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GUN TURRET SIGHTING COMPENSATION SYSTEM

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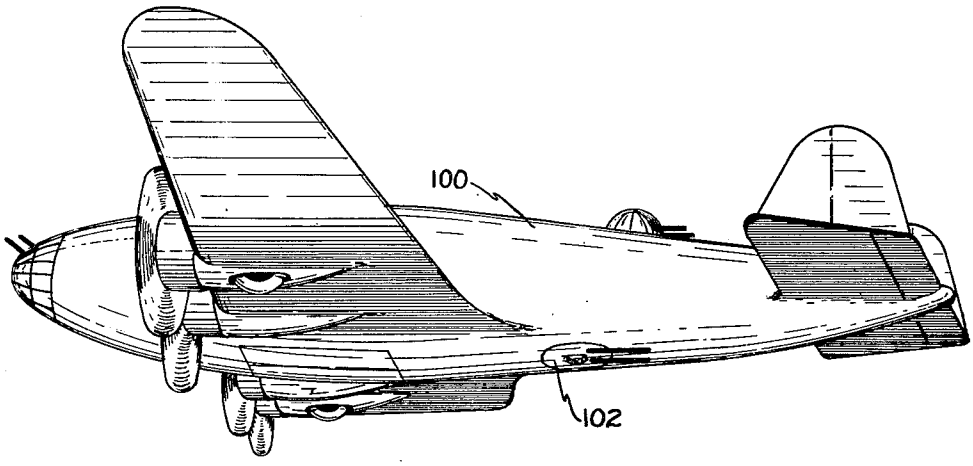


FIG. 1

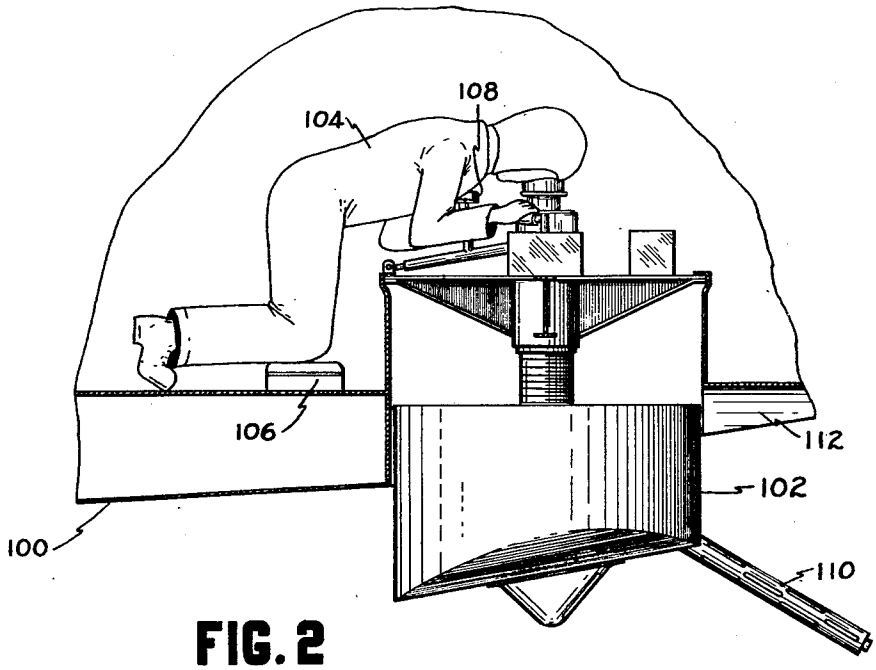


FIG. 2

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GUN TURRET SIGHTING COMPENSATION SYSTEM

