Jan. 23, 1951

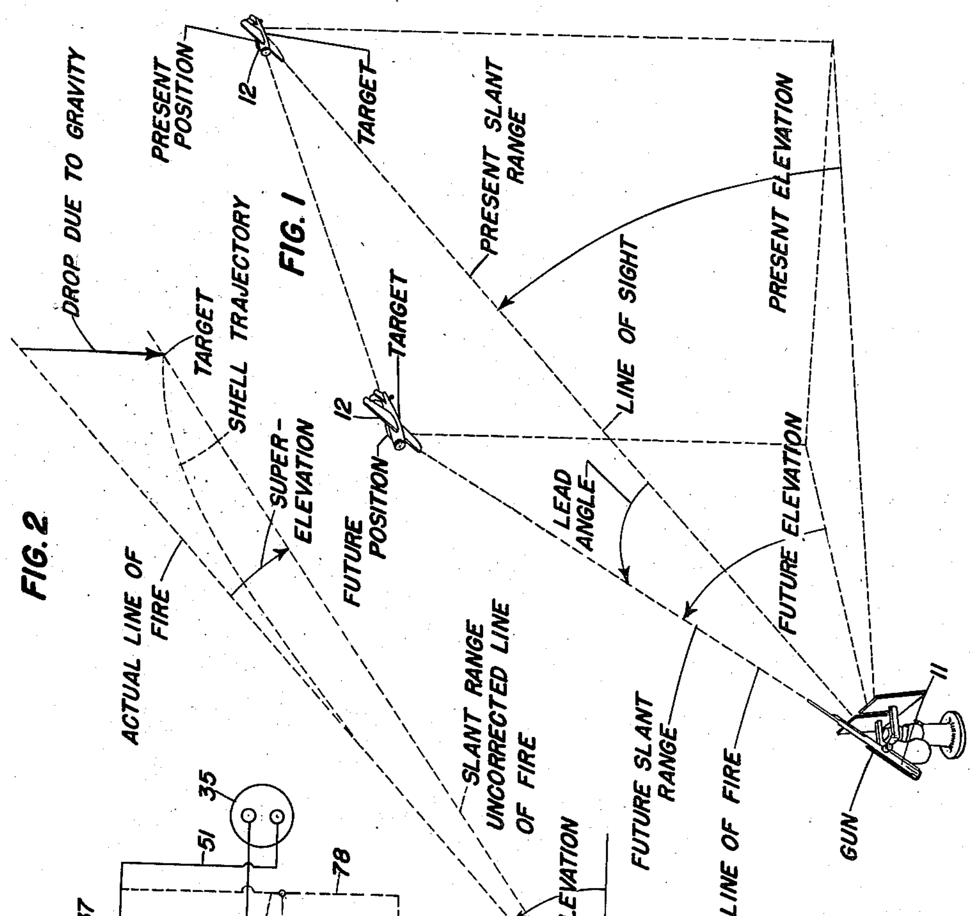
P. R. WHEELER

ELECTRICAL GUNSIGHT SUPERELEVATION AND ROLL CORRECTING DEVICE

2,538,821

Filed Dec. 19, 1945

