

Oct. 7, 1952

H. K. WEISS
GYROSCOPIC GUN SIGHT

2,612,692

Filed July 14, 1945

3 Sheets-Sheet 1

Fig. 1-

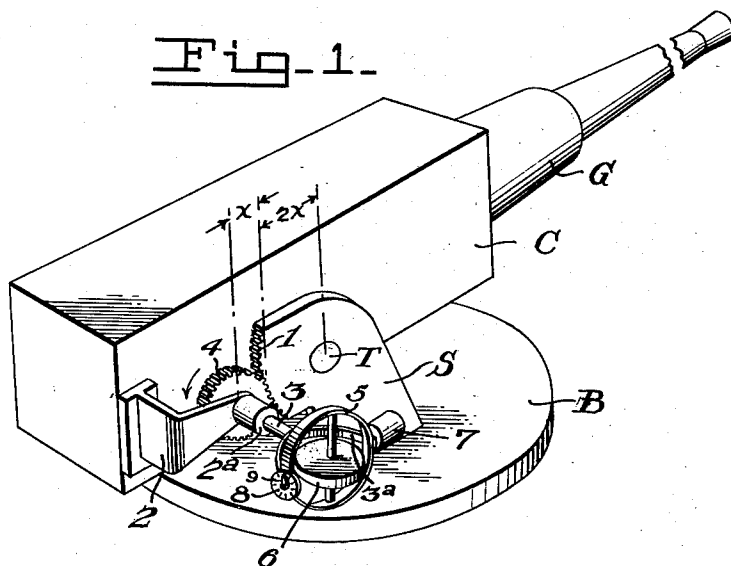


Fig. 2-

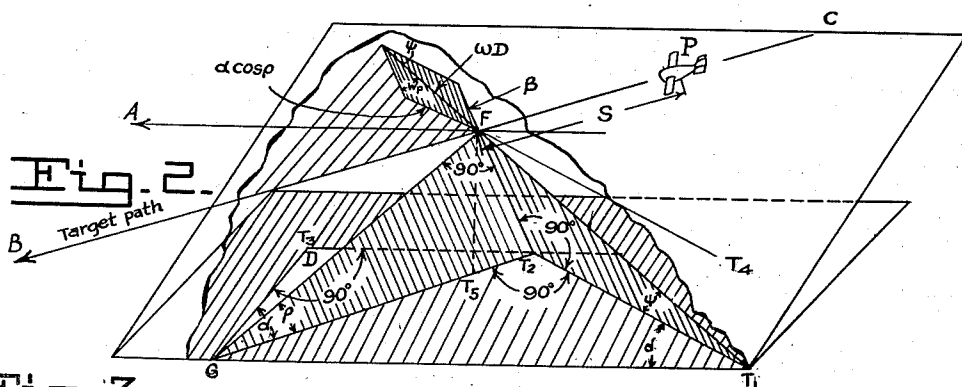
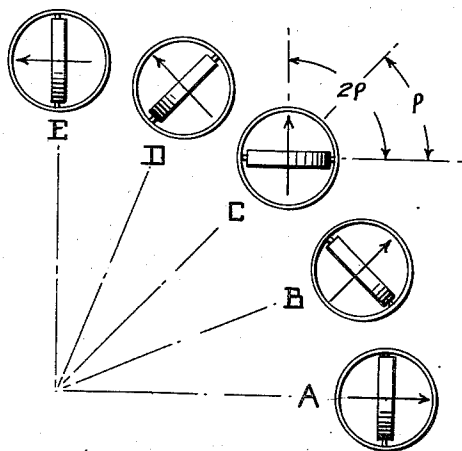


Fig. 3-



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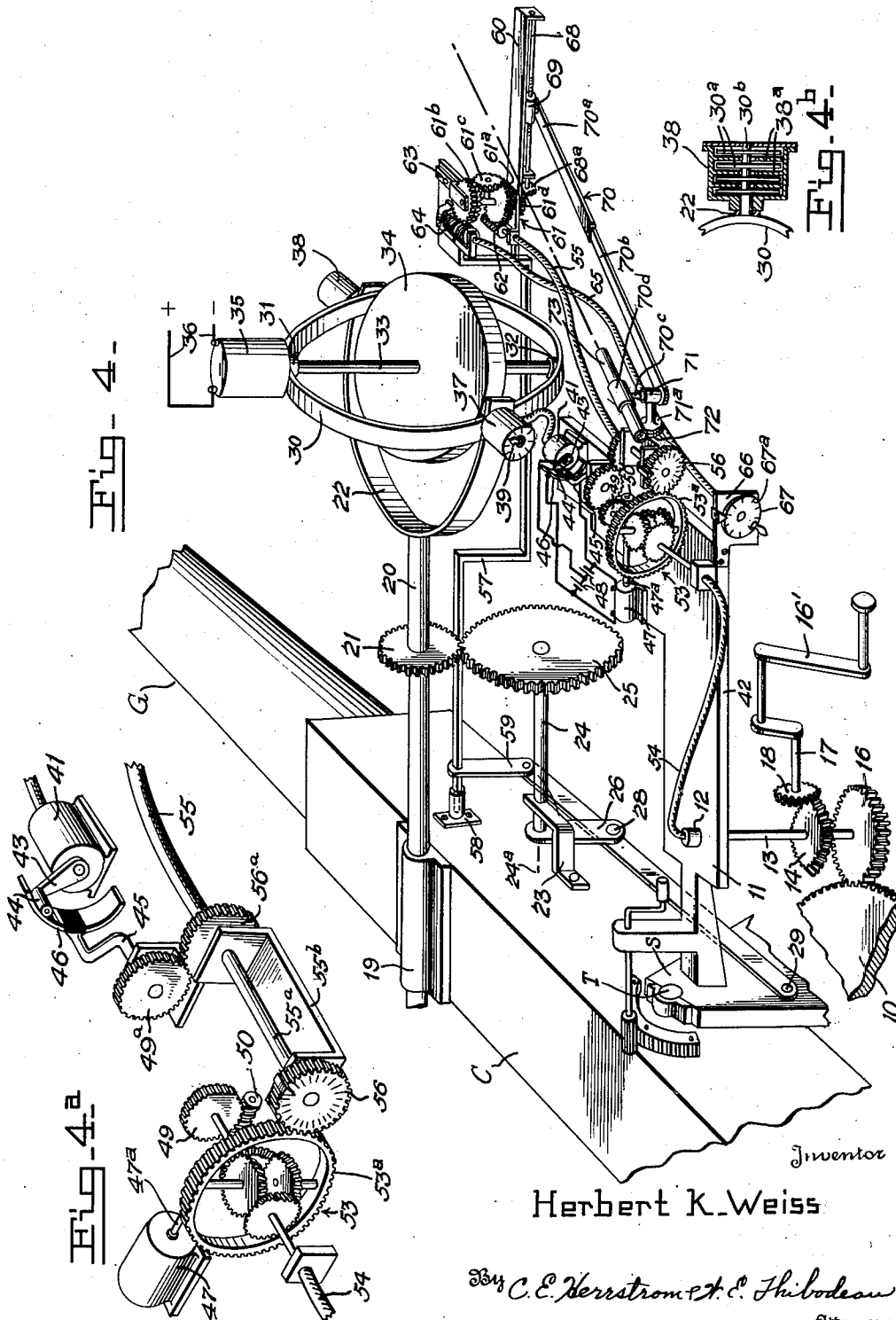
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GYROSCOPIC GUN SIGHT