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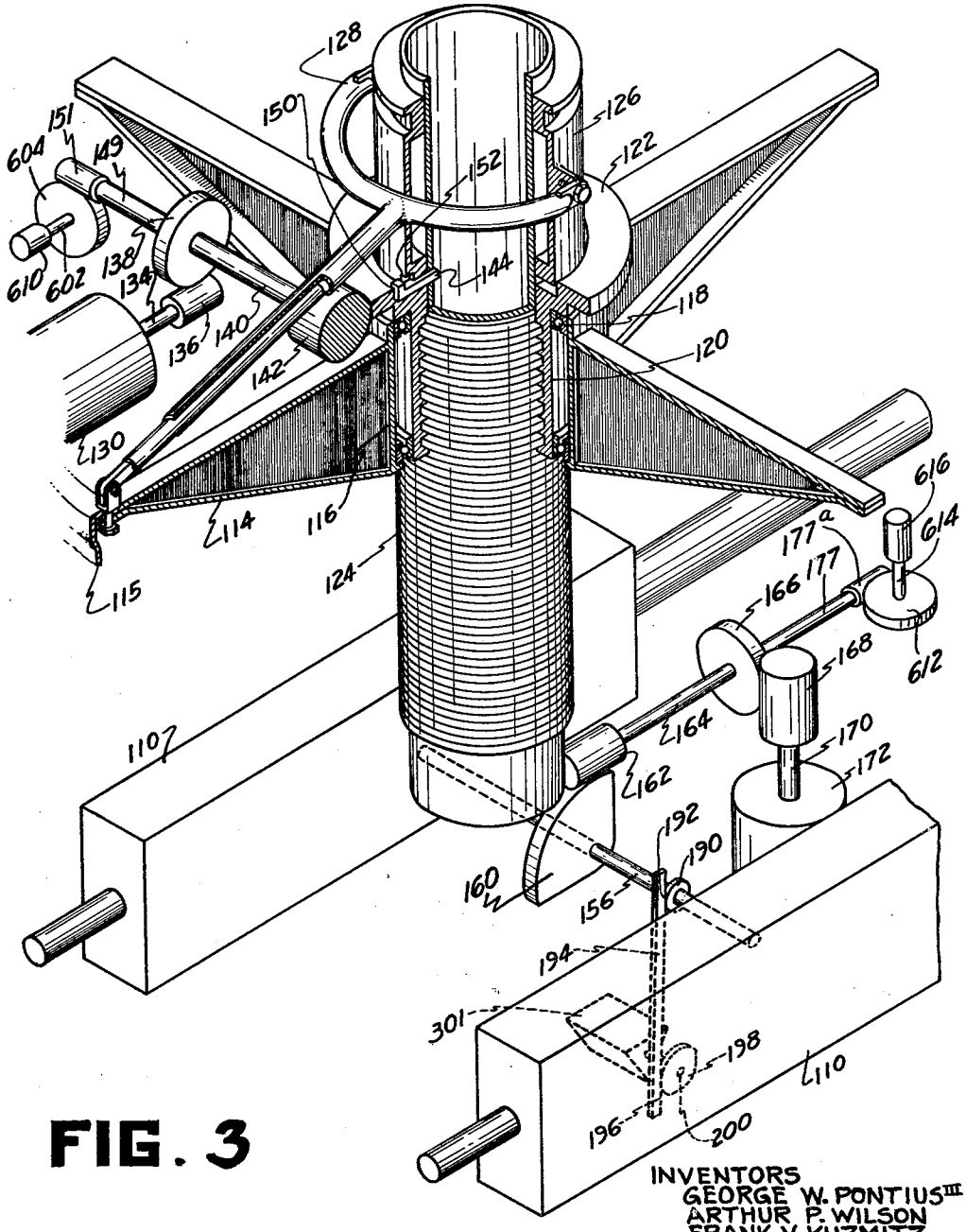


FIG. 3

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GUN TURRET SIGHTING COMPENSATION SYSTEM