3 Sheets-Sheet 1



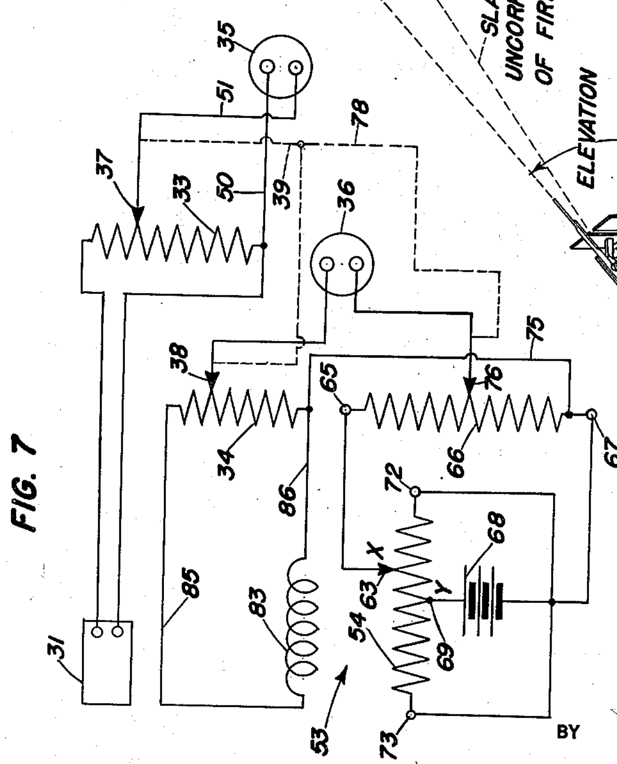


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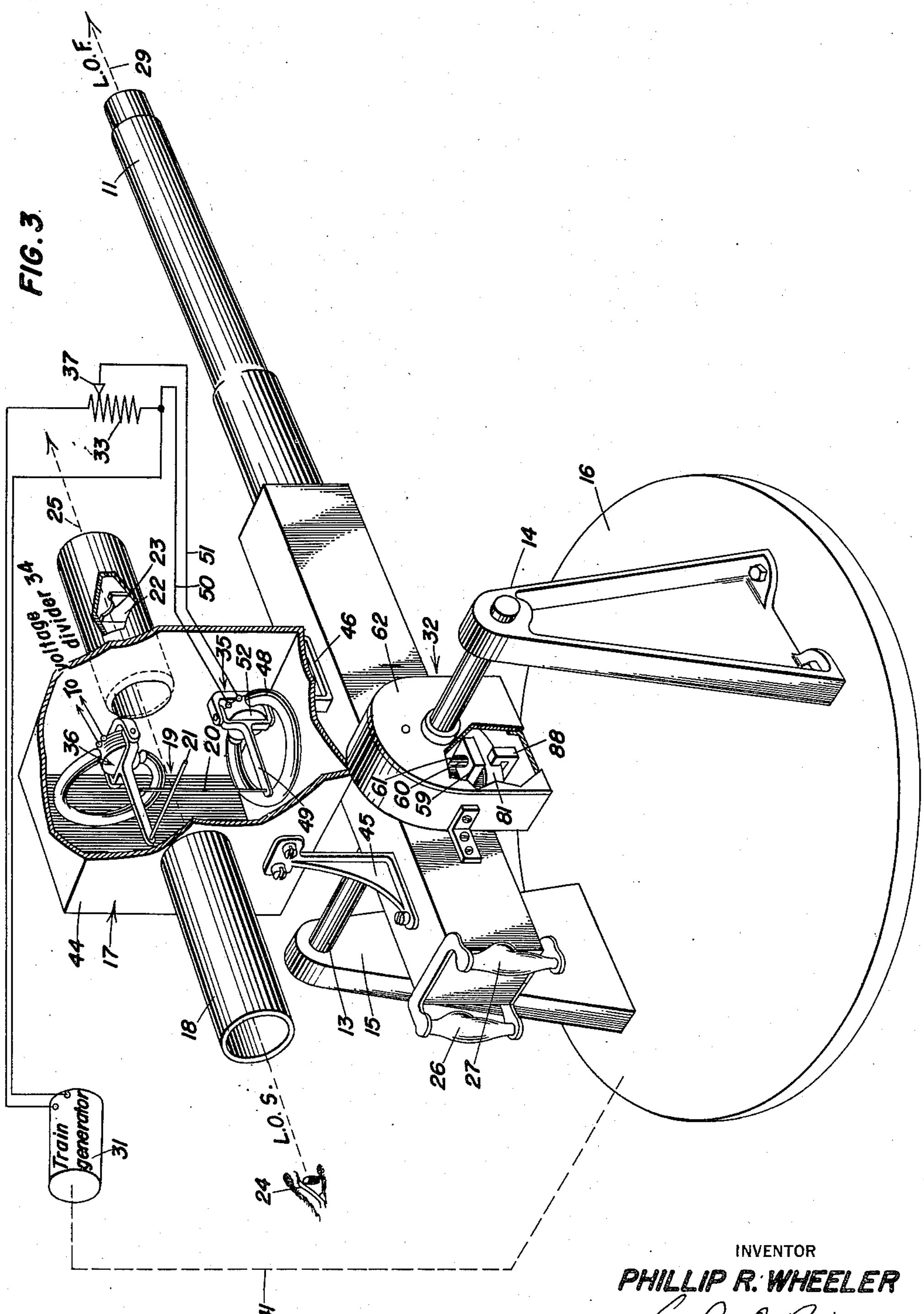
FIG. 3



