March 8, 1949. R. M. BURLEY ET AL 2,464,195

GUN SIGHTING DEVICE AND REFLECTING MEANS THEREFOR

Filed Jan. 4, 1940 4 Sheets-Sheet 1

Fig. 1

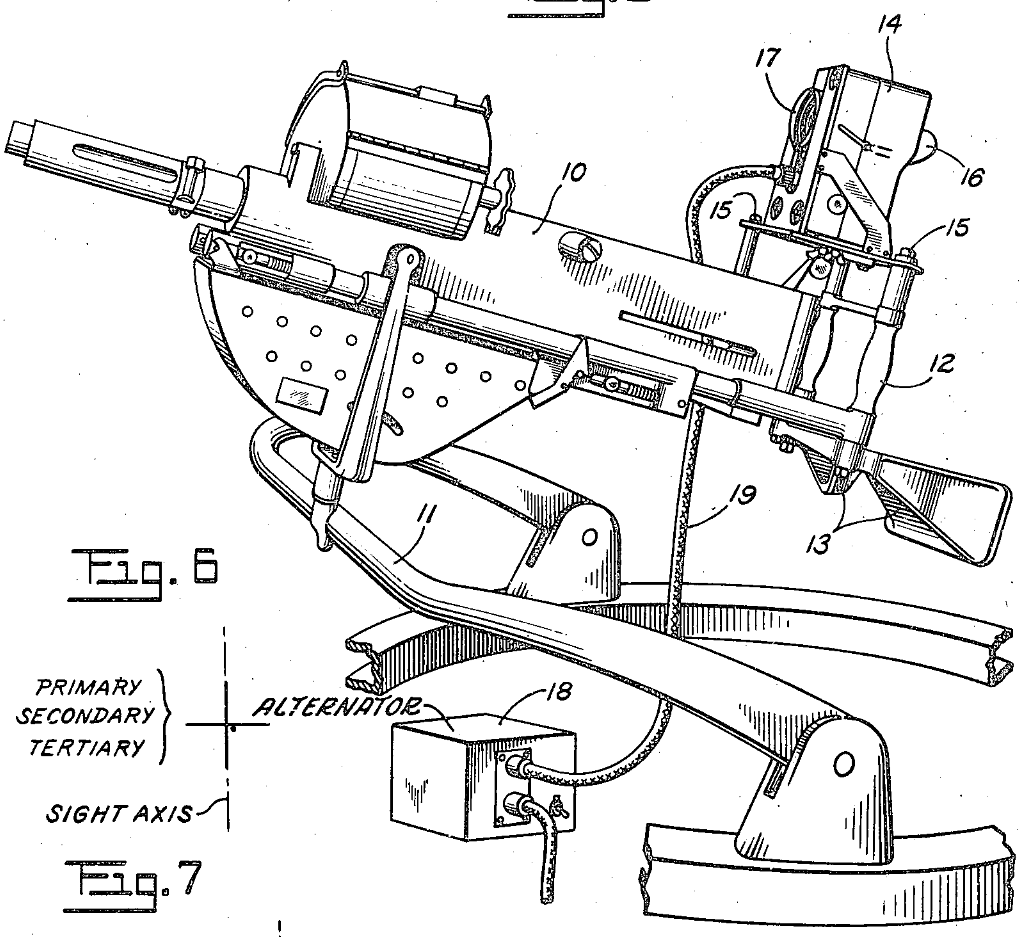


Fig. 7

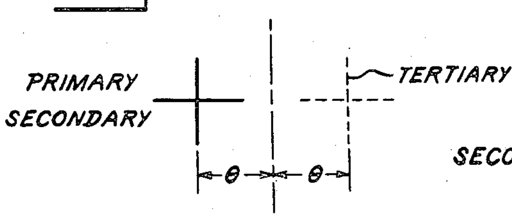


Fig. 8

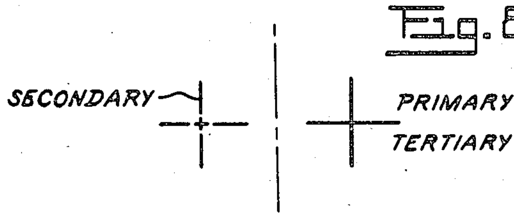
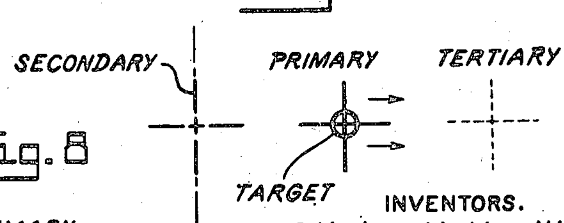


Fig. 9



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GUN SIGHTING DEVICE AND REFLECTING MEANS THEREFOR

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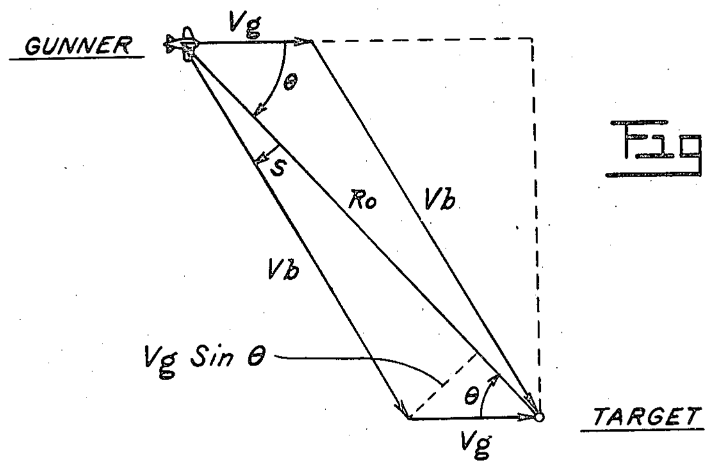