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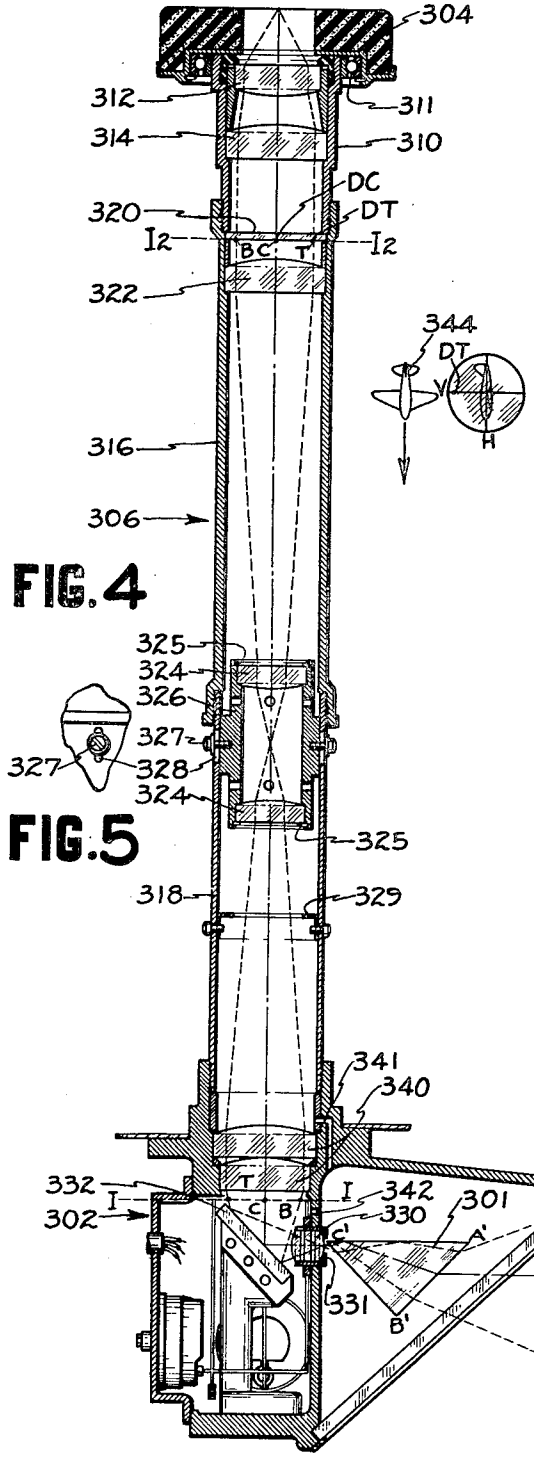


FIG. 4

FIG. 5

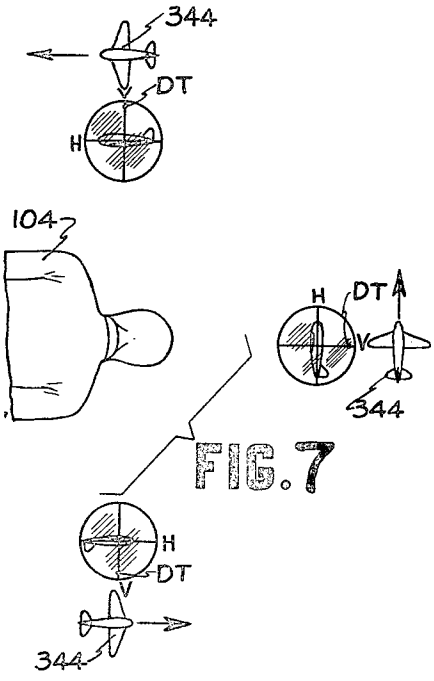


FIG. 7

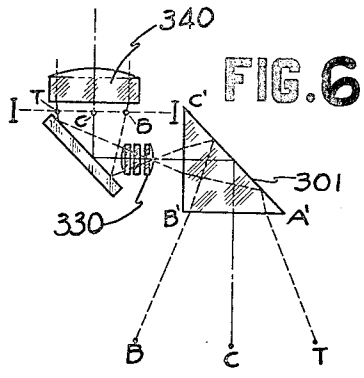


FIG. 6

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GUN TURRET SIGHTING COMPENSATION SYSTEM