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3 Sheets-Sheet 3

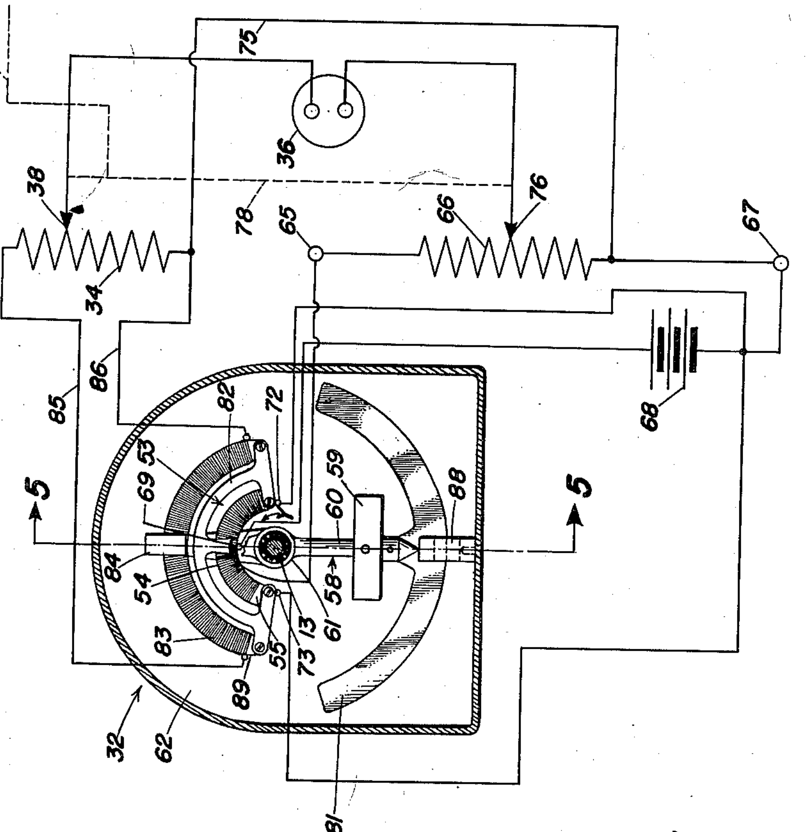

FIG. 6

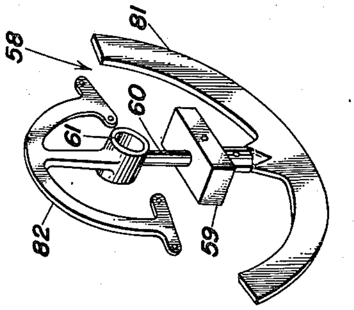

FIG. 4

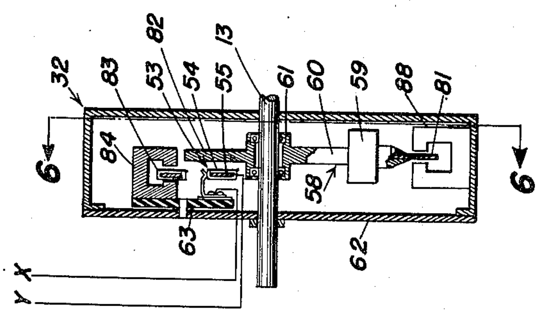

FIG. 5

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UNITED STATES PATENT OFFICE

2,538,821

ELECTRICAL GUNSIGHT SUPERELEVATION AND ROLL CORRECTING DEVICE

Phillip Rood Wheeler, Alexandria, Va.

Application December 19, 1945, Serial No. 636,046

3 Claims. (Cl. 33—49)

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

The present invention relates to gun sights and particularly to an improved gun sight superelevation and roll control device to be employed in sights operating on the disturbed-line-of-sight principle. Sights of this general character are described in the following United States patents: 1,322,153, J. S. Wilson and W. E. Dalby, issued November 18, 1919; 2,183,530, Robert Alkan, issued December 19, 1939; 1,724,093, Robert Kauch and Charles L. Paulus, issued August 13, 1929.

The present application is a continuation-in-part of my abandoned patent application, Serial Number 510,403 entitled "Cathode-ray Gun Sight" and filed in the U. S. Patent Office on November 15, 1943.

When a gunner establishes a line of sight on a moving target, he must "lead" the target by a suitable angle. That is, the weapon must be so pointed that the line of fire leads the line of sight. This "leading" is accomplished by the "target velocity" corrections of the sight setting. In the absence of these corrections the projectile would pass behind the target. The lead angle depends on the target velocity and the time of flight of the projectile, the last-mentioned parameter varying almost linearly with range for short ranges. The gunner must allow also for the effect of gravity on the projectile. In other words, he must elevate the gun above the direct line of sight to the target to allow for the drop of the projectile after it leaves the gun muzzle. This is accomplished by the superelevation corrections of the sight setting. Superelevation to correct for gravity is functionally related to range and varies as the cosine of the angle of elevation. In gun sights which operate on the disturbed-line-of-sight principle the gunner maintains the line of sight on a target by tracking the target and as he does so he manually positions the gun and sight housing. The required target velocity and superelevation corrections furnish a basis for angularly so disturbing the line of sight with respect to the line of fire that when the line of sight is maintained on the target the line of fire is appropriate to score a hit.

It is an object of the present invention to provide an improved and simple electrical arrangement for automatically applying superelevation and target-elevational-velocity-component corrections to a gun sight of the type having a displaceable reference mark.