Fig. 2

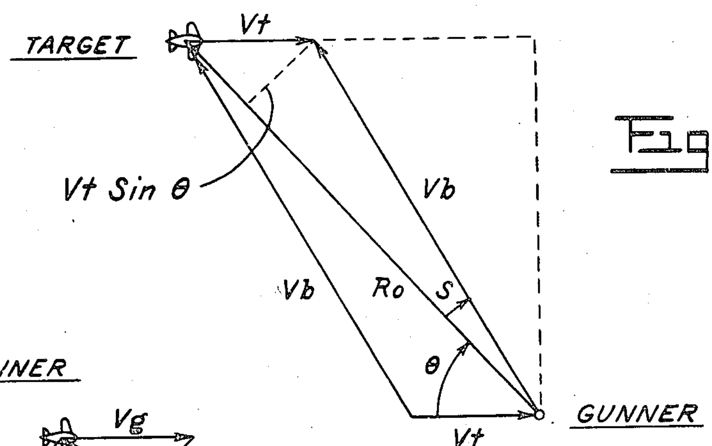

Fig. 3

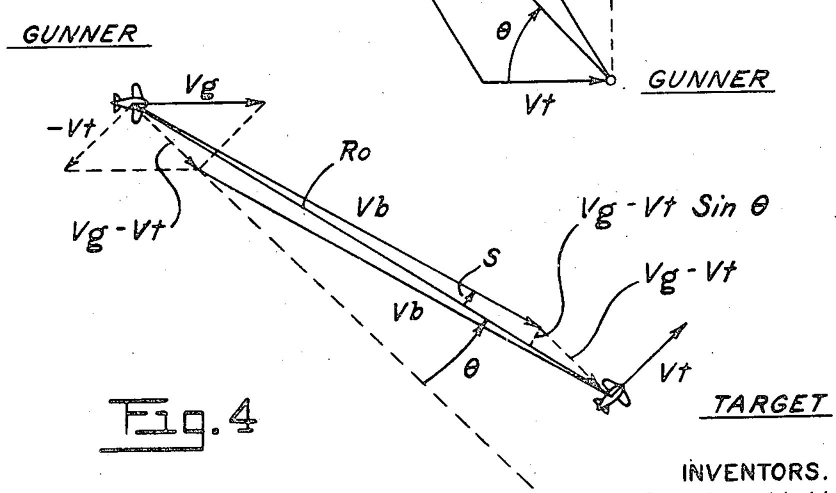

Fig. 4

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GUN SIGHTING DEVICE AND REFLECTING MEANS THEREFOR

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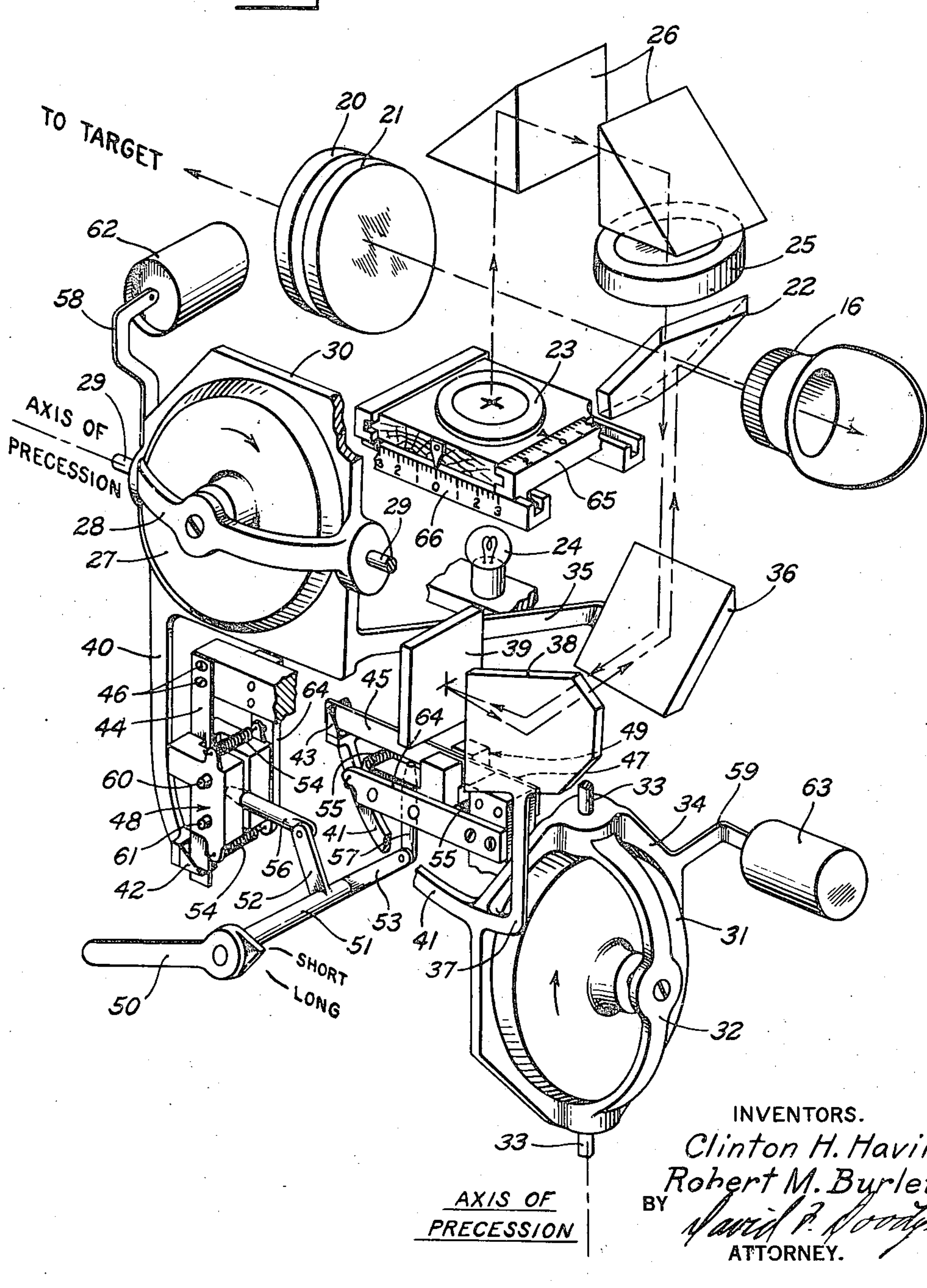
Fig. 5