Filed July 14, 1945

3 Sheets-Sheet 2



Oct. 7, 1952

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3 Sheets-Sheet 3

Fig. 5.

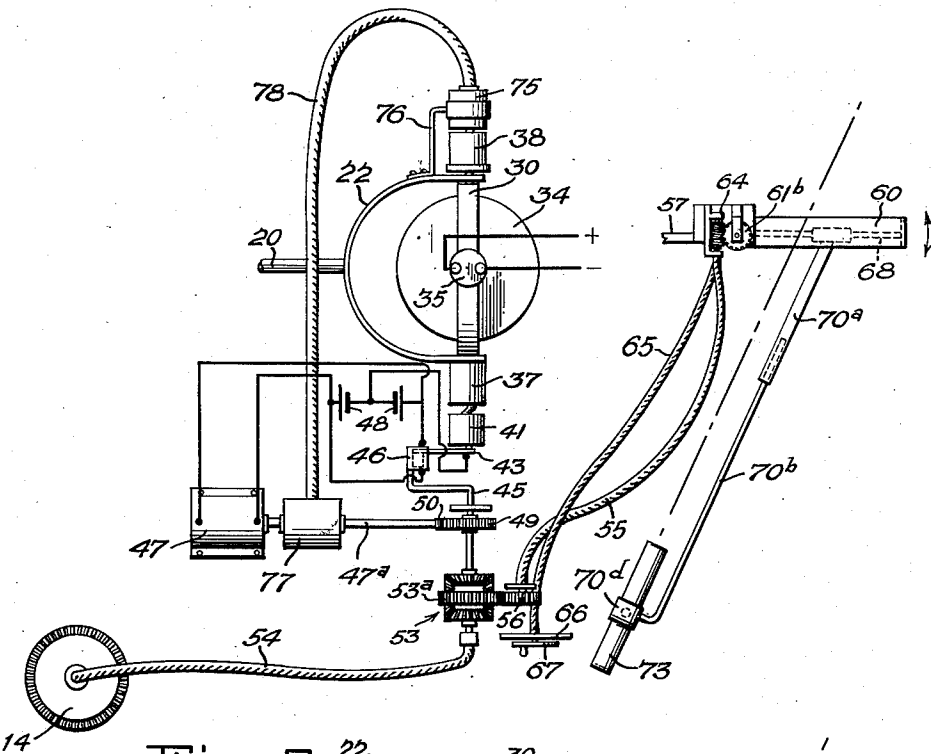
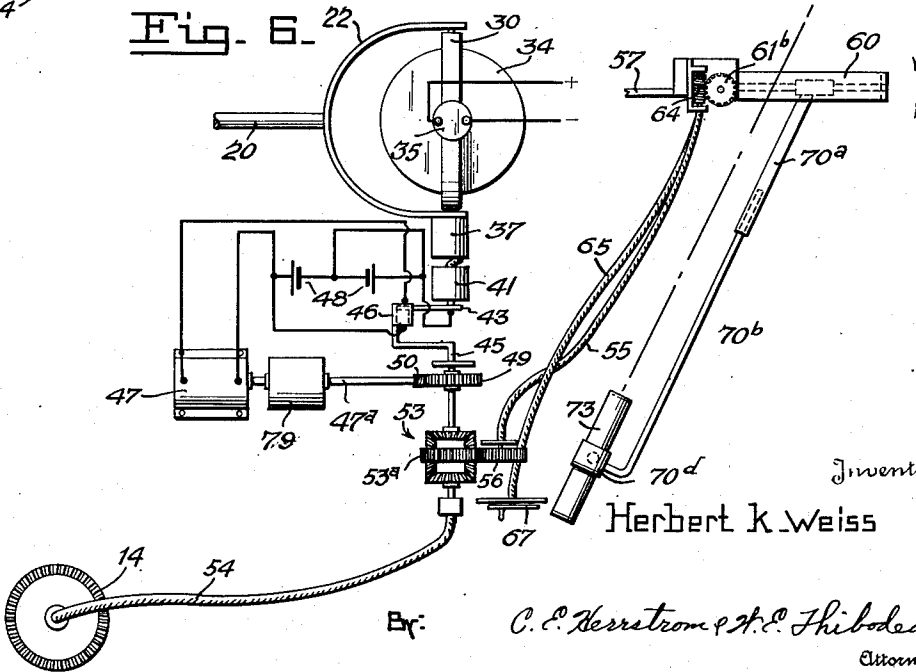


Fig. 6.



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UNITED STATES PATENT OFFICE

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GYROSCOPIC GUN SIGHT

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United States of America as represented by the
Secretary of War

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19 Claims. (Cl. 33—49)

(Granted under the act of March 3, 1883, as
amended April 30, 1928; 370 O. G. 757)

1

The invention described herein may be manufactured and used by or for the Government for governmental purposes without the payment to me of any royalty thereon.