For a better understanding of the present invention, together with other and further objects thereof, reference is made to the following specification, to the claims appended thereto, and to the accompanying drawings in which:

Fig. 1 comprises a geometrical presentation of the target velocity computation;

Fig. 2 comprises a geometrical presentation of the superelevation computation;

Fig. 3 comprises a gun and sight including a superelevation and roll control device in accordance with my invention;

Figs. 4, 5 and 6 comprise, respectively, a detailed perspective view of the pendulous member of my correcting device, an elevational sectional view taken on line 5—5 of Fig. 6, and looking in the direction of the arrows, and an elevational sectional view taken on line 6—6 of Fig. 5.

Fig. 7 comprises a diagram of the electrical circuits of my device.

Fig. 1 shows the essential features of the short range fire control problem. A gun 11 is fired at an airplane 12. At the instant of fire the airplane is at a position called the "present position." The gun should be pointed at some later position of the target called the "future position," such that the projectile will reach the future position at the same time as the target. The angle between the line from the gun to the present target position (or line of sight) and the line from the gun to the future position (or line of fire) is the lead angle. This lead angle has components in elevation and in azimuth. One of the parameters upon which the proper lead angle and sight setting are premised is the component of target velocity in the plane of elevation.

The angular velocity of the target as observed from a gun on a stationary platform is the angular movement of the target about the gun per second of time. The time of flight is obviously the time taken by a projectile to reach the target. The total angular motion of the target during the time of flight is equal approximately to the angular velocity of the target at the present position multiplied by the time of flight in seconds. Other quantities involved in the lead-computing fire control problem, such as present and future slant range are appropriately labeled in Fig. 1. It will be seen that range or time of flight is a second parameter in part determinative of the appropriate elevational sight setting.

If the gun bore is pointed at the future position of the target without further correction the projectile would then fall below the target because of the downward force of gravity. To compensate for this undesired effect of gravity the gun elevation is increased by an additional angle herein called the "superelevation" angle, as illustrated in Fig. 2. The superelevation angle required is dependent upon (*a*) the ballistics of the gun and projectile, (*b*) the time of flight of the projectile to the target, and (*c*) the cosine of the angle of gun elevation. The ballistics data of the gun can be considered constant over short ranges, and therefore the superelevation angle is calculated with a reasonable approximation according to the following equation:

$$\text{Superelevation} = \text{constant} \times \text{time of flight} \times \text{cosine of gun elevation}$$

In my copending application entitled "Gun Sight Superelevation Control Device," Ser. No. 636,045 filed in the U. S. Patent Office on December 19, 1945, now Patent 2,504,168 granted April 18, 1950, there is shown a gun sight of the type in which a reference mark is electrically deflected, not only for the purpose of introducing the target velocity correction, but also for the purpose of introducing the superelevation correction and thus overcoming the undesired effects of gravity. In my copending patent application, Serial No. 636,047, entitled "Cathode Ray Tube Gun Sight," and filed in the U. S. Patent Office on December 19, 1945, now Patent 2,459,206 granted January 18, 1949, there is shown a gun sight providing for both target velocity and superelevation corrections.

It will be noted that the discussion of the fire control problem has to this point been premised on the assumption that the gun is mounted on a stationary platform. If a gun is mounted aboard a ship, which is subject to rolling, pitching, and yawing, the problem of introducing a correction for the rate of generation of the level angle is introduced. In my above-mentioned copending patent application entitled, "Gun Sight Superelevation Control Device," the superelevation signal is referred to the true horizontal plane, but the target-elevational-velocity-component signal is obtained from a generator which produces a signal proportional to rate of motion of the gun about the supporting plane in tracking the target. This signal is a function of the rate of angular movement of the gun about trunnions which are fixed to this supporting plane. This angular movement is functionally related to target velocity when the supporting plane is stationary, but when the supporting plane rolls, then an arrangement for generating a signal proportional to rate of motion of the gun about the true horizontal is required.

In my copending patent application entitled "Gyroscopically Controlled Electrical Gun Sight," Ser. No. 636,048 filed in the U. S. Patent Office on December 19, 1945, there is shown a system which provides for the introduction of corrections to compensate both for roll and pitch (i. e. for both level angle and cross-level angle generating rates). The instant application also represents a step forward in the art but along a different route and it is addressed to the correction of superelevation and roll.

The apparent elevational component of target velocity as it appears to a gunner is related not only to target velocity but also to the time rate of change of the level angle or angle of roll. The level or roll angle is measured about an axis in the true horizontal plane. It is the angle between the true horizontal plane and the supporting deck plane, measured in a vertical plane through the line of sight.