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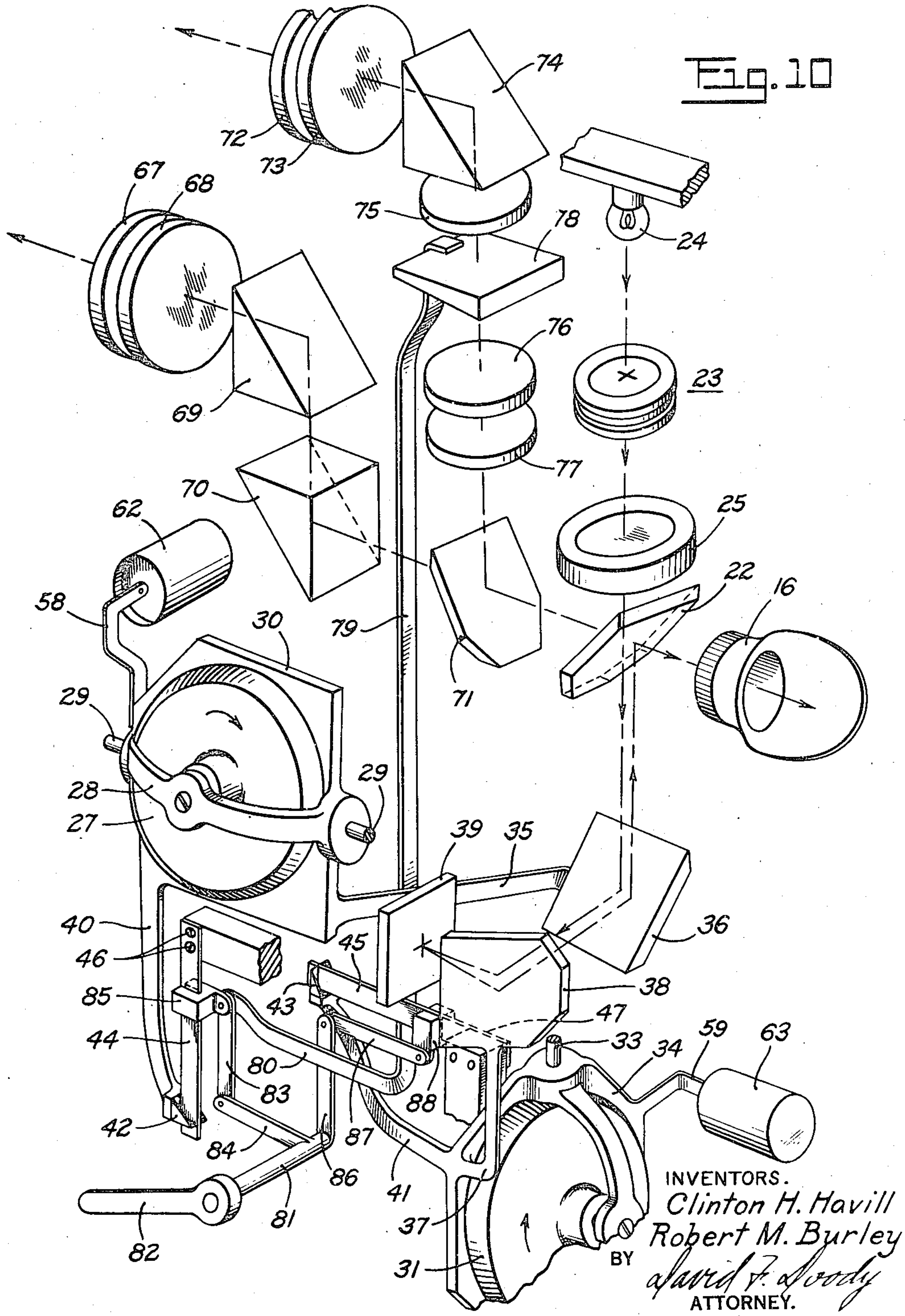
GUN SIGHTING DEVICE AND REFLECTING MEANS THEREFOR

Filed Jan. 4, 1940 4 Sheets-Sheet 4

Fig. 10



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Patented Mar. 8, 1949 2,464,195

UNITED STATES PATENT OFFICE

2,464,195

GUN SIGHTING DEVICE AND REFLECTING MEANS THEREFOR

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Application January 4, 1940, Serial No. 312,416

15 Claims. (Cl. 88—1)

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This invention relates to optical systems and more particularly to a sighting device intended for use with military arms.

In firing at a background or target where there is relative motion between the gun and the target, it is necessary in sighting, to allow the gun-barrel to lead the target by a definite amount since in the interval between firing and the arrival of the projectile at the target, the target has moved forward a distance depending on its velocity during the interval. Since the elements entering into determination of the proper angle of lead are difficult to resolve mentally, mechanical and optical devices have been devised in the past for predetermining the proper lead of gun-barrel over a target, but heretofore none of these devices have been able to consistently operate with the precision, accuracy, and reliance necessary for a satisfactory sighting device adapted to modern combat conditions.

In accordance with the present invention, an improved sighting device is provided which utilizes a novel combination of known gyroscopic and optical principles so that when the device is adapted to a military arm, such as an anti-aircraft or aircraft machine gun, accurate fire control is obtained.

It is one of the objects of the present invention to provide a sighting device adapted particularly for gun use which will be highly accurate and dependable in the directing and controlling of fire.

Another object of the present invention resides in the provision of a novel device utilizing the precessional movement of gyroscopes in order to control the operation of a novel optical system for giving precision in sighting.

Other objects of the invention include the application of a novel calibrating system for sighting devices and the provision of means for adjusting operation of the sighting device in accordance with the range of the target. Additional objects and advantages of the novel system of the present invention will appear in the reading of the following specification in conjunction with the attached drawings, in which numerals of like character designate similar parts throughout the several figures:

Fig. 1 is a view in perspective showing the novel sighting device of the present invention mounted upon an aircraft machine gun;

Fig. 2 is a vector diagram from which the formula for the sight correction angle is derived for the condition in which the gunner is moving and the target is stationary;

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Fig. 3 is a similar diagram for the condition in which the gunner is stationary and the target is moving;

Fig. 4 is a similar diagram for the conditions in which both gunner and target are moving;

Fig. 5 is a diagrammatic showing of one embodiment of the novel optical system and gyroscopic control therefor in accordance with the present invention;

Fig. 6 is a diagrammatic representation of the reticule images produced when the sighting device and the gun are at rest;

Fig. 7 is a representation of the reticule images of the sighting device as they appear under certain conditions of calibration;

Fig. 8 is a representation of the reticule images as they appear under certain other conditions of calibration;

Fig. 9 represents the reticule images as they appear under certain conditions of firing; and

Fig. 10 is a view similar to Fig. 5 showing another embodiment of the present invention.

Generally speaking, the present invention comprises a novel optical system adapted particularly for use in a gun-sight, whereby the correct sight angle or angle of gun-barrel lead is obtained by merely rotating the gun in train and elevation upon its object until a moving reticule image becomes superimposed upon the object. In this condition, the sighting device determines the proper position of the gun-barrel, taking into account the relative velocity between the object or target and the gunner's position, so that accurate fire control is obtained. Also in accordance with the present invention, a novel method of calibrating the gun is provided to determine the rate of response of the sighting device as a function of angular velocity modified by range.

The displacement of the reticule image as the gun is moving in order to maintain it trained upon the target, effects the necessary sight correction between gun-barrel and gun-sighting device so that the transit time of a projectile is compensated for by an amount proportional to the relative angular velocity between gunner and target.

It is well known that if a gyroscope is mounted so that its axis of spin is in a certain plane, then upon angular motion of that axis, the gyroscope will precess about an axis at right angles to the direction of application of the disturbing force, provided that the gyroscope is free to precess about such an axis. It is also known that the torque exerted by a gyroscope in precessing, is proportional to the rate at which the axis of spin is disturbed. These known laws have been utilized in the present invention to control certain optical elements which are made variable in order to displace a reticule image in accordance with the apparent angular velocity of an object upon which the gun-sight is directed.