In my application, Serial No. 560,831, filed October 28, 1944, now Patent 2,476,342, dated July 19, 1949, I have disclosed a gun sighting mechanism intended for firing at moving targets. This sight includes deformable and pivotal linkages by which a triangle may be set up or simulated. The first side of this triangle represents to a fixed, predetermined scale, the slant range of a target or, approximately, the average velocity of the projectile multiplied by its time of flight. This value is taken as constant at the most advantageous range at which the particular type of gun is adapted to engage the enemy. The mechanism is so attached to the gun that the aforesaid first side of the triangle is at all times parallel to the bore of the gun.

The second side of the triangle is adjustable in length and is pivotal at its intersection with the forward, or muzzle end, of the first side. This second side represents to scale the speed of the target multiplied by the time of flight of the projectile. Connections to this side are provided so that it may be maintained substantially parallel to the path of the target.

The third side of the triangle is adjustable in length, in accordance with the adjustments of the second side, and represents the line of sight to the target. A sight is so connected with this third arm as to be at all times parallel thereto. Thus, as the second arm is properly adjusted in length and direction, so that the intersection of the second and third sides represents the instantaneous target position, the gun is given a deflection or lead such that the projectile and target will arrive at the same point at the same time, and a hit will be effected.

In the aforesaid patent, adjustments of the second arm are introduced manually. In addition, a connection is provided between the train mechanism of the gun and the pivotal adjusting means whereby said arm is maintained parallel to itself despite training movements of the gun.

I have discovered that it is possible to determine the angle of approach of the target automatically by means of a neutrally mounted gyroscope having three degrees of freedom, and so mounted upon the gun that the third degree of freedom is constrained to rotation by and in proportion to the angle of elevation of the gun, as will be subsequently described.

It is therefore an object of my invention to

2

provide a novel mounting for a gyroscope, together with means operated thereby to indicate directly the angle of approach or departure of an object relatively to the location of the gyroscope, as the gyroscope is moved about its third axis of freedom so as to maintain its second or precession axis in a vertical plane through the gyroscope and object, while at the same time rotating said axis in said plane by an amount proportional to the elevation of a line between the gyroscope and object.

More specifically, it is an object of my invention to provide a gyroscopic device so associated and related to a gun, that the gyroscope will precess from a predetermined position, by an angle proportional to or equal to the angle of approach of a target, as the gun is moved to maintain its line of sight upon said target.

A further object is to provide a sighting mechanism associated with a gun whereby the gun, target and point of impact triangle is simulated to scale and automatically maintained in proper size and relation to the gun so long as the target speed remains constant.

A still further object is to provide a mechanism as outlined in the preceding paragraph, wherein the said triangle is utilized to maintain a line of sight in proper angular relation to the gun to effect a hit as the gun is moved to maintain said line of sight upon the target.

Another object is to provide a mechanism in which a triangle as aforesaid is automatically maintained correctly adjusted by a gyroscope, as the gun is moved to follow a target.

A further object is to provide a gun sighting device having a line of sight positioned relatively to the gun bore by a mechanism setting up and representing the gun position, target, and point of impact triangle, wherein said triangle is adjusted automatically by means of a gyroscopically-controlled follow-up, as the gun is moved to maintain the sighting device upon the target.

Other objects and advantages will be apparent on study of the disclosure.

In the drawings:

Figure 1 is a schematic view showing one construction for combining a gun and gyroscope to carry out the basic principle of the invention,

Figure 2 is a three-dimensional diagram showing the factors involved in the theory of operation of the invention,

Figure 3 is a diagrammatic view showing the relation between the gyroscope and the gun for several positions of gun elevation,

Figure 4 is a perspective view of a complete assembly of gun, gyroscope and resolving mechanism, together with connections therebetween.

Figure 4a is an enlarged detail view of the follow-up control and differential of Fig. 4.

Figure 4b is an enlarged sectional view of a suitable form of damper for use with the gyroscope.

Figure 5 is a view of a modification of the construction shown in Fig. 4, wherein a power-driven damping mechanism is employed, and

Figure 6 is a view of a modification using a still different form of damping mechanism.

In the explanatory diagram of Fig. 2, the various points angles and angular rates are identified by the following symbols:

P—actual target position at any time "t."

CB—target path.

F—predicted future position corresponding to P, or the point at which the projectile and target will meet.

G—gun position.

s—speed of target along path CB.

t_p —time of flight of shell from G to F.

S—distance from P to F, equal to st_p .

θ —azimuth angle of gun from an arbitrarily selected reference line such as a N-S line.

ρ —elevation angle of gun.

ω —rate of angular movement of the gun in slant plane GCB.

α —rate of angular movement of the gun in azimuth.

β —rate of angular movement of gun in elevation.

ψ —elevation angle of slant plane velocity component.

D—length of line GF or future predicted range.

The slant plane GCB contains the line GF connecting the gun with the predicted position F. The gun is positioned to point at F by rotating it in a horizontal plane to an azimuth angle θ and then rotating it in a vertical plane about a horizontal axis to a predicted angular elevation. As the gun moves to continuously maintain a proper position in advance of the target, the angles θ and ρ change at the rates α and β , respectively.

The line GF must always cross the extrapolated target path PFB and therefore rotates about G with an angular velocity ω , while remaining in the slant plane GCB. The component of linear velocity of point F in the slant plane, measured perpendicularly to the line GF is, then, ωD . This component ωD may be decomposed into vertical and horizontal components as follows.

At F pass a plane perpendicular to GF. This plane cuts the slant plane in a line FT₁, the horizontal plane through G in a line T₁T₂, and the vertical plane through GF in a line FT₂. The vector representing the angular velocity ω is an extension of line FT₁, and makes the angle ψ with a horizontal vector, which angle appears in the diagram as T₂T₁F.