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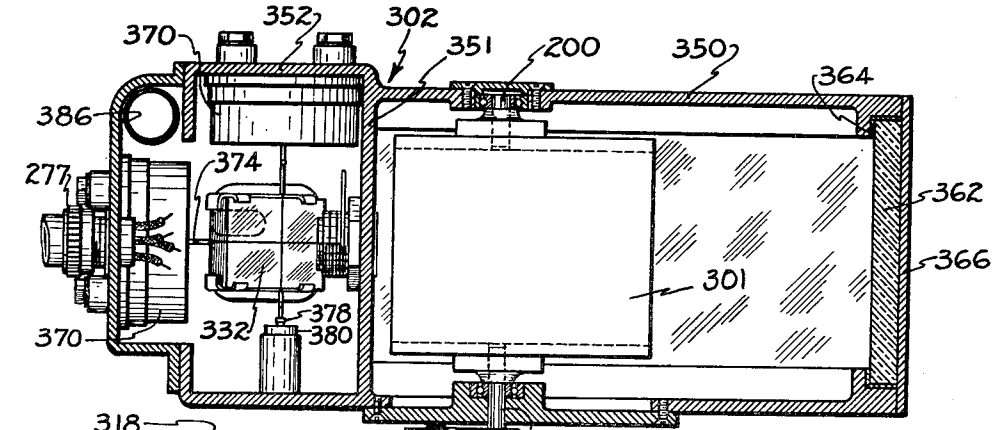