Having reference to Fig. 1, there is shown generally a machine gun 10 of conventional design, carried by a flexible mounting designated 11 so that the gun is free to be moved about associated horizontal and vertical axes by an operator who normally stands at the right of the gun 10, grasping handles 12 and having the stocks 13 tightly pressed against his upper arms. In this position the operator is directly in the line of sight of the object upon which the gun is directed. The sighting device of the present invention is shown at 14 rigidly mounted upon gun 10 by any well known means, such as bolts 15. An eyepiece 16 is provided in the wall of the housing facing the operator's position and on the opposite wall thereof is an annular member 17 surrounding an aperture containing suitable transparent members such as Polaroids, as will be later described. An alternator 18, or other source of voltage is shown connected to housing 14 by means of a flexible cable 19 introducing an electrical driving source to the housing for a purpose to be described below.

It can be shown that the mathematical formula upon which the sight correction depends utilizes the same constant and variable elements for the three cases of:

I. Gunner moving and target stationary;
II. Gunner stationary and target moving; and
III. Gunner moving and target moving.

In the derivation of the formulae for the three cases above set forth, Vb, the velocity of the bullet has been considered as a constant. This is substantially so, for the ranges and calibre for which the gun-sight shown in Fig. 5, for example, is intended for use.

In Fig. 2, which is a vector diagram setting forth the conditions applicable to case I above, S=the sight correction angle in radians, commonly called the angle of lead, by which the gun-barrel is trained in advance of the sighting device in order to compensate for the transit time of a projectile, which time is obviously a function of the range.

Ro=the range,
Vg=the gunner's velocity vector
Vb=bullet velocity vector.

In this case the proper sight correction angle S is found to be that for which the vector sum of

Vb and Vg=Ro

It will be seen that

$$\sin S=\frac{Vg}{Vb}\sin\theta \qquad (1)$$

where θ=the target bearing angle with respect to the gunner's course.
Let W=angular velocity of gun-sight axis, then

$$W=\frac{Vg}{Ro}\sin\theta \qquad (2)$$

Let

$$K=\frac{Ro}{Vb}=\text{time of flight of bullet}$$

and since over the ranges for which the device of the present invention is intended for use, Vb is

practically constant, then K, for a given gun and type of bullet, varies directly with range, and

$$KW=\frac{Vg}{Vb}\sin\theta$$

and

$$\sin S=KW \qquad (3)$$

Having reference to Fig. 3 which relates to the conditions set forth for case II above

Vt=target velocity vector

For proper sight correction angle the vector sum of

Vb and Vt=Ro

Similarly to (1) above,

$$\sin S=\frac{Vt}{Vb}\sin\theta$$

and similarly to (2) above,

$$W=\frac{Vt}{Ro}\sin\theta$$

then

$$\sin S=KW \qquad (4)$$

Case III represents the usual combat conditions existing between aircraft and these conditions are set forth in Fig. 4. Since in this case, target, gunner and bullet all have velocities with respect to an observer on the ground, the relative velocity between gunner and target is the vector difference, $Vg-Vt$ and as Ro, the range, is the resultant or vector sum of all velocities, then

$$Ro=(Vg-Vt)+Vb$$

Similarly to (1) above,

$$\sin S=\frac{(Vg-Vt)}{Vb}\sin\theta \qquad (5)$$

and similarly to (2) above,

$$W=\frac{(Vg-Vt)}{Ro}\sin\theta$$

introducing

$$K=\frac{Ro}{Vb}$$

and substituting in (5) above,

$$\sin S=KW \qquad (6)$$

It will be noticed that the Formulae 3, 4, and 6 are identical, hence the same formula applies in each of the cases I, II and III, to give the correct sight correction angle. As W is the angular velocity of the gun-sight axis, it is seen that the sight correction angle varies with the speed of rotation of the gun and the sight. As K is said to depend upon the time of flight of the bullet from gun to target, it will be readily seen that K is a function of the range and, therefore, the sight correction angle depends not only on the velocity of the gun-sight about its axis, but also upon the range. The effects of gravity and windage have been neglected in this formula, but these effects can be considered in a manner to be described later.

One embodiment of the gun-sight of the present invention is shown in Fig. 5, which is a partly schematic representation of the optical system and the gyroscope control of the system. Light from a target or background, not shown, is transmitted through suitable light filters, such as Polaroids 20 and 21 and to the eye of an observer through eyepiece 16. Disposed in the line of sight between Polaroids 20 and 21 and eyepiece 16, is a reflecting glass 22, mounted in a plane at 45° to the neutral axis of sight. This glass may have its surfaces treated in any conventional manner so that it is transparent to about 60 per cent of light and opaque to about 40 per cent of light. A reticule 23, the surface of which may be of glass etched and painted with a cross thereon, is illuminated by any suitable light source such as lamp 24 shown mounted directly below reticule 23. A lens 25 of any suitable design is placed at its focal distance from reticule 23 and serves to cause the image of reticule 23 to appear in focus when superposed on the field of the target. In order to make the optical system compact, reflecting prisms 26 are utilized and are conventionally mounted, as shown, in the path of light between the reticule 23 and lens 25. Since reflecting glass 22 is mounted at 45° to the neutral axis of sight and since Polaroids 20 and 21 are mounted perpendicular to the neutral axis of sight, light coming from the reticule 23 will be reflected from the surfaces of glass 22 to the surface of Polaroid 21, thence to the eye of an observer through eyepiece 16. This image, which hereafter may be called the secondary image of the reticule, will always appear stationary with respect to the line of sight as long as reticule 23 is in fixed position.

As shown, a gyroscope 27 of conventional design is mounted to spin in a horizontal axis in bearings carried by gimbal 28. At right angles to the axis of spin and in a horizontal plane, is a second axis of rotation about which gyroscope 27 is free to precess, namely, that through horizontal shaft 29 of gimbal frame 30. Another gyroscope 31, mounted to spin in a horizontal axis by means of bearings carried by gimbal 32, is mounted so as to be rotatable about a precessional axis through vertical shaft 33 carried by gimbal frame 34. These gyroscopes may be spun by any conventional means. For example, they might have incorporated into their structure suitable electric motors and be driven by a voltage source such as 18 of Fig. 1. An arm 35 extends from gimbal frame 30 and carries a mirror 36 normally at an angle of 45° to the horizontal, rotatable about axis 29 according to precession of gimbal frame 30. Another arm 37 is carried by gimbal frame 34 and there is mounted thereon mirror 38 disposed in a vertical plane and adapted to be rotated upon precession of gyroscope 31 about vertical axis of shaft 33.

Another mirror 39 is fixedly mounted in a vertical plane and all three mirrors 36, 38 and 39 are so mounted with respect to the line of light from reticule 23 through lens 25 and reflecting glass 22, that light is reflected from mirror 36 to mirror 38, thence to mirror 39 whence it is reflected back to mirror 38, thence to mirror 36 to the surfaces of reflecting glass 22 and to the eye of an observer through eyepiece 16. This image may be referred to as the primary image of the reticule.