The horizontal component of ωD is then $\omega D \cos \psi$. The vertical component is the vertical angular rate of movement of line GF multiplied by the length of GF or D. That is

$$\beta D = \omega D \sin \psi; \text{ or } \beta = \omega \sin \psi \quad (1)$$

To obtain a similar expression for azimuth rate, it will be noted that azimuth rate is measured about a vertical axis and that the magnitude of the horizontal component of ωD , that

is $\omega D \cos \psi$ is obtained by dropping a perpendicular from F to the horizontal plane at T₃. Thus the aforesaid horizontal component is α multiplied by the distance GT₃ or $\alpha D \cos \rho$. Thus

$$\alpha D \cos \rho = \omega D \cos \psi \text{ or } \alpha \cos \rho = \omega \cos \psi \quad (2)$$

From Equations 1 and 2 it is possible to obtain the angle ψ , since the quantities upon the left-hand side of both may be measured in the tracking process. However, this is not the course angle used for sights of the type herein disclosed. It is sufficient for the present development to state that the heading which must be determined for the sight disclosed is that of a horizontal line through F which also lies in the slant plane. This heading is shown in Fig. 2 as the line FA. Since this line is horizontal, it is desirable to refer its heading in a horizontal plane to some convenient reference line in that plane, such as GT₃T₂, the intersection of a vertical plane through GF with the horizontal plane through G. If a line T₂T₃ parallel to FA is drawn through T₂ and a perpendicular is dropped from G to T₂T₃ intersecting T₂T₃ at T₃, the angle T₃GT₂ defines the heading of T₂T₃ and hence, of FA. The angle T₃GT₂ will be identified as δ and since it is also an azimuth angle of GT₂, measured with respect to a fixed reference GT₃, the rate of change of δ is equal to α , the rate of angular movement of the gun in azimuth.

Now, through F, draw line FT₄ so that it is horizontal and in plane T₁T₂F and so, by construction, parallel to line T₁T₂. Since plane T₁T₂F was constructed perpendicular to GF, the angles GFT₄ and GFT₂ are both right angles. Also, since FT₄ is horizontal and FT₂ is vertical by construction, the angle T₄FT₂ is a right angle. Thus T₄F is perpendicular to plane FT₂G, being perpendicular to two nonparallel lines in said plane, so that T₄FT₂ is a right angle. Since T₁T₂ is parallel to T₄F, angle T₁T₂F is a right angle. Also, since GT₂ lies in plane T₂FG, angle T₁T₂G is a right angle. There are thus established three right triangles whose vertices are G, F, T₁ and T₂.

Lines AF and GT₁ are parallel, both being horizontal and contained in the same slant plane. Thus GT₁ is parallel to T₂T₃ and, from the similar right triangles GT₂T₃ and GT₂T₁, the angle GT₁T₂ = δ .

In triangle T₁T₂F,

$$\tan \psi = T_2F/T_1T_2 \quad (3)$$

In triangle GT₂F,

$$\sin \rho = T_2F/GT_2 \quad (4)$$

In triangle GT₂T₁,

$$\tan \delta = GT_2/T_1T_2 \quad (5)$$

Combining (3), (4), and (5) we have

$$\tan \psi = \sin \rho \tan \delta \quad (6)$$

Dividing (1) by (2) we have

$$\tan \psi = \frac{\beta}{\alpha \cos \rho} \quad (7)$$

Equating (6) and (7)

$$\tan \delta = \frac{\beta}{\alpha \sin \rho \cos \rho} \quad (8)$$

Since $2 \sin \rho \cos \rho = \sin 2\rho$

$$\tan \delta = \frac{2\beta}{\alpha \sin 2\rho} \quad (9)$$

Equation 9 suggests that by properly connecting a gyroscope to train and elevate with the gun, that angle δ may be directly obtained there-

from provided it can be subjected to a rate of angular movement equal to $\alpha \sin 2\phi$.

Figure 3 shows basically how such a mounting may be effected. At position A the gun is horizontal and the gyroscope has its spin axis parallel to the gun bore. At position B, the gun has been elevated $22\frac{1}{2}^\circ$ while the gyroscope spin axis has been turned in the same direction by twice this angle or 45° . At position C, with a gun elevation of 45° , the gyroscope spin axis has been turned through 90° . This relation is maintained throughout the elevation of the gun, so that when elevated 90° , the gyroscope spin axis has been turned 180° . Thus the precession axis of the gyroscope is at all times turned through twice the angle of gun elevation to satisfy the requirements of Equation 9.

Referring to Figure 1, G indicates a gun of any type or calibre, mounted in a cradle C carried on trunnions T, only one of which is shown. Said trunnions are carried by supports S fixed to a trainable base B. One support S is formed with, or has attached thereto, a gear segment 1 concentric of the axis of trunnions T. A bracket 2 is fixed to the side of cradle C and has a sleeve bearing 2a journaling a shaft 3. Said shaft has a gear 4 fixed on its inner end and in mesh with segment 1. As indicated, the pitch diameter of segment 1 is twice that of gear 4 so that the latter rotates at twice the rate of elevation of the gun. Shaft 3 has a fork or yoke 3a on its outer end. The fork mounts a gimbal 5 for pivoting about an axis lying in a vertical plane parallel to the gun bore and which is preferably horizontal when the quadrant elevation of the gun is zero. Gimbal 5 mounts a gyroscope rotor 6 for spinning about an axis normal to its own axis. A damper 7 that may be of the type shown at Fig. 4b has one element secured to gimbal 5, and another secured to the adjacent end of yoke 3a, whereby pivotal movement of ring 5 is damped. At the end opposite damper 7, yoke 3a carries a dial 8 over which moves a pointer 9 fixed to a trunnion rotating with gimbal 5, whereby the angle of movement of gimbal 5 may be determined. Thus it will be apparent that, as the gun is elevated, the axis of gimbal 5 is likewise elevated, but at twice the angle of gun elevation. In accordance with the principle of my invention, combined train and elevation of the gun in following a target, causes the spin axis to precess about the axis of gimbal 5 through an angle equal to the angle of approach of the target, as will be more fully explained in connection with Figure 4.

Figure 4 shows one embodiment of the invention wherein 10 indicates a section of a large gear fixed to the gun platform and whose center defines the axis of train of the gun G. A gun carriage including trunnion supports S is mounted for pivotal movement on the axis of train. These supports have bearings at their upper ends receiving the gun trunnions T, only one of which is shown. It will be understood that the gun cradle C is provided with conventional gearing by which it may be elevated about the axis of trunnions T.

A bracket 11 is rigidly associated with and extends from the side of one trunnion support S to provide a bearing 12 for a train shaft 13 having fixed thereon a bevel gear 14 and a pinion 16 the latter meshing with platform gear 10. A training crank 16' is fixed to an axle 17, journaled in bearings not shown but which may be carried by bracket 11. Axle 17 carries a bevel

pinion 18 meshing with gear 14 so that, as crank 16' is turned, the gun is pivotally moved in train about the center of gear 10.