FIG.9

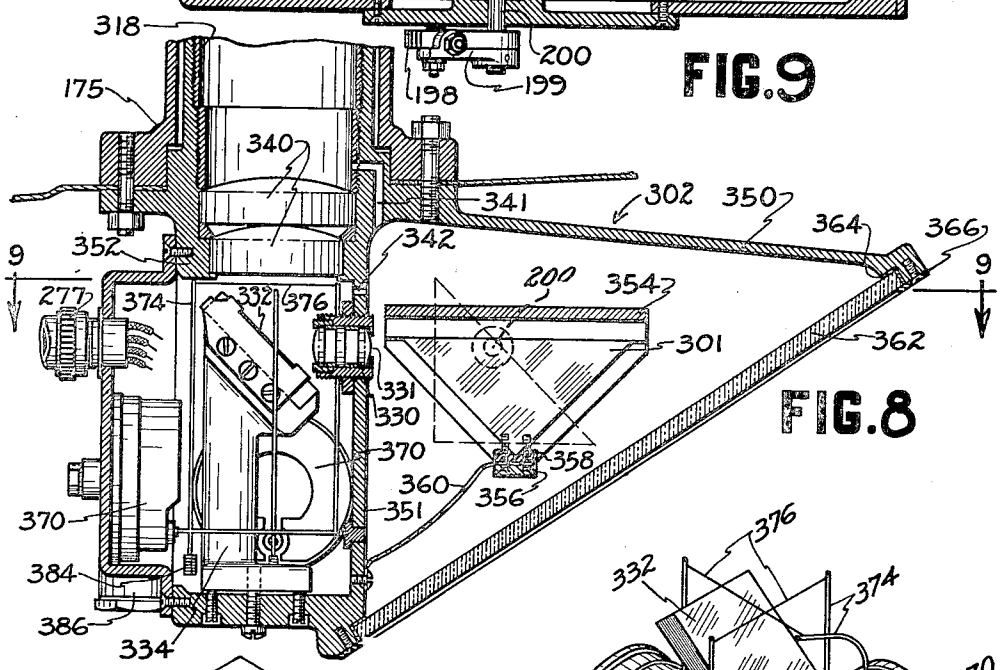


FIG.8

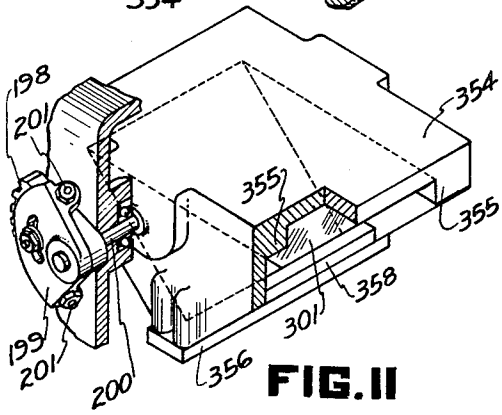


FIG.11

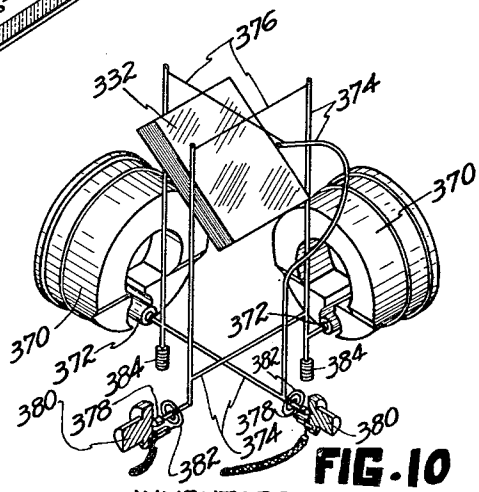


FIG.10

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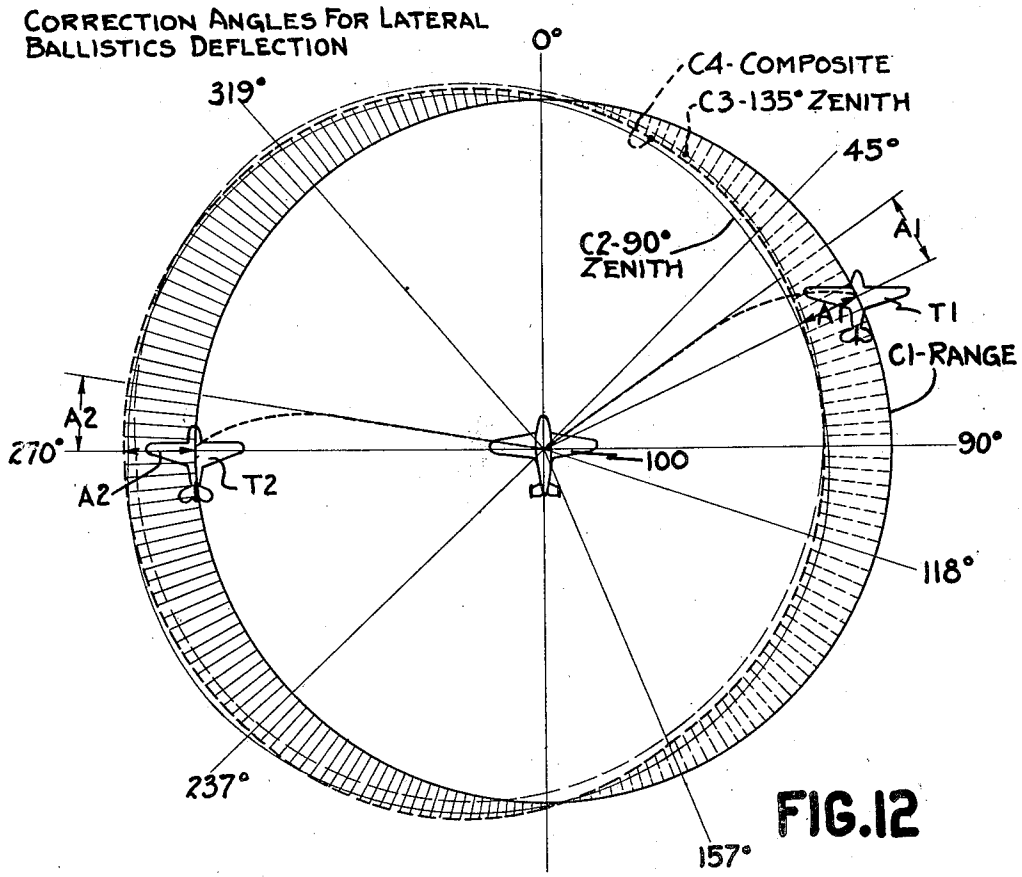


