopic system and said gimbal support for maintaining the latter in a horizontal plane, operative connections between said second gyroscopic system and said sight for stabilizing the latter in the horizontal plane, and operative connections between said first gyroscopic system and said sight for stabilizing the latter in a vertical plane.

7. In gun fire control apparatus, the combination of a sight, means for moving the sight manually in accordance with the movements of a target, independent driving means, connections between said driving means and said sight, a variable speed means in said connections having an adjustable part, operative connections between said manual means and said part whereby the movements of said manual means adjust the speed at which the sight is driven by said driving means, a normally disengaged electrically actuated clutch in the connections between said driving means and said sight, a normally disengaged switch at the said manual means for engaging said clutch during operation of said manual means to transfer the drive of said sight to said driving means, and calculating mechanism actuated by said driving means in accordance with the movements of said sight for continuously providing target rate for use in determining data for laying the gun.

8. In gun fire control apparatus, the combination of sighting means, driving means, connections between said driving means and sighting means for driving the latter in elevation, variable speed mechanism in said connections, single manually operable means for adjusting said mechanism to vary the speed of movement of said sighting means in elevation, a second driving means, second connections between said driving means and sighting means for driving the latter in train, second variable speed mechanism in said second connections, second single manually operable means for adjusting said second mechanism to vary the speed of movement of said sighting means in train, means interposed between said second variable speed mechanism and said sighting means for modifying the movement of the sighting means in train, and operative connections between said first connections and said last-named means for operating the latter in accordance with the movements of the sighting means in elevation.

9. In gun fire control apparatus mounted on an unstable platform, the combination of sighting means, a variable speed driving means having an adjustable part, connections between said driving means and sighting means for driving the latter in elevation, manually operable means for adjusting the said adjustable part of said mechanism to vary the speed of movement of said sighting means in elevation, a second variable speed driving means having an adjustable part, second connections between said driving means and sighting means for driving the latter in train, second manually operable means for adjusting the said adjustable part of said second mechanism to vary the speed of movement of said sighting means in train, a stable element, operative connections between said element and said first connections for stabilizing said sighting means against movements of said platform in a vertical plane normal to the line of sight and the target, and operative connections between said element and said second connections for stabilizing said sighting means against movement of said platform in a vertical plane in the line sight to the target.

10. In gun fire control apparatus, the combination of a rotatable support about a vertical axis, a sight thereon movable in elevation, driving means for rotating said support, whereby said sight is driven in train, a normally disengaged clutch interposed between said driving means

and said support, manually operable means for driving said support in train independently of said driving means, a variable speed means interposed between said support and said driving means and having an adjustable part, operative connections between said manually operable means and said part for adjusting said variable speed means in accordance with the movements of the target in train, means for engaging said clutch and operable at will for transferring the drive of said support in train to said driving means, second driving means for actuating said sight in elevation, a second normally disengaged clutch interposed between said second driving means and said sight, second manually operable means for actuating said sight in elevation independently of said second driving means, second variable speed means interposed between said sight and said second driving means and having an adjustable part, operative connections between said second manually operable means and

said last-named part for adjusting said second variable speed means in accordance with movements of the target in elevation, and means for engaging said last-named clutch and operable at will for transferring the drive of said sight in elevation to said second driving means, whereby said sight is moved automatically to follow the moving target in train and elevation.

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References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
1,464,208	Makaroff	Aug. 7, 1923
1,468,712	Ford	Sept. 25, 1923
1,831,595	Gray	Nov. 10, 1931
1,849,611	Bussei	Mar. 15, 1932
2,071,424	Papello	Feb. 23, 1937
2,105,985	Papello	Jan. 18, 1938