Let it be assumed that fire is being directed athwartships at a stationary target. Let it also be assumed that the ship is rolling upwardly so that the gunner moves the gun and sight relative to the deck in keeping the line of sight on the target. In such a case it is manifest that no correction for an elevational component of velocity of the target is required. However, in a sight such as that shown in my copending application entitled "Gun Sight Superelevation Control Device," and operating under such an assumed set of facts the gun would be turning about the trunnions and the action of the elevation generator would be such as to introduce an undesired disturbance of the line of sight with respect to the line of fire. It will be seen that when the trunnions are supported on a stationary horizontal platform the elevational rate of tracking of the target is linearly functionally related to target velocity. However, when the gun is mounted on a platform which rolls and introduces the generation of a level angle into the fire-control problem, then the tracking of the target must be referred to the true horizontal, that is, it must be functionally related to the motion between the gun and the true horizontal plane, rather than the motion between the gun and the supporting plane. In the case of a gun mounted on a rolling ship, the generated signals for the elevational-component-of-target-velocity-correction should be obtained from a generator which produces a signal functionally related to the rate of generation of the angle between the gun and the true horizontal rather than a signal functionally related to the rate of generation of the angle between the gun and the deck. In accordance with one aspect of my invention I provide a generator in which the tracking rate is referred to the true horizontal. Under the facts assumed above, a gun and sight equipped with my improved electrical gun sight superelevation and roll correcting device would operate in this manner: The gun would not move relative to the horizontal, the generator would not generate any signal and the line of sight would not be disturbed with reference to the line of fire by introducing an undesired elevational-component-of-target-velocity-correction.

Referring now specifically to Fig. 3, there is illustrated in combination with a universal gun mount carrying a gun for movement in elevation and in azimuth, a sighting arrangement. This arrangement comprises an optical system which provides a reference mark on which a target is viewed and means responsive to dynamic movement of the gun in azimuth for moving the reference mark in azimuth. The system also comprises my novel gun sight superelevation and roll-correcting device and this device comprises means responsive to dynamic movement of the gun in elevation with reference to a fixed frame of coordinates for moving the reference mark in elevation by an amount functionally related to the rate of such movement and means for displacing the reference mark in elevation by an additional amount functionally related to the elevational position of the gun with respect to a fixed frame of coordinates.

The system disclosed in Fig. 3 may be briefly described by stating that it essentially comprises the combination illustrated in Fig. 3 of my copending patent application, Ser. No. 636,045, entitled "Gun Sight Super Elevation Control Device," filed in the U. S. Patent Office on December 19, 1945, as modified by the substitution of my improved electrical gun sight superelevation and roll correcting device for the elevation generator and the gun sight superelevation control device there illustrated. Specifically, however, a gun 11 is mounted for turning in elevation on trunnions (one of which has the reference numeral 13) journaled in bearings on suitable supports 14, 15. The gun is suitably mounted for movement in train (azimuth) by reason of the fact that the supports 14, 15 are secured to a turnable platform 16. The Fig. 3 embodiment also includes automatic compensating sighting apparatus for use in combination with the gun, this apparatus being generally designated by the numeral 17. The sighting apparatus comprises a telescope casing 18, a back sight member or reference mark 19 comprising movable crosshairs 20 and 21, a front sight 22, and other desired optical elements (not shown). The reference mark provided by the intersection of the crosshairs 20 and 21 is centered in the peep or arcuate notch 23 on the front sight 22, as viewed by the eye 24 of the gunner and a line of sight 25 is in this manner defined from the operator's eye to the target. In placing the line of sight on a target the operator grasps the handles 26, 27 and swings the gun in elevation and train while keeping the line of sight defined by the reference mark and by peep 23 on the target, the reference mark being superimposed on the target.

It will be noted that the gun defines a line of fire 29. The target-velocity, ship's roll, range, and superelevation correction are developed in the sighting apparatus in such a manner as to govern the position of the reference mark provided by the intersection of crosshairs 20, 21 and thus to disturb the line of sight with reference to the line of fire. By keeping the disturbed line of sight on the target the operator then automatically manually maintains the line of fire in a correct position. The gun 11, trunnions 13, supports 14, 15, turntable 16, telescope casing 18, crosshairs 20, 21 and front sight 22 are individually of the prior art and schematically shown. Any suitable arrangements for performing the same functions may be substituted for them.