FIG.12

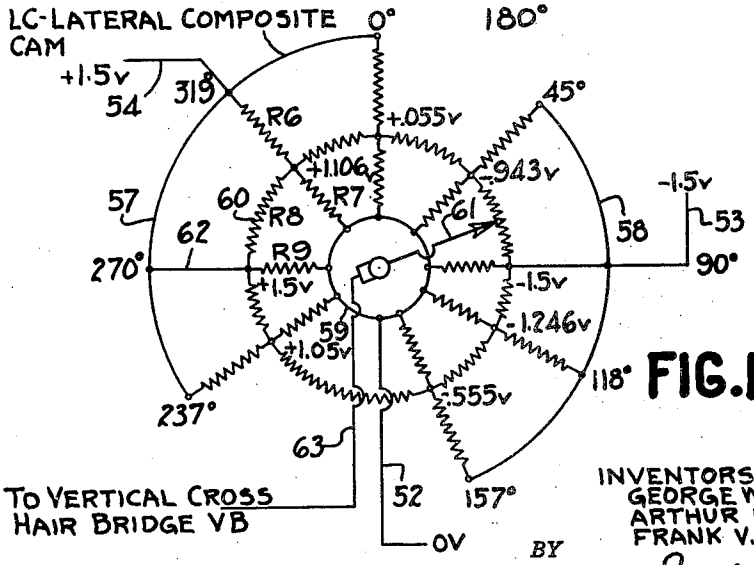


FIG.13

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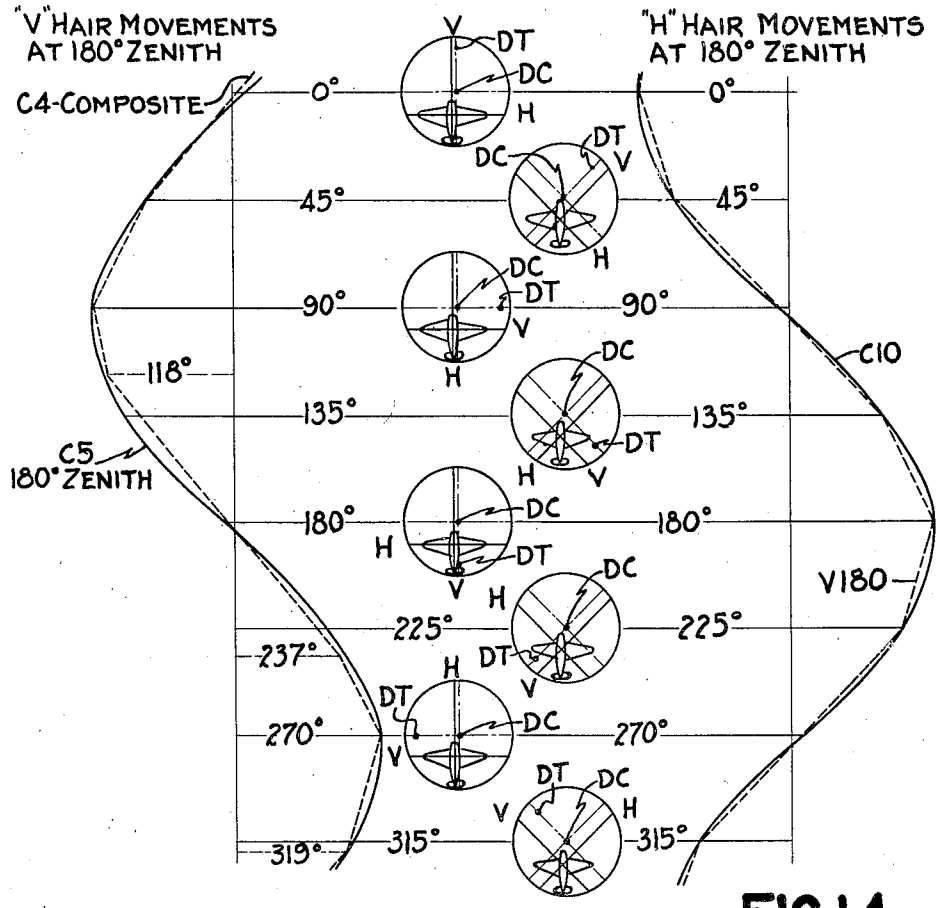