A sleeve bearing 19 is fixed to the top side of cradle C and journals a shaft 20 having fixed thereto a gear 21 and carrying a semi-circular yoke 22 at its outer end. A bracket 23 is bolted to the side of carriage C and has a bearing journaling a shaft 24 that has a gear 25 fixed to its outer end and a link 26 secured to its inner end. The axis of shaft 24 intersects the carriage C at a point 24a. Gear 25 is twice the diameter of gear 21, for a purpose that will be explained later.

A second link 27 is pivoted to the end of link 26, as at 28. Link 27 is also pivoted at 29 to gun trunnion support S; and the connections are such that the axis of trunnion T, pivots 29, 28 and the axis of shaft 24, projected upon a plane normal to the trunnion axis form a parallelogram. Thus, link 26 and a diameter of gear 25, remain vertical for all angles of gun elevation, and gear 21 rolls about gear 25 as the gun is elevated, to rotate shaft 20 and yoke 22 through an angle that is at all times equal to twice the angle of gun elevation. The gyroscope includes, in addition to the yoke 22, a ring 30 that has trunnions journaled in the ends of yoke 22 so that ring 30 may pivot relatively to said yoke about an axis that is normal to the axis of shaft 20. Ring 30 has bearings 31 and 32 defining an axis at right angles to its own pivot axis and journaling the axle 33 upon which rotor 34 is fixed.

Any suitable arrangement may be used for spinning the rotor. For example, the rotor may be simply the armature of an electric motor having the desired moment of inertia with well known means for leading current in through the trunnion axes. I have indicated schematically at 35 a motor having its field coils fixed to ring 30 and its armature or rotor directly connected with axle 33, together with current leads 36. It will be understood, of course, that ring 30 and all parts carried thereby, are balanced so that their center of gravity lies at the intersection of the three concurrent axes, previously mentioned.

One trunnion of ring 30 has the rotor of a telemetric transmitter 37, secured thereto, the stator being fixed to yoke 22. The other trunnion of said ring has one element of a damping device 38 secured thereto. As shown at Fig. 4b this device may consist merely of a casing 38, fixed to yoke 22 and having a series of centrally apertured spaced plates 38a secured therein and between which are mounted discs 30a, fixed upon trunnion 30b. The casing 38 is filled with a suitable viscous liquid, such as oil, whereby rotation of ring 30 relatively to yoke 22, is effectively damped. The rotor shaft of transmitter 37 may project through the end of the casing and have there attached, a pointer 39, movable over a scale on the transmitter casing to indicate the angular relation between the planes of ring 30 and yoke 22 or more specifically, the angle of approach of a target.

The aforesaid angular relation is transmitted by 37 through a flexible cable connection, to a repeater 41, mounted upon a platform 42. This repeater has its rotor shaft connected to an arm 43 (see Fig. 4a) having a contact trolley 44 pivoted at its distal end. A shaft 45 is journaled in suitable bearings on platform 42 and at its end is provided with an arm bearing an arcuate surface 46 concentric with the axis of shaft 45 and having two contact portions, separated by a narrow strip of insulation. A follow-up motor 47

is mounted upon platform 42 and is connected in a circuit as shown upon Fig. 4, so as to rotate in one direction when trolley 44 moves into contact with one portion of element 46; and in the opposite direction when said trolley moves into contact with the other portion, in a manner obvious from inspection of the circuit including sources of D. C. 48. The shaft 45 has fixed thereon a gear 49a in mesh with a gear 56a that is fixed to a shaft 55a journaled in a bracket 55b and forming an extension of a flexible drive shaft 55.

The motor 47 is connected to drive one side of a differential 53 by means of a worm 50 and gear 49. The other side of said differential is connected to be driven from shaft 13, as by means of a flexible shaft element 54. The center, or planetary of said differential is connected to drive flexible shaft element 55 by means of ring gear 53a and a pinion 56, connected to shaft 55a. Thus, the degree of rotation of flexible drive 55 is proportional to the algebraic sum of the rotations of motor 47 and the angle of train of the gun. The purpose of this will be subsequently explained.

A bracket 57 is pivotally mounted upon the gun cradle by means of a bearing sleeve 58. This bracket has a link 59 at its end adjacent the gun cradle that is pivoted to link 27. As the effective lengths of links 26 and 59 are the same, link 59 and bracket 57 are maintained in fixed angular relation to the horizontal plane for all angles of gun elevation. Bracket 57 is shaped at its free or outer end, to support and journal the several elements of one portion of the resolving device.

As previously stated, this resolving device is constructed to set up to scale a triangle, a first side of which is fixed in length and represents the product of the time of flight of the projectile for an average assumed slant range and its average velocity for that range. This first side is maintained at all times parallel to the gun bore. The second side, pivotally joining the forward end of the first side, represents the product of the time of flight of the projectile, as aforesaid, and the average velocity of the target during that time, in other words, the distance that the target travels from the time the projectile leaves the gun until it hits the target.

Said second side is represented by an arm 60 pivoted on an axis on the outer end of bracket 57. This axis is maintained vertical by the previously described parallelogram linkage 59, etc. Arm 60 is attached to a gear 61a forming one side of a differential, generally identified by the numeral 61. Gear 61a meshes with and is driven by a worm 62 connected to flexible shaft element 55. The other side of differential 61 is a gear 61b, pivoted in a bracket 63 and in mesh with a worm 64, connected to be rotated by a flexible shaft drive 65. The other end of the aforesaid drive is journaled in a bearing plate 66, secured to platform 42 and adapted to be rotated by a handwheel 67 having engraved thereon a scale of target speeds 67a. This scale is read by means of a pointer fixed to plate 66.

The center of differential 61 is represented by a planetary gear 61c mounted upon an arm extending radially of a central shaft that extends downwardly through gear 61a and arm 60 and there carries a bevel pinion 61d. A screw shaft 68 is journaled in bearings defining an axis parallel to arm 60. This shaft, at its inner end, carries a bevel pinion 68a in mesh with pinion 61d. A nut 69 is threaded upon shaft 68 and has pivotally connected thereto, one section 70a, of a

telescoping rod 70. The other section 70b of said rod telescopes within section 70a at one end and has a pivot pin 70c fixed to its other end. This pin is journaled in a bearing formed by a member 71 having a flange 71a pivoted to a flanged element 72 on platform 42. The axis thus defined is perpendicular to the axis of pin 70c.