The Fig. 3 embodiment also includes prior-art means responsive to dynamic movement of the gun in azimuth for moving the reference mark in azimuth for the purpose of introducing that component of the lead angle which is functionally related to the train component of target velocity and range. This means includes a conventional reversible generator 31 for generating a direct-current electrical signal-voltage representative of the rate of tracking of the target in train (i. e., the component of target velocity in the plane of train or slant plane). My improved electrical gun sight superelevation and roll correcting device indicated generally by the numeral 32 on Fig. 3 (and described in detail in connection with the explanation of Figs. 4, 5 and 6) generates an electrical signal voltage representative of the elevational component of the target velocity (i. e., the tracking range in elevation). The output circuits of these generators are individually coupled to variable voltage dividers 33 and 34 (Fig. 7). The output of voltage divider 33 is coupled to a galvanometer 35 and the output of voltage divider 34 is coupled to a galvanometer 36. The sliding contacts 37, 38 of potentiometers 33 and 34 are ganged by any suitable expedient indicated by the dashed line 39 for purposes of range or time-of-flight correction. Galvanometer 35 positions crosshair 20 and galvanometer 36 positions crosshair 21. The operation of elements 31, the generator part of 32, 33, 34, 35, 36, 37, 38 and 39, is such as to cause the reference mark to be positioned in elevation and in azimuth in coordination with the movements of the gun in elevation and in azimuth and thus to introduce the proper lead angle by causing the reference mark to be so positioned that the line of fire leads the line of sight. With the exception of unit 32, elements 31—39 are of the prior art and further description thereof is deemed unnecessary. A suitable generator corresponding to generator 31 is shown in the above mentioned U. S. Patent No. 1,322,153. Suitable galvanometers and crosshair arrangements corresponding to elements 20, 21, 35 and 36 are shown in the above mentioned U. S. Patent No. 1,724,093.

The rotor of train generator 31 is coupled to turntable 16 by any suitable mechanical expedient indicated by the dashed line 41 in such manner as to cause the generator rotor to move in coordination with the movement of the gun in train. This generator may be secured adjacent the turntable 16 by any suitable supports such as brackets (not shown). The elements of my sighting system so far described in detail and assigned numbers, taken in the aggregate, essentially constitute a sight as shown in the above-mentioned U. S. Patent No. 1,724,093, as modified by the substitution of the train generator of the above mentioned U. S. Patent No. 1,322,153 for the hydraulic train lead computing arrangement shown in said U. S. Patent No. 1,724,093, and as further modified by the substitution of my improved superelevation and roll correcting device 32 for the elevational lead computing arrangement shown in said U. S. Patent No. 1,724,093. This device performs not only the function of an elevation generator such as that shown in U. S. Patent No. 1,322,153 but also the additional functions of providing for roll and superelevation correction.

Formed about the casing 18 is a suitable housing 44. The assembly of housing 44 and casing 18 is rigidly secured to the gun by suitable brackets 45, 46. Galvanometer 35 comprises a circular magnet 48. This magnet influences lever 49 at the extremity of which is mounted crosshair 20. At least a part of the current flowing in conductors 50 and 51 passes through a coil 52 mounted near the fulcrum point of the lever 49. This arrangement causes the lever which controls crosshair 20 to move from the central position shown by an amount directly proportional to the amount of current flowing through the circuit and thus by an amount functionally related to the input signal applied thereto by train generator 31. The movement is in a direction dependent on the polarity of this signal, which polarity in turn depends upon the direction of train. Galvanometer 36 is similar in construction and operation to galvanometer 35 and its relationship to the superelevation and roll correcting device 32 is substantially the same as that of galvanometer 35 to train generator 31.

The operation of that part of the sighting arrangement so far described is briefly as follows: As an ascending target is tracked by the operator the signals from unit 32 cause crosshair 21 to be elevated, with the ultimate result that the line of fire has a greater elevation than the line of sight; conversely, as a descending target is tracked, crosshair 21 is downwardly displaced and the lead-angle correction tends to depress the line of fire with respect to the line of sight; similarly, as a target moving to the left is tracked, crosshair 20 is moved to the left and as a target moving to the right is tracked, crosshair 20 is moved to the right. Thus the problem posed by Fig. 1 is effectively solved The range factor is introduced by positioning elements 37, 38 and 39 in a manner taught in the above mentioned U. S. Patent No. 1,322,153. For a given rate of target velocity, the deflection of the reference mark should be relatively small at short ranges and relatively greater at longer ranges, as is well known to those skilled in the fire-control art.

The sighting arrangement also includes my improved superelevation and roll correcting device, shown in detail in Figs. 4, 5 and 6. For purposes of describing the construction and operation of the superelevation-correction portion of the device, it will be assumed that turntable 16 is at a stop and on the true horizontal and that the trunnions 13, 13 are parallel to turntable 16. It will further be assumed that the line of fire provided by gun 11 is normal to the axis of the trunnions. The line of sight has already been disturbed in such a manner as to introduce corrections for target velocity. However, the solution of the problem posed in Fig. 2 requires a superelevation control for applying to the disturbing means (galvanometer 36) an electrical signal having a magnitude trigonometrically functionally related to the angle of the elevation of the gun, thereby to actuate the galvanometer 36 to disturb the reference mark and the line of sight by an amount trigonometrically functionally related (as the cosine), to the angle of elevation. When such a superelevation control is provided the maintenance of the line of sight on a target causes the line of fire to be angularly elevated with respect to the line of sight by the amount of the desired superelevation correction. The means for supplying the superelevation-correction signals comprises a potentiometer 53, including a resistor 54 wound on an insulating and supporting form 55. The form is secured to segment 82 of a pendulous member indicated generally at 58 and comprising a weight-portion 59 integral with an arm 60. The pendulous member is pivotally secured to one of the trunnions 13 by a suitable bearing expedient indicated at 61. The pendulous member is angularly movable relative to gun 11. Secured to the housing 62 is an insulating block on which is mounted a metallic contact element 63. Weight portion 59 maintains arm 60 on the true vertical and the unit 32 is so arranged that contactor 63 is in the center of resistor 54 when the line of fire is parallel to the horizontal plane. Housing 62 is rigidly secured to gun 11.