A third image is also formed, and is apparent on the surface of Polaroid 21 through eyepiece 16. This image is due to the reticule image which is cast back upon the painted surface of the reticule glass after traversing prisms 26, lens 25, glass 22, mirrors 36, 38, and 39, and then returning over the same path. It is then viewed by the eye through the same optical system which forms the primary image. This image, which may hereafter be called the tertiary, actually moves over the surface of the reticule glass according to the movements of mirrors 36 and 38, but it appears to stand still to the observer since its motion is actually counteracted by the motion of mirrors 36 and 38 through which it is viewed. Its movement can be verified, since looking through the gun-sight from Polaroids 20 and 21, it appears to move with gun rotation, as it is not then viewed through the movable mirrors 36 and 38.

Gimbal frames 30 and 34 carry additional arms 40 and 41, respectively, which are also rotatable with their gimbal frames about the horizontal and vertical axes of shafts 29 and 33, respectively. Arms 40 and 41 (the latter shown broken for clarity) carry, at their outer extremities, slotted guide members 42 and 43, respectively, which are adapted to frictionally engage leaf springs 44 and 45, respectively. These springs are rigidly mounted at points 46 and 47 and having a predetermined stiffness or spring rate, offer resistance equal to the force of precession at a rate proportional to the rotation or precession of gyroscopes 27 and 31. Split blocks designated generally as 48 and 49 are interposed between the ends of springs 44 and 45, respectively, so as to alter the effective lengths thereof. A handle 50 is mounted on the end of shaft 51, carrying lever arms 52 and 53 which are pivotally connected to conical-ended rods 56 and 57. By means of handle 50, rods 56 and 57 are simultaneously withdrawn from, or inserted into, semi-circular slots or holes carried by opposite faces of the split blocks 48 and 49. In the drawing, rods 56 and 57 are shown inserted in the semi-circular slots of these split blocks so as to force pairs of the blocks apart against the tension of the coil springs 54 and 55 and in this position the split blocks are maintained out of contact with springs 44 and 45. Upon manipulation of handle 50 to withdraw rods 56 and 57, the split blocks will be drawn together by action of coil springs 54 and 55 and will clamp springs 44 and 45 at fixed points along their lengths in order to change the stiffness or spring rate of springs 44 and 45 by a predetermined amount. The split pairs of blocks 48 and 49 are constrained to move toward and away from each other in parallel relationship by means of pins 60 and 61, which have their far ends, not shown, fixed to any suitable portion of the sight housing, such as member 64. Similar pins are utilized to maintain split blocks 49 in parallel relation when in motion, but these pins are not shown since they are identical in structure to pins 60 and 61, and it is believed their operation is sufficiently described above.

Changing the stiffness or spring rate of the springs 44 and 45 changes their resistance to precessional torque and serves to govern the movement and the rate of movement of the gyroscopes upon rotation of the gun-sight about its horizontal or vertical axis. In order to damp the movement of the gyroscopes and thus prevent excessive oscillation of the movable mirrors 36 and 38 upon precession of gyroscopes 27 and 31, arms 58 and 59 extending from gimbal frames 30 and 34, respectively, are attached to pistons movable within dash-pots 62 and 63 of any conventional form.

It is well known that the precessive torque exerted is proportional to the angular velocity of the disturbance of the gyroscope's axis of spin. If the gyro is allowed to precess through a large angle, the spin axis, which moves through the same angle, becomes appreciably displaced with respect to the plane in which it is desired to measure the angular rate. This results in an error in the measurement of angular rate in the desired plane, and further causes the gyro to be affected by angular rates in the plane at right angles to that in which angular rate measurement is desired. These errors are minimized to a negligible amount when the angles through which precession occurs are small, but where the precessive angles are appreciable, the errors become a sizeable factor.

By means of the structure shown in Fig. 5, very small angles of precession are adequate to cause rotation of movable mirrors **36** and **38** a sufficient amount to cause the primary image of the recticule to move through an angle equal to the largest sight correction angles occurring in present aerial combat. The spring rate of springs **44** and **45** is made such that when the sight is trained upon a target at long range, then the stiffness of the spring controls the speed of precession in an amount sufficient to allow the gun-barrel to lead over the gun-sight by an angle which, depending upon the muzzle velocity of the projectile and the distance or range to be traversed, is correct for making a hit. When the sight is trained upon a target at short range, handle **50** is manipulated to withdraw conical-ended rods **56** and **57** from the split blocks **48** and **49** and force these blocks to clamp springs **44** and **45** at a point along the length of each which is predetermined to control the precession of gyroscopes **27** and **31** at a different rate, thus changing the angle of lead of gun-barrel over gun-sight by an amount sufficient to compensate for the transit time of a bullet to reach the target at short range.

In the operation of aiming the gun at a moving target, the reticule images are at first all in registry on the sight axis or zero reference, as indicated in Fig. 6, but as the gun is trained upon the target, the primary image will be displaced and when, while the gun is still being rotated, the primary image is superposed upon the target, as shown in Fig. 9, the gun is in position to be fired.

In order to correctly center the reticule **23** with reference to the complete optical system of the gun-sight, there is schematically shown in Fig. 5, scale means **65** and **66** by which the reticule's zero position can be gauged. Scales **65** and **66** which, in actual practice may be micrometers of any conventional form, serve also to enable the gun-sight to be accurately bore-sighted to offset the effect of gravity upon a projectile. When the recticule **23** is in the zero-zero position, as indicated by the scales **65** and **66**, the secondary and tertiary images are superposed at a zero point which point becomes an important reference from which it is possible to introduce the correct amount of bore-sighting to compensate for gravity and windage and, by virtue of which, a novel and valuable method of calibration (described below), in order to introduce the correct value for K, the range factor, can be based. Since the time for light to travel from the target to the gunner is practically zero as compared to the time that it takes a projectile to travel from the gun to the target, it is obvious that if the angle of sight correction disregards the transit time of the projectile, then a hit cannot be correctly predicted.

The windage correction can be introduced by offsetting the reticule image. Considering windage to be a force exerted upon the projectile in proportion to the air speed of the gunner, which force acts in a horizontal direction upon the projectile, reticule **23** can be moved horizontally and vertically at predetermined amounts from the zero reference in order to offset the effect of windage and windage jump due to gyroscopic action of the projectile. As the particular method of determining the amount of windage correction is no part of the invention, and since methods for computing the amount of correction are well known, this correction will not be further described herein.

In accordance with the present invention, a novel means and system is provided for calibrating a gun-sight in order to measure the (K) constant of proportionality between sight correction angle and angular velocity of the gun-sight, developed by the device.

Assuming that Polaroid **21** is fixed, and assuming that Polaroid **20** has been rotated to exclude most of the external light, reticule **23** can be centered by means of scales **65** and **66** so that its primary, secondary and tertiary images coincide and this can represent the condition of zero bore-sight and zero correction for muzzle velocity. When the base of the gun-sight is situated in a horizontal plane and when the gun-sight is otherwise at rest, the primary, secondary and tertiary images will coincide as indicated in Fig. 6. When it is desired to calibrate, i. e. measure the value of K, the range constant produced by the device in the horizontal plane, reticule **23** can be moved so that its image will shift in the horizontal plane by an amount measured upon scale **65**. This condition is set forth in Fig. 7 and the amount by which the tertiary image has been displaced horizontally is indicated as θ. At the same time, the primary and secondary images is 2θ. This apparent angle through an angle θ in the opposite direction, so that the total relative apparent movement between the tertiary image and the primary and secondary images is 2θ. This apparent angle 2θ can, in practice, be measured by viewing through the device a known reference scale.