Pin 70c projects upwardly from the bearing in flanged member 71 and has fixed thereto, a sleeve 70d within which fits a sighting device, such as telescope 73. Any other well known sight may be used, it being essential only that the line of sight determined thereby remain at all times parallel to rod 70.

The operation of my invention will now be clear. With all electrical parts energized and the gyroscope spinning, handwheel 67 is turned to indicate the known or estimated speed of a target to be engaged. A drive is thus effected through flexible shaft 65, worm 64, side 61b and center 61c of differential 61, through gears 61d and 68a to shaft 68. The parts are so proportioned that nut 69 will be thereby translated along shaft 68 until the distance of the pivot axis of rod 70 upon nut 69 from the central axis of differential 61 will represent to the predetermined scale, the product of target velocity and time of flight of projectile. The parts are so connected and proportioned that the distance between the point of intersection of the axis of shaft 68 with the normally upright axis of differential 61, and the point of intersection between the axis of pin 70c and the axis of flange 71a, remains constant and substantially parallel to the gun bore. This distance, of course, represents to scale the fixed range at which the target is usually engaged. Therefore, when arm 60 is so turned as to be parallel to the actual path of the target, the third side of the triangle, as materialized by rod 70, will indicate the line of sight along which the target should be viewed when the gun is fired.

As the gun is elevated, gear 21 rolls around gear 25 and elevates the precession axis of the gyroscope at twice the angular rate of the gun itself. Other factors remaining constant, the angle of precession of the spin axis about the axis of ring 30 will be proportional to the ratio of rate of elevation to rate of train of the gun, divided by the sine of twice the gun elevation angle. This, of course, assumes that the gun is continuously trained and elevated in the manner necessary to keep its line of sight continuously upon the target.

For example, with a target directly incoming so that $\alpha = 0$, the angle of approach is zero and the gyroscope precesses until its axis is parallel to the trunnion axis with its top end, say, toward the gun. Under this condition, the arm 60 will be aligned with the first side of the triangle, parallel to the gun bore and pointing away from the telescope. As arm 60 is maintained horizontal for all angles of gun elevation, it will be noted that the line of sight is moved into a vertical plane parallel to the gun bore, but making an angle therewith that lies below the bore. Thus, to hold the sight upon the target, the gun must be elevated so that its trajectory lies the proper distance in advance of the target.

Likewise, in the case of a directly outgoing target, α is zero and the gyroscope will precess until its spin axis is parallel to the trunnion axis with its top end away from the gun. Under this condition, the connections are such that the arm 60 will be aligned with the first side of the tri-

angle, parallel to the gun bore and pointing toward the telescope, whereby the line of sight makes an angle with and above the gun bore, so that as the line of sight is held upon the target, the gun is properly aimed in the vertical plane of, and below, the target.

These limiting conditions suggest the manner in which the instrument is to be calibrated. For example, arm 60 pivots in synchronism with the precession of the gyroscope spin axis about the axis of ring 30, and lies in a vertical plane parallel to the gun bore and pointing in one direction, when the spin axis is parallel to the gun trunnions with its top end in one direction, and in the same plane but rotated 180° when the top end of the spin axis is parallel to the gun trunnions with its top end pointing in the other direction. The particular relation will depend upon the direction of spin of the gyro rotor. For all intermediate positions the arm is correctly positioned, and in accordance with Equation 9.

As ring 30 pivots relatively to yoke 22, the angular movement is detected by transmitter 37 and repeated at instrument 41, thus rotating arm 43 and trolley 44 accordingly. As soon as trolley 44 moves off the insulated portion on element 46 and onto one or the other of the live segments, follow-up motor 47 is energized to rotate in the proper direction to restore the insulated portion of element 46 to contact with trolley 44, by means of gear 49, a first side of differential 53, ring gear 53a, gear 56, shaft 55a, and gears 56a and 49a. In addition to the control of motor 47 by trolley arm 43, training of the gun by means of handle 16' correspondingly drives flexible shaft 54, a second side of differential 53, ring gear 53a, shaft 55a, and gears 56a and 49a, to rotate shaft 45 and sector 46. Thus both sector 46 and trolley 44 rotate at gun azimuth rate, the former because of the connections just described and the latter as a result of gyroscopic motion according to Equation 9. This arrangement permits the motor 47 to set in the proper orientation of arm 60 initially, after which it stops, while the drive from the gun both rotates the arm 60 properly and maintains the neutral section of sector 46 on trolley 43 as said trolley rotates at gun azimuth rate. The action is smooth and continuous so that shafts 45 and 55 are at all times rotated in exact synchronism with the precessional movement of gyro rotor 34, and motor 47 operates to supply the excess or deficiency of movement of sector 46 necessary to effect such synchronism over the movement supplied by way of the drive from flexible shaft 54 to shaft 55.

Differential 61 is a conventional "take-out" device and is provided to avoid erroneous adjustment of nut 69 that would otherwise be effected by pinion 68a "walking around" pinion 61d, as arm 60 is rotated. By the construction shown, actuation of drive 55 to rotate arm 60, causes the center of the differential to rotate pinion 61d by the amount necessary to maintain screw shaft 68 motionless. Thus speed settings are unaffected by pivotal adjustments of arm 60 and such settings are determined solely by rotation of handwheel 67.

The purpose of damping device 38 is to prevent the gyroscope from rotating or responding too rapidly in response to angular movements of the gun and causing instability in the circuit together with excessive hunting of the follow-up motor. It is clear that a damping value should be selected that is small enough to allow the

gyroscope to respond to true angular rates but, at the same time of sufficient value to prevent instability and excessive hunting.

An alternative damping mechanism is shown at Fig. 5 where a number of parts are duplicates of the corresponding parts used in the construction of Fig. 4 and are identified by like reference numbers so that it is considered unnecessary to describe them in detail. The damper 38 may, in general, be of the same disc-in-oil type, as used in the construction of Fig. 4. However, while the discs 30a may be secured to a trunnion 30b of ring 30, as in Fig. 4b, the casing 38 and its plates, are affixed to the rotor shaft of a repeater 75 fixed to yoke 22, as by means of a bracket 76. A transmitter 77 of any well-known type, has its rotor driven from follow-up motor 47 and is connected to control repeater 75 by standard three-phase connecting cable 78. In this manner, the damping action is transferred to the follow-up motor 47 so that only a negligible resistance to rotation of ring 30 exists when motor 47 is at rest. However, because of its rapid rotation through geared-down connection 49 and 50, motor 47 exerts a large torque on ring 30 so that said ring is effectively damped while able to respond at the proper rate to precession induced by the gun rates in following a target.