A closed circuit (Fig. 7) is formed from contact 63, terminal 65, resistor 66, terminal 67, battery 68, terminal 69 and that portion of resistor 54 between contact 63 and the terminal 69. Terminal 69 is connected to the midpoint of resistor 54 (as indicated by the letter "Y"). When the line of fire is parallel to the horizontal plane and contact 63 is at the midpoint on resistor 54, the full (positive, say) potential of battery 68 is impressed across resistor 66. When the line of fire is elevated by 80°, for example, resistors 66 and 54 are so proportioned that the potential appearing across resistor 66 is equal to the product of 0.1736 and the full potential of battery 68. This potential is of the same polarity. When the line of fire is depressed from the horizontal by 10°, the potential of positive polarity then appearing across resistor 66 is equal to the product of 0.9848 and the full potential of battery 68. The two halves of resistor 54 are therefore not uniformly distributed and resistor 54 is so wound that the variation of resistance as contact 63 moves from terminal 69 to terminal 72 is not linear, but varies in accordance with a cosine function of the angle of elevation. The angle of elevation is the angle between the line of fire and the horizontal plane as measured in a plane perpendicular to trunnions 13 and the horizontal plane. Additionally, the resistor winding portion between terminals 69 and 73 is also so shaped that the potential impressed across resistor 66 varies in accordance with a cosine function of the angle of depression of the line of fire 29. The output portion of voltage divider 34 and the output portion of resistor 66 are connected in series by conductor 75 and the terminals 38, 76 of this series combination are coupled to galvanometer 36. The output potential of voltage divider 34 causes the behavior of crosshair 21 to be determined in part by the elevational component of the velocity of the target and range as explained hereinabove. The output potential appearing in resistor 66 causes the behavior of galvonometer 36 and the crosshair 21 also to be determined in part by the elevation of the target. Therefore, the position of crosshair 21 is a function of two arguments, the first of these arguments being a rate or dynamic condition and the second being a position or static condition. Additionally, the first of these arguments is in turn a function of two parameters: motion of own ship and motion of the target.

As described above, the ganging of contacts 37 and 38 by expedient 39 provides a range adjustment. Since the superelevation correction is also functionally related to range there is provided a sliding contact 76 on the potentiometer which includes resistor 66. This sliding contact is ganged with sliding contacts 37 and 38 by any suitable expedient indicated by the dashed line 78, to the end that the range adjustments for target velocity and for superelevation may be made by one operation.

In explaining the operation of the above described superelevation control portion of my improved superelevation and the roll correcting device, it will be assumed that the interior and exterior ballistics have been determined, that range tables are available, that the characteristics of the gun and the projectile are known, and that a selected stationary target is depressed from the horizontal plane and located on a line normal to trunnion 13. For purposes of simplicity it will be assumed that the target position is such that a hit is mathematically predictable if the line of fire 29 is horizontal. Under that assumed condition, gravity is exercising its maximum effect on the projectile. The sight is therefore so adjusted that contact 63 is at terminal 69 and the full potential of battery 68 appears across the resistor 66. Crosshair 20 is then centered within tube 18 and crosshair 21 is moved from center by adjustment of galvanometer 36 while the gun is held stationary, in order to align the eye of the operator 24, the reference mark formed by the intersection of the crosshairs, the peep 23 and the target. The line of sight is then on the target and a hit should be scored when the gun is fired. The line of sight is disturbed to a maximum extent for any given range, under this condition. Now let it be assumed that fire should be directed to another target which is stationary and located immediately above and at 90° of elevation to the gun. Under that condition the potential appearing across resistor 66 is 0, contact 63 is at terminal 72, and the reference mark provided by cross-hairs 20 and 21 is centered in tube 18, so that the line of fire is not disturbed. The distance of the gun from target may be regarded as infinite with respect to the distance between casing 18 and the gun. Between these two terminal conditions (when firing on targets between 0 and 90° of elevation) the voltage appearing across resistor 66 is trigonometrically functionally related to and varies as the cosine of the angle of elevation. The range adjustment is provided by the ganging expedient 78 which adjusts the position of sliding contact 76.