FIG.14

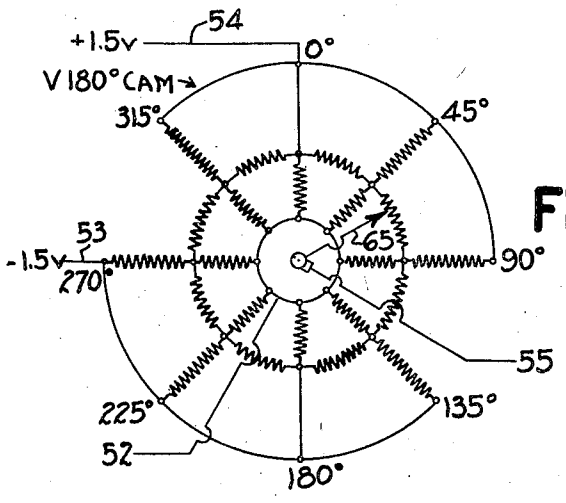


FIG.15

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GUN TURRET SIGHTING COMPENSATION SYSTEM

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CORRECTION ANGLES FOR VERTICAL BALLISTICS DEFLECTION

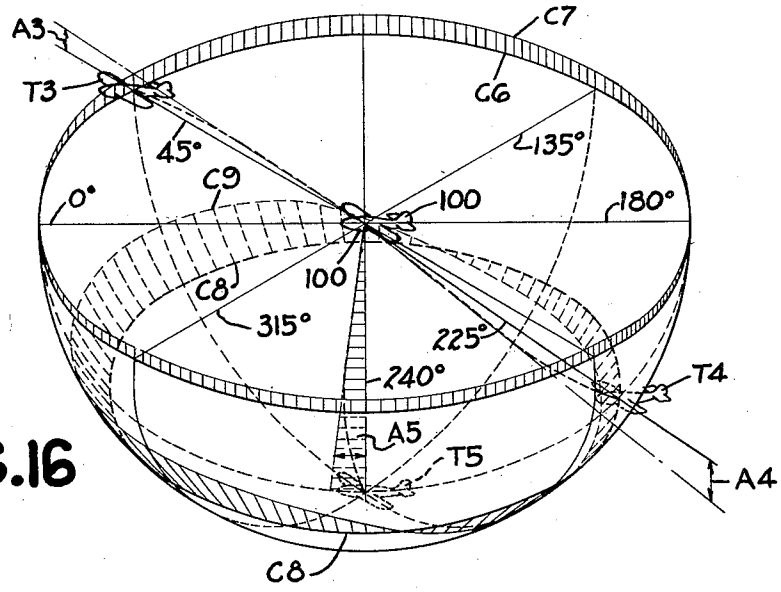


FIG.16

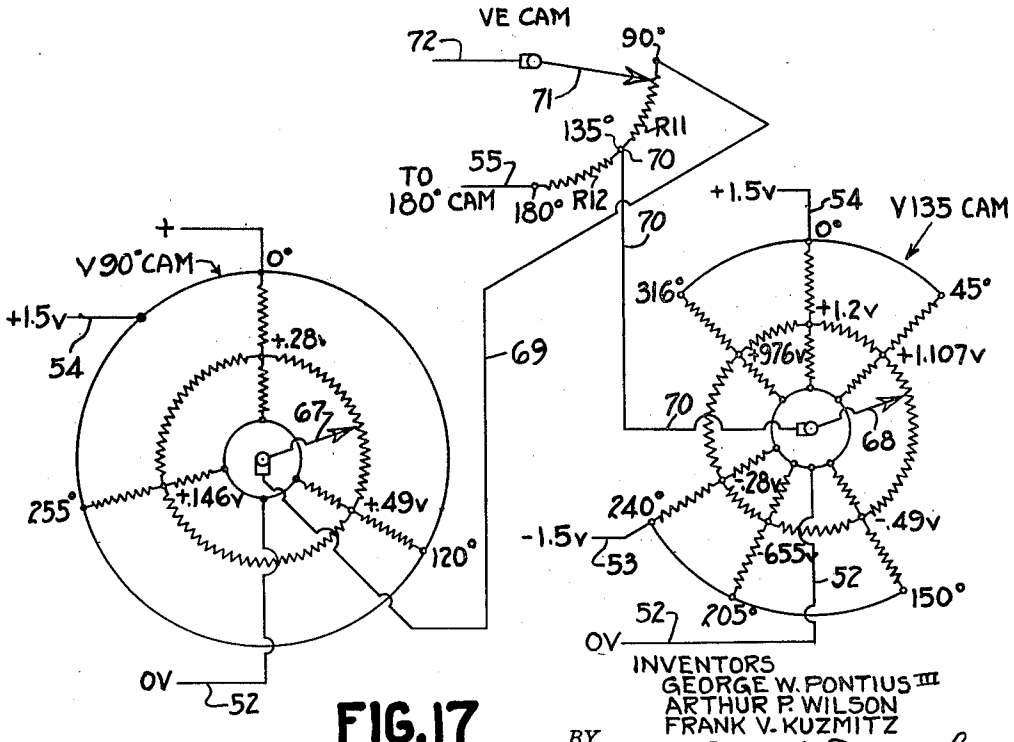


FIG.17

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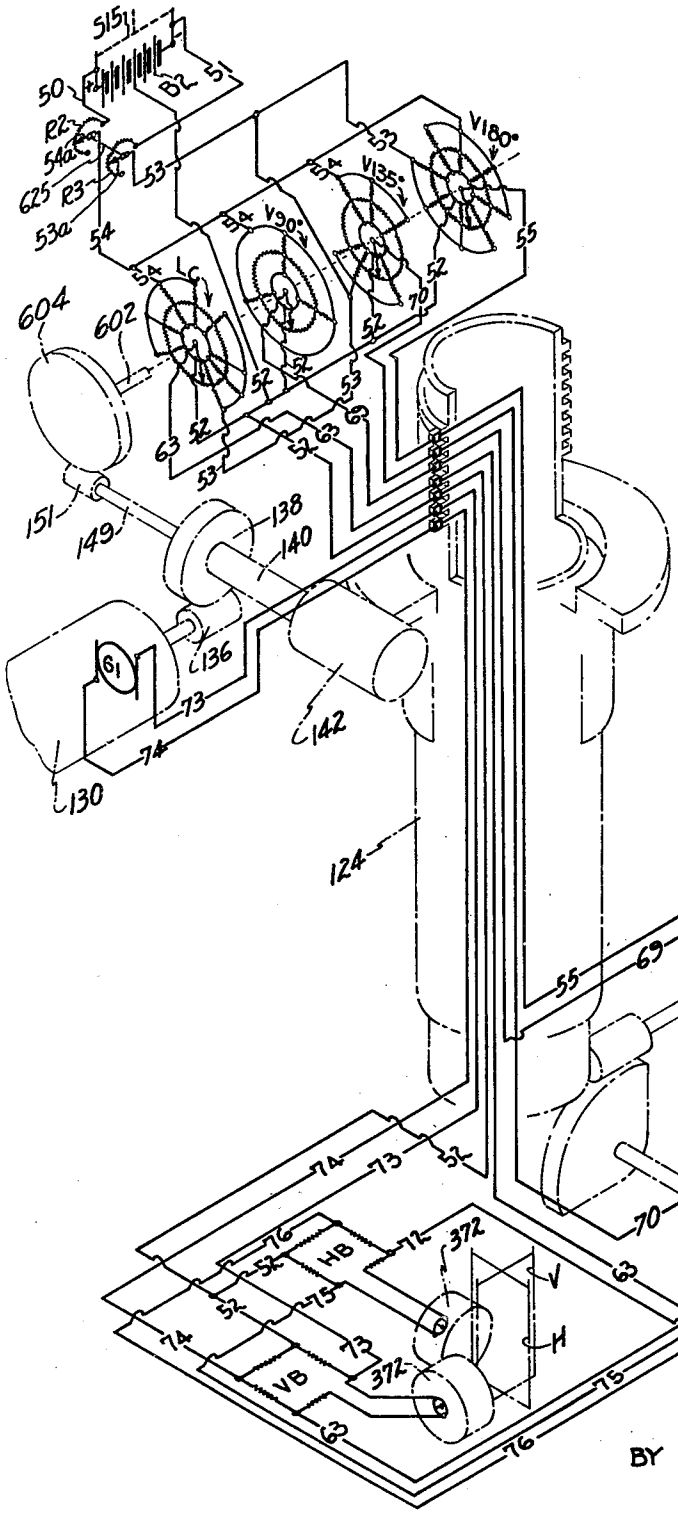


FIG. 18

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