Measurement of the value of K can then be effected by rotating the device in a horizontal plane at an angular velocity sufficient to bring the primary and tertiary images into coincidence, measuring the said angular velocity W by any conventional means, such as a tachometer, and substituting the known values 2θ, and W in the formula

$$\sin 2\theta = KW$$

By similarly displacing reticule **23** in a vertical plane and rotating the device in a vertical plane, the K in the vertical plane may be likewise measured.

A range finding device may be embodied in the present invention, as shown in Fig. 10, and the act of setting the range of the target introduces, by the novel means shown, the proper rate of gyroscopic precession control to correctly direct fire. In addition to those elements shown with numerals corresponding to the same parts as in Fig. 5, there is also provided a pair of Polaroids **67** and **68**, similar to **20** and **21** of Fig. 5, prisms **69** and **70**, and reflecting glass **71**, through which may be viewed an image of a background or target, not shown. Reflecting glass **71** is disposed at forty-five degrees to the neutral axis of sight and may have its surfaces treated in a manner similar to the surfaces of glass **22**, so as to partially transmit and partially reflect light. Prisms **69** and **70** serve to direct light, in a conventional manner, to eyepiece **16** from Polaroids **67** and **68**. There are also provided an additional pair of Polaroids 72 and 73, similar to 67 and 68, and a prism 74 for deflecting light from a target to reflecting glass 71. In the path of light from prism 74 to reflecting glass 71, there is interposed a system of focusing lenses 75, 76, 77, of any conventional type, and also a prism 78 having its upper and lower faces in non-parallel or angular relation. Prism 78 is supported and made adjustable vertically by arm 79 to which it is secured by any conventional means. Vertical arm 79 has a horizontal, or otherwise angularly disposed portion 80, which is connected to shaft 81 and handle 82, by means of a loosely pivoted link 83 and crank arm 84. Connected to link 83 and movable by handle 82 is a block 85, frictionally engaging spring 44 and slidable therealong. Also connected to shaft 81, and movable together therewith upon manipulation of handle 82, is another crank arm 86, to which is loosely pivoted a link member 87. A second block 88, similar to block 85, frictionally engages spring 45 and is slidable therealong in a horizontal line of direction upon manipulation of handle 82.

There is only one position of prism 78, between lenses 75 and 76, at which the background image, viewable through eyepiece 16, due to light received at reflecting glass 71 from Polaroids 72 and 73, will be in registry, upon reflecting glass 71, with the image of the background received through Polaroids 67 and 68. This is true, since due to the angular relation between its upper and lower surfaces, light will be refracted and leave the lower face at a constant angle from the vertical. Therefore, the position at which light strikes lens 76 depends on the axial position of prism 78.

If the images of the background, as viewed through eyepiece 16, do not coincide, then by manipulation of handle 82, prism 78 can be moved to such a position that the images do coincide, and in this position the range of the background or target is obtained. The correct range setting is then utilized to control the rate of precession of gyroscopes 27 and 31 in a manner quite similiar to that set forth in the description of Fig. 5. Blocks 85 and 88 which, while slidable along springs 44 and 45, respectively, nevertheless tightly engage the surfaces of the springs in such a manner as to act as fulcrums for the flexing of the springs at the points at which the blocks 85 and 88 grip springs 44 and 45. It will be seen, therefore that the rate of precession of the gyroscopes will be varied in accordance with the points of contact between blocks 85 and 88 and springs 44 and 45, respectively, and these points of contact are dependent upon the position of prism 78 which effects registry of the binocular images of the target. As the registry depends directly upon the range of the target, sliding blocks 85 and 88 can be maintained at the proper points along springs 44 and 45, so that the factor K, which varies with the range, will be automatically introduced upon the finding of the range of the target. Since the device shown in Fig. 10, is otherwise similar to that shown in Fig. 5, which has been fully described above, it is believed that the operation of the device, as shown in Fig. 10, will be clearly understood from the description of Fig. 5 above, without further description. Reticule 23 is adjustable in the manner as set forth for reticule 23 of Fig. 5, but for clarity, scales 65 and 66 are omitted from Fig. 10. Also the novel system of calibration, above described, in accordance with which the correct value for K is introduced into the instrument, is applicable to the embodiment shown in Fig. 10.

While the sighting device of the present invention is shown mounted to an aircraft machine gun, it will be obvious that the novel sighting device is also adapted for use as a bomb-sight and for control of fire from anti-aircraft and other guns which are intended to be fired at a target having motion relative to the gun.

While the words "horizontal" and "vertical" have been constantly referred to throughout the specification as descriptive of the axes about which gyroscopes 27 and 31, respectively, precess, and the word "horizontal" has been used also to define the axes of spin of gyroscopes 27 and 31, the respective axes are movable in planes other than the horizontal and vertical, particularly when the sighting device is mounted to an aircraft machine gun as illustrated in Fig. 1. Since the invention is obviously not limited to a fixed sight and since the sight is equally effective in operation regardless of its attitude with respect to the horizontal and vertical, the word "normally" as used in certain of the claims, has reference to the case in which the base of gunsight 14 is in a horizontal plane. Reference therefor to "horizontal" and "vertical" axes or planes is not intended as a limitation of the invention to an instrument having gyroscopes in fixed planes and with fixed axes, but merely as an indication of one condition of use. While the gyroscopes are mounted fixedly with respect to each other, in use they may be rotated as a unit into innumerable planes other than the horizontal and vertical, as will be readily understood. Further, it is to be understood that gyroscopes 27 and 31 may be of any conventional design. Their showing in Figs. 5 and 10 is primarily schematic and they may be driven by any means, such as air, conventional in the art.

While only two embodiments of the invention have been described in detail, the invention may be embodied in other forms and it will be understood that many changes may be made without exceeding the scope of the invention. It is, therefore, not intended to limit the invention to the particular embodiments described, but by the scope of the appended claims.

What is claimed is:

1. A sighting device for a gun rotatable about normally horizontal and vertical axes, said sighting device comprising a housing, an eyepiece for viewing a background through said housing, a transparent glass within said housing and angularly disposed with respect to the line of sight, an optical system within said housing, said system comprising a reticule, means for directly lighting said reticule, a lens placed at its focal distance from said reticule for projecting an image of said reticule in focus with the background viewed a first mirror rotatable about a normally vertical axis, a second mirror rotatable about a normally horizontal axis, a third mirror to receive and reflect back light from said first and second mirrors, said mirrors being optically disposed between said lens and said eyepiece, a first gyroscope mounted so as to precess about a normally vertical axis upon rotation of said gun about its normally horizontal axis, a second gyroscope mounted so as to precess about a normally horizontal axis upon rotation of said gun about its normally vertical axis, said first and second mirrors being connected to said first and second gyroscopes, respectively, and so mounted

with respect thereto as to be rotated about their aforesaid axes upon precession of their respective gyroscopes, said third mirror being stationary, whereby upon precession of either gyroscope, the image of the reticule becomes displaced.