The general construction disclosed at Fig. 6 is the same as used in Figs. 4 and 5. However, instead of providing damping means directly associated with gimbal ring 30, I have mounted a damper 79 directly upon the shaft 47a of follow-up motor 47 to thereby reduce the initial acceleration and top speed of the motor. The inertia thereby added is assisted by the moment of inertia of the rotating parts of the motor 47 and that of its shaft 47a. Depending upon the value of the total moment of inertia found necessary, an inertia wheel may be added to shaft 47a. When the inertia of damper 79 is found to be too great, the inertia of the rotating parts of the motor only may be sufficient. Thus, when the tracker makes a sudden correction, the gyroscope attempts to respond, but is restrained by the damper in the species of Figures 4 and 5, while in the species of Figure 6, motor 47 is restrained. The effect of the tracker's sudden corrections upon the position of the gyroscope and arm 60, is thus minimized and the response at all times closely approaches the true average of such step-by-step corrections as the tracker may introduce. Thus the action is smooth and continuous and arm 60 is at all times positioned at the angle of approach or departure of the target relatively to a vertical plane through the gun bore.

In the claims, the term "resolving unit" means the arm 60 and parts carried thereby, together with rod 70 and connections to arm 60.

While for simplicity of explanation I have shown my invention as applied directly to, and operated by, movements of the gun itself, it will be appreciated that such a mechanical tie-up between the director and gun is not necessary. It will be obvious to those skilled in the art that the triangle-simulating mechanism may be entirely separate from the gun and connected to have its several parts adjusted with the gun, as by electric, pneumatic or hydraulic repeater connections. Furthermore, the parts of the triangle-simulating mechanism are not required to bear the exact relation to the vertical and horizontal as shown in Figure 4. Any system of Cartesian coordinate axes may be chosen to represent the vertical, and mutually normal horizontal axes,

and so long as the parts of the mechanism are adjusted with relation to these chosen coordinate axes, in the same manner as the corresponding parts of Fig. 4 are adjusted with respect to the actual corresponding vertical and horizontal axes, the device will operate as and for its intended purpose, and the angle between the sight-line side of the triangle and the part representing the gun can then be transmitted to correspondingly adjust the actual sight relatively to the real gun.

Having now fully disclosed my invention, what I claim and desire to secure by Letters Patent is:

1. In combination with means operable to angularly move a gun in train and elevation, a gyroscope including first means mounting the spin axis of said gyroscope for precession about a first axis normal to said spin axis and second means mounting said first means for pivotal movement about a second axis normal to said first axis, said second axis being parallel to the axis of gun elevation, and third means synchronously operated in response to actuation of said gun elevation means, to rotate said second means through an angle equal to two times the angle of gun elevation.

2. In combination with a gun having means to train and elevate the same, a gyroscope rotor, first means mounting said rotor for movement about a first axis normal to its spin axis, second means mounting said first means for pivotal movement about a second axis normal to said first axis and parallel to the elevation axis of said gun, and means positively operated in response to actuation of said gun elevation means, to synchronously rotate said second means and first axis, about said second axis, through an angle equal to twice the angle of gun elevation.

3. In combination with a gun movable in train and elevation, sighting means for said gun movable with said gun and angularly adjustable relatively thereto, a gyroscope including first means mounting the spin axis of said gyroscope for precession about a first axis maintained in a plane parallel to a vertical plane through the bore axis of said gun, means for angularly moving said first means to rotate said precession axis through twice the angle of gun elevation, and means responsive to the precession of said gyroscope about said first axis to angularly adjust said sighting means relatively to said gun.

4. In a gun-directing mechanism for a gun movable in elevation and train, a resolving unit comprising a plurality of pivotally mounted, interconnected arms adapted to be adjusted to define to scale a first point representing gun position, a second point representing target position at impact, and a third point representing present target position, means maintaining a line through said first and second points parallel to the gun bore, gyroscopic means precessing in response to change of elevation of the gun, and means controlled by said precession to maintain said second and third points parallel to the actual target path, means adjusting said third point relatively to said second point by a distance proportional to target speed, and sighting means having its line of sight determined by a line connecting said first and third points.

5. In a gun directing instrument, a gyroscope mounted to precess about an axis lying in a plane parallel to a vertical plane through the gun bore, means operable to elevate said axis through twice the angle of gun elevation, a resolving unit including an arm pivoted to move about a vertical

axis, a follow-up motor controlled by and in accordance with precession of said gyroscope, means connected to pivot said arm in accordance with the algebraic sum of the rotation of said motor and the train of said gun, and a sight for said gun having its angular relation thereto determined in part by pivotal movement of said arm.

6. In a gun directing mechanism, a neutrally mounted gyroscope, including first means mounting said gyroscope rotor for rotation about a first axis normal to the spin axis of said gyroscope, and second means mounting said first means for rotation about a second axis normal to said first axis, means connected to damp relative angular movement between said first and second means about said first axis, and means operable to rotate said second means about said second axis, to synchronously elevate said first axis at a rate equal to twice the rate of gun elevation.

7. In a gun directing mechanism, a gyroscope mounted in neutral equilibrium, including first means mounting the rotor of said gyroscope for pivotal movement about a first axis normal to its spin axis, and second means mounting said first means for rotation about a second axis normal to said first axis, all said axes being concurrent, means operable by and in accordance with gun elevation to rotate said second means about said second axis at a rate equal to twice the rate of gun elevation, a follow-up motor, connections responsive to precession of said gyroscope about said first axis operable to control said motor, and damping means having relatively rotatable parts, one part being connected to said first means and a second part connected to be actuated by said motor.

8. In combination with a gun having train and elevation axes, a resolving unit including means defining a triangle having a first side maintained parallel to the bore of said gun, an arm representing a second side and rotatable on an axis passing through one end of said first side, means to maintain said axis substantially vertical, a part adjustable along said arm in proportion to target velocity, a rod pivoted to said part and the other end of said first side, a gyroscope mounted to precess about an axis lying in a plane normal to said elevation axis, means to elevate said precession axis about an axis parallel to said elevation axis synchronously with, and at twice the rate of elevation of, said gun, a differential, follow-up means controlled by precession of said gyroscope to operate one side of said differential, means responsive to training of said gun to operate the other side of said differential, means driven by the center of said differential to rotate said arm, and a sight mounted in predetermined angular relation with said rod.