In practice, the ballistics of the gun and the projectile are obtained from range tables. The fire control problem is capable of mathematical solution and the characteristics of the train and elevation units 31 and 32, resistor 66, resistor 54, and voltage dividers 33—34, and 66—76, as well as those of galvanometers 35 and 36 are mathematically determinable, so that specific circuits parameters are a matter of specific engineering design and depend upon the individual requirements for the system to be used, as will be clearly understood by those skilled in the art.

Figs. 4, 5 and 6 illustrate further details of my improved electrical gun sight superelevation and roll correcting device. A pendulum 58 is mounted on pivot 61 in housing 62. The housing is rigidly secured to gun 11 (Fig. 3). The pendulum has a weight 59 located below the pivot and has an arcuate sheet of copper, aluminum or other conductor 81 located at its lower end. The sheet 81 comprises an arc of a circle having the pivot 61 as its center. On the upper arm of the pendulum is an arcuate segment 82 which is formed as an arc of a circle having the pivot 61 at its center but having a smaller diameter than the arc of sheet 81. Segment 82 is T-shaped at each end in order to support the forms on which coils of wire 54 and 83 are wound. As hereinabove described, winding 54 comprises the resistor portion of the superelevation control potentiometer. Winding 83 comprises the armature winding of the elevation generator. The armature winding 83 is positioned to move between the poles of a magnet 84, this magnet being rigidly secured to housing 62. The motion of the coil of wire 83 in moving between the poles of the magnet as gun 11 is elevated or depressed causes a voltage to be generated in the coil 83 which is then conveyed by suitable wiring 85, 86 to potentiometer 34.

A resilient contact 63, rigidly secured to housing 62 and properly insulated bears against the coil 54 to form the superelevation control potentiometer, the contact and the coil being connected to the galvanometer 36 by the wiring arrangement hereinabove described. The coil 83 is wound on and insulated from a metallic form 89. A magnet 88 is positioned in the lower part of the pendulum housing 62 so that the segment 81 moves between its poles. The purpose of magnet 88 and segment 81 is to provide desired damping of the oscillation of the pendulum.

The output voltage from the pendulum controlled generator comprising elements 83 and 84 is combined with the output from the superelevation correction potentiometer and applied to the elevation galvanometer 36 as indicated above.

Returning now to the hypothetical situation posed hereinabove, let it be assumed that the gunner does not move the gun 11 relative to the true horizontal in maintaining a line of sight on a stationary target. Under that assumed set of facts pendulum 58 does not move, coil 83 does not move relative to magnet 84 and no target elevational velocity component signal appears across conductors 85, 86. This is a desired condition. The output signal of the elevation generator is therefore referred to the true horizontal. That is, this generator generates a voltage which is proportional to the rate of the motion of gun 11 in the elevational plane with respect to the true horizontal.

While there has been shown and described what is at present considered to be a preferred embodiment of the invention, it will be obvious to those skilled in the art that various modifications and changes may be made therein without departing from the true scope of the invention. And it is, accordingly, intended in the appended claims to cover all such changes and modifications as fall within the true scope of the invention and without the proper scope of the prior art.

The invention herein described may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

I claim:

1. In combination with a gun movable in planes of elevation and train, a gunsight adapted to move in unison with said gun comprising electrical means for providing a reference mark in the line of sight of a gunner movable in two mutually perpendicular directions each substantially normal to said line of sight in response to a first and second electrical quantity, means responsive to the dynamic movement of the gun in train for developing said first electrical quantity of magnitude proportional to the rate of said movement, circuit connections for applying said value to said electrical means to cause movement of said reference mark in a direction substantially normal to the plane of elevation and opposite the direction of train, stabilizing means mounted on said gun for establishing a plane of reference, means moveable about said stabilizing means for developing said second electrical quantity comprised of the algebraic sum of a first component and a second component, said first component being produced by the dynamic movement of said gun in the plane of elevation relative to said reference plane and of a magnitude proportional to the rate of said movement, said second component being produced by the angular position of said gun in the plane of elevation relative to said reference plane and of a magnitude proportional to the cosine thereof, and circuit connections for applying said second electrical quantity to said electrical means to cause movement of said reference mark in a direction parallel to the plane of elevation of said gun.

2. The combination defined in claim 1 above wherein said circuit connections contain adjustable impedance means whereby the magnitude of said first and second quantities may be altered in accordance with changes in the range to said target.

3. The combination defined in claim 1 wherein said stabilizing means comprises a damped pen-

dulous means, said first component producing means comprises respectively a generator having an armature winding and a field producing magnet, and said second component producing means comprises a potentiometer coupled to a voltage source having a moving contact and resistor portion, said winding and resistor portion being supported by said damped pendulous means, said stabilizing means being further characterized by the addition of a housing for said pendulous means secured to said gun for movement about said pendulous means on movement of said gun in the plane of elevation, said housing supporting said contact and said magnet.

PHILLIP ROOD WHEELER.

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