2. A gun sight for a gun rotatable about normally horizontal and vertical axes, said gun sight comprising an optical system and a control system operative upon movement of said gun to adjust portions of said optical system in accordance with the velocity between said gun and a target, said optical system including an eyepiece, a reticule, a reflecting glass, said control system including a first gyroscope mounted to precess about a normally vertical axis, a second gyroscope mounted to precess about a normally horizontal axis, a mirror in said optical system mounted upon each gyroscope so as to be rotatable about their respective axes of precession, said mirrors being located in the path of light between said reticule and said eyepiece, a stationary mirror in said optical system and mounted adjacent the mirrors mounted upon said gyroscopes and so adjusted as to reflect light from one of the movable mirrors back to said movable mirror, thence to the other of said movable mirrors, to said reflecting glass and to said eyepiece, whereupon as said control system is moved, the mirrors mounted upon said gyroscopes will be rotated and displace the image of said reticule upon the background sighted.

3. A sighting device for a gun adapted to be directed about normally horizontal and vertical axes, said sighting device having an optical system comprising certain light reflecting elements fixed with respect to said gun, other light reflecting elements movable with respect to said gun, a reticule and a reflecting glass in said optical system, means for projecting an image of said reticule in focus with the background viewed, a gyroscope mounted upon said gun so as to precess upon normally horizontal motion of said gun about said vertical axis, a second gyroscope mounted upon said gun so as to precess upon vertical movement of said gun about said normally horizontal axis, said light reflecting elements being disposed in a line of light from said reticule, one of said movable light reflecting elements being mounted upon each of said gyroscopes and rotatable thereby about their axes of precession whereby upon movement of either of said movable elements, the image of the reticule is displaced.

4. A gun sight adapted to be mounted on a gun in a fixed relation, comprising an optical system and a mechanical system to control said optical system upon movement of the gun-barrel, said optical system comprising an eyepiece through which a background is to be viewed, a reflecting glass mounted in the line of sight, a reticule, means for illuminating said reticule, a lens placed at its focal distance from said reticule for projecting an image of said reticule in focus with the background sighted, said mechanical system comprising a first gyroscope mounted to precess about a normally horizontal axis, a second gyroscope mounted to precess about a normally vertical axis, and a mirror mounted upon each gyroscope so as to be in said optical system and to be rotatable about their respective axes of precession, a stationary mirror mounted adjacent the first mentioned mirrors and so situated that light from said mirrors is reflected from said stationary mirror back to said first mentioned mirrors, to said reflecting glass and thence to said eyepiece to form a second image in focus with said background, whereby both said images are visible through said eyepiece to an observer, said first mentioned mirrors being rotated upon precession of said gyroscopes, and means connected to said gyroscopes to move one of said images with respect to the other at a rate proportional to the rate of movement of said gun.

5. A sighting device adapted to be trained upon an object, comprising a housing, an aperture in one wall of said housing facing the object, an eyepiece on a wall of said housing opposite said aperture so that the object is in the line of sight passing through said aperture and said eyepiece, a reflecting glass disposed within said housing in said line of sight, a reticule, means for illuminating said reticule, means for optically superposing an image in focus with the background of said object, a first mirror, a second mirror, a first gyroscope mounted so as to precess about a normally vertical axis, a second gyroscope mounted so as to precess about a normally horizontal axis, said first and second mirrors being mounted upon said first and second gyroscopes, respectively, so as to be rotatable about their axes of precession, a third mirror mounted adjacent said first and second mirrors, said mirrors being in the light path between said reticule and said eyepiece and so disposed relative to each other that a light from said reticule is thrown upon said reflecting glass so that upon precession of either of said gyroscopes upon movement of said housing, the said mirror mounted thereon will be rotated, and displace said image with respect to said background.

6. In a sighting device, an eyepiece through which an object may be viewed, a reflecting glass disposed within the line of sight, a reticule, means for illuminating said reticule, means for focusing an image of said reticule upon the background of said object, a reflecting member beyond said eyepiece and said reflecting glass and disposed in the line of sight normal thereto, a first mirror mounted so as to receive light from said reticule through said reflecting glass, a second mirror mounted so as to receive light reflected from said first mirror, a third mirror so mounted as to receive light from said second mirror and reflect it back to said second mirror, thence to said first mentioned mirror to said reflecting glass and reflect a second reticule image toward said eyepiece, a first gyroscope mounted to precess about a normally horizontal axis upon movement of the sighting device in a normally horizontal plane, a second gyroscope mounted to precess about a normally vertical axis upon movement of said sighting device in a normally vertical plane, said first and second mirrors being mounted to be rotatable about the said axes of precession of said first and second gyroscopes, respectively, so that upon movement of said sighting device said second reticule image is displaced upon said background.

7. Apparatus for sighting upon a background, comprising a housing having an aperture in the wall intended to face said background, an eyepiece in the opposite wall thereof, a reflecting glass within said housing and disposed in the line of sight, a semi-transparent and reflecting member located within said aperture, a reticule, means for illuminating said reticule, means for forming an image of said reticule viewable at said eyepiece, a first mirror angularly movable with respect to said housing upon movement of said housing in a normally horizontal plane,

a second mirror angularly movable with respect to said housing upon movement of said housing in a normally vertical plane, said mirrors being in the path of light from said reticule to said eyepiece and disposed so that light from said reticule passing through said reflecting glass strikes said mirrors in sequence and is reflected back in reverse sequence to said reflecting glass forming a second image of said reticule upon said background, moveable with respect to the first mentioned image and reflecting light from said second image through said eyepiece.

8. Apparatus for sighting upon an object, comprising a housing containing in one wall thereof, an eyepiece, a combined reflecting and transparent member in the wall opposite said eyepiece, a reflecting glass within said housing and disposed in the line of sight between said eyepiece and said reflecting and transparent member, a reticule, means for casting an image of said reticule in focus with said object, said image being reflected from said combined reflecting and transparent member through said eyepiece, a first mirror optically disposed between said reflecting glass and said eyepiece, a second mirror optically disposed to receive light reflected from said first mirror, a third mirror mounted to receive light from said second mirror and reflect it to said second mirror, said mirrors being so disposed that they receive light in series from said reticule through said reflecting glass and reflect said light back to said reflecting glass, forming a second image viewable from said eyepiece, and means for moving said first and second mirrors in accordance with the relative velocity between the object being viewed and the sighting apparatus so that said second image is displaced with respect to the first named image.