9. In combination with a gun having a carriage mounted for training about a substantially vertical axis, and said gun being mounted for elevation about trunnions defining a substantially horizontal axis and supported on said carriage, a first bracket fixed to said carriage, a second bracket pivoted on said gun on an axis parallel to said trunnion axis, an arm pivoted on said second bracket on an axis normal to the axis of said second bracket, means maintaining the axis of said arm parallel to the train axis of said gun, a screw shaft journaled on and along said arm, a nut threaded on said shaft, an extensible rod having one end pivotally connected with said nut and its other end uni-

13

versally pivoted on said first bracket, gyroscopic means mounted for precession about an axis in a plane normal to said trunnion axis, means operated by elevation of said gun to revolve said precession axis in said plane by twice the angle of gun elevation, and connections responsive to the precession of said gyroscope to rotate said arm.

10. The combination as specified in claim 9 and a sight connected to have its objective optical axis maintained parallel to said rod.

11. In a gun directing mechanism, means simulating to scale a triangle having a first side of fixed length and maintained substantially parallel to the bore of a gun to be directed, and a second side pivoted at one end to an end of said first side and having its effective length adjustable in accordance with the speed of a target, means mounting said second side for rotation about said one end and in a horizontal plane, a sight line device connected to remain parallel to a third side of said triangle, a gyroscope having a precession axis normal to its spin axis, said precession axis lying in a vertical plane parallel to the vertical plane through the axis of the bore of said gun and connected to be elevated in said plane at twice the rate of elevation of said gun, and means controlled by precession of said gyroscope to correspondingly rotate said second side of said triangle.

12. In a gun directing device, means simulating to scale a triangle of the gun position, present target position and future target position at the point of impact of a projectile thereon fired from said gun, the side of said triangle determined by said target positions, being adjustable in length in accordance with target speed, a gyroscope, means effecting precession of said gyroscope in accordance with a combined function of train and elevation rates of the gun, and means responsive to precession of said gyroscope for pivoting the side of said triangle determined by said target positions.

13. In combination with a gun, a carriage trainable about a vertical axis, and having bearings supporting said gun for elevation on said carriage about a horizontal axis, gear means on said carriage concentric of said elevation axis, a bracket on said gun, a pinion journaled in said bracket having one-half the effective diameter of said gear means and meshing with said gear means, a yoke rotatable by and in synchronism with said pinion, a gimbal pivoted in said yoke on a precession axis lying in a plane normal to said elevation axis, a gyroscope journaled in said gimbal for spinning on an axis normal to said precession axis and lead-determining means responsive to the precession of said gyroscope.

14. In combination with a gun, having a carriage and trunnions journaled in said carriage, first gear means fixed to said carriage concentric of said trunnions, second gear means journaled on said gun on an axis parallel to said trunnion axis, said first gear means being twice the diameter of, and meshing with said second gear means, a yoke carried by said second gear means, and a gyroscope carried by said yoke for precession about an axis lying in a plane normal to the axis of said second gear means.

15. The combination with a gun movable in train and elevation, a gyroscope mounted to precess about an axis maintained in a vertical

14

plane parallel to the gun bore and having its spin axis normal to said precession axis, means connected with said gun to rotate said precession axis in said plane about an axis normal to said plane and at an angle equal to twice the angle of gun elevation, and indicating means operated by the precession of said gyroscope.

16. In combination with a gun mounted to have mutually perpendicular train and elevation axes, a gyroscope mounted on said gun and having a first spin axis, a second precession axis normal to said spin axis and a third axis of elevation normal to said precession axis and parallel to said gun elevation axis, connections rotating said precession axis about said third axis at a predetermined multiple of the rate of gun elevation, means rotated by and in synchronism with the resulting precession of said gyroscope about said second axis, including follow-up contact means and a sector in contact with said contact means and rotatable on an axis concentric therewith, said sector having opposed insulated contacts, a differential, follow-up motor means reversely controlled by said contact means and sector, said motor operating one side of said differential, means operating a second side of said differential by and in accordance with movement of said gun about its train axis, and a shaft driven by the center of said differential and connected to operate said sector.

17. In combination with a gun trainable and elevatable about mutually perpendicular axes, a gyroscope, means mounting said gyroscope for pivotal movement about mutually normal first and second axes, said second axis being normal to the spin axis of said gyroscope, all said axes being concurrent at a point, and means connecting said gun and mounting means to positively rotate said gyroscope about its said first axis in a corresponding direction and at an angular rate equal to twice the angular rate of change of elevation of said gun, whereby said gyroscope is induced to precess about said second axis through an angle proportional to the angle of approach of a target as the gun is moved to fire on the target.

18. In combination with a gun mounted for elevation on a trainable base to follow a moving target, a gyroscope, means mounting said gyroscope on said gun for pivotal movement about mutually normal first and second axes, said second axis being normal to the spin axis of said gyroscope, all said axes being concurrent at a point, said first axis being fixed parallel with the elevation axis of said gun, and means responsive to change of elevation of said gun to rotate said gyroscope about said first axis at a rate equal to twice the rate of change of elevation of said gun as the latter is moved to follow said target, whereby said gyroscope is caused to precess about said second axis.

19. In a device for directing a gun, a speed arm pivoted at one end for angular movement about a first axis normal to said arm, an element on said arm and adjustable therealong to vary its distance from said axis in accordance with speed of a target, a directional arm pivoted at one end for angular movement about a second axis in spaced parallel fixed relation with said first axis, said axes being spaced a distance proportional to time of flight to predetermined range, of a projectile from the gun, a pivotal connection between said element and the other end of said directional arm, a gyroscope, means mounting said gyroscope in neutral equilibrium for preces-

15

sion about a third axis, means rotating said mounting means about a fourth axis normal to said precession axis, at a rate equal to twice the rate of gun elevation, means responsive to precession of said gyroscope to pivot said speed arm about said first axis, a sight, and means angularly moving said sight relatively to the gun in accordance with angular movement of said directional arm.

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