9. A sighting device adapted to be directed in train and elevation upon an object, comprising a housing having a transparent member in one wall thereof, an eyepiece in the opposite wall thereof, a reflecting glass disposed in the line of sight, a reticule, means for casting an image of said reticule in the plane of said object, said reflecting glass being so mounted as to project said image upon the surface of said transparent member to be thereby viewable through said eyepiece, mirrors mounted within said housing so as to be rotatable about different axes at right angles, said mirrors being so disposed as to be in the path of light between said reflecting glass and said eyepiece and reflect light from an image of said reticule upon said reflecting glass, and means for rotating said mirrors upon movement of said housing in elevation and train, whereby the last named image moves with respect to the first named image, and may be directed upon the object to be viewed.

10. A sighting device for mounting in fixed relation to a flexible gun, comprising a casing, an eyepiece in one wall of said casing, a transparent member in the wall opposite said eyepiece and being in the line of sight between said eyepiece and an object to be viewed, a reflecting glass disposed within the line of sight, a reticule, said reflecting glass being mounted at such an angle to the line of sight as to reflect light to said transparent member, a first mirror mounted to receive light from said reticule through said reflecting glass, means associated with said mirror to rotate it about a certain axis upon rotation of said gun, a second mirror mounted to receive light from said first mirror, means associated with said second mirror for rotating it about an axis at right angles to the first mentioned axis upon rotation of said gun and means adjacent said first and second mirrors for doubling the light from said mirrors back upon said mirrors and to said reflecting glass, whereby upon rotation of said gun, an image viewed through said eyepiece moves in accordance with the relative motion between the gun and the object viewed.

11. Sighting means for a gun adapted to be mounted on a universal gun mount for movement in elevation and in azimuth, said sighting means comprising an optical system including a reticule fixed with respect to said gun and displaceable means for forming an image of said reticule in the field of view in which the target is observed, said last-named means comprising a first mirror mounted to receive an image of said reticule thereon, a second mirror mounted to receive the image from said first mirror, a third relatively fixed mirror for receiving and transmitting the image of said reticule back to said second and first mirrors and therefrom into the field of view in which the target is observed, and means responsive to the movement of said gun in elevation and in azimuth for moving said first and second mirrors relative to said third mirror whereby said image is displaced in coordination with the movement of the gun.

12. Sighting means for a gun adapted to be mounted on a universal gun mount for movement in elevation and in azimuth, said sighting means comprising an optical system including a reticule fixed with respect to said gun and displaceable means for forming an image of said reticule in the field of view in which the target is observed, said last-named means comprising a first mirror mounted to receive an image of said reticule thereon, a second mirror mounted to receive the image from said first mirror, a third relatively fixed mirror for receiving and transmitting the image of said reticule back to said second and first mirrors and therefrom into the field of view in which the target is observed, and rate-of-turn gyros actuated by movement of said gun in elevation and in azimuth for moving said first and second mirrors relative to said third mirror whereby said image is displaced in coordination with the movement of the gun.

13. Sighting means for a gun adapted to be mounted on a universal gun mount for movement in elevation and in azimuth, said sighting means comprising an optical system including a reticule fixed with respect to said gun and displaceable means for forming an image of said reticule in the field of view in which the target is observed, said last-named means comprising a first mirror mounted to receive an image of said reticule thereon, a second mirror mounted to receive the image from said first mirror, a third relatively fixed mirror for receiving and transmitting the image of said reticule back to said second and first mirrors and therefrom into the field of view in which the target is observed, means comprising a pair of two-degree-of-freedom gyros mounted for precession about two axes normal to each other, yieldable means for said gyros for constraining precession of one of said gyros to a rate of turn function during movement of said gun in elevation and for constraining precession of the other of said gyros to a rate of turn function during movement of said gun in azimuth, and means connecting said first and second mirrors to said gyros whereby in response to movement of said gun in elevation and in azimuth said first and second mirrors are moved by said

gyros relative to said third mirror to thereby displace said image in coordination with the movement of the gun.

14. Sighting means for a gun adapted to be mounted on a universal gun mount for movement in elevation and in azimuth, said sighting means comprising an optical system including a reticule fixed with respect to said gun and displaceable means for forming an image of said reticule in the field of view in which the target is observed, said last-named means comprising a first mirror mounted to receive an image of said reticule thereon, a second mirror mounted to receive the image from said first mirror, a third relatively fixed mirror for receiving and transmitting the image of said reticule back to said second and first mirrors and therefrom into the field of view in which the target is observed, means comprising a pair of two-degree-of-freedom gyros mounted for precession in axes normal to each other, yieldable means for said gyros for constraining precession of one of said gyros to a rate of turn function during movement of said gun in elevation and for constraining precession of the other of said gyros to a rate of turn function during movement of said gun in azimuth, means connecting said first and second mirrors to said gyros whereby in response to the movement of said gun in elevation and in azimuth said first and second mirrors are moved by said gyros relative to said third mirror to thereby displace said image in coordination with the movement of the gun, and range setting means connected to said yieldable means for altering the constraint thereof on said gyros.

15. Sighting means for a gun adapted to be mounted on a universal gun mount for movement in elevation and in azimuth, said sighting means comprising an optical system including a reticule fixed with respect to said gun and displaceable means for forming an image of said reticule in the field of view in which the target is observed, means responsive to movement of said gun in elevation and in azimuth for moving said image forming means relative to said reticule whereby said image is displaced in coordination with the movement of the gun, range finding means for said sighting means comprising a movable prism for producing an image of said target and for bringing said image into coincidence with the image of said reticule in the same field of view, means for altering the motion of said image forming means, and control means for operating said prism and said last-named means.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,067,859	Bacon et al.	July 22, 1918
1,308,134	Wilson et al.	July 1, 1919
1,324,519	Power	Dec. 9, 1919
1,383,660	Proctor	July 5, 1921
1,493,095	Barr et al.	May 6, 1924
1,509,167	Morse	Sept. 23, 1924
1,524,788	Gardner	Feb. 3, 1925
1,616,660	Henderson	Feb. 8, 1927
1,639,229	Luckey	Aug. 16, 1927
1,650,626	Hewlett et al.	Nov. 29, 1927
1,664,454	Hunt et al.	Apr. 3, 1928
1,783,769	Bates	Dec. 2, 1930
1,852,166	Kaster	Apr. 5, 1932
1,935,615	Coupland	Nov. 21, 1933
1,936,442	Willard	Nov. 21, 1933
1,980,886	Talafre et al.	Nov. 13, 1934
2,125,225	Gourdou	July 26, 1938
2,155,436	McNally	Apr. 25, 1939
2,183,530	Alkan	Dec. 19, 1939
2,194,141	Estoppey	Mar. 19, 1940

FOREIGN PATENTS

Number	Country	Date
749,767	France	May 15, 1933
480,185	Great Britain	Feb. 18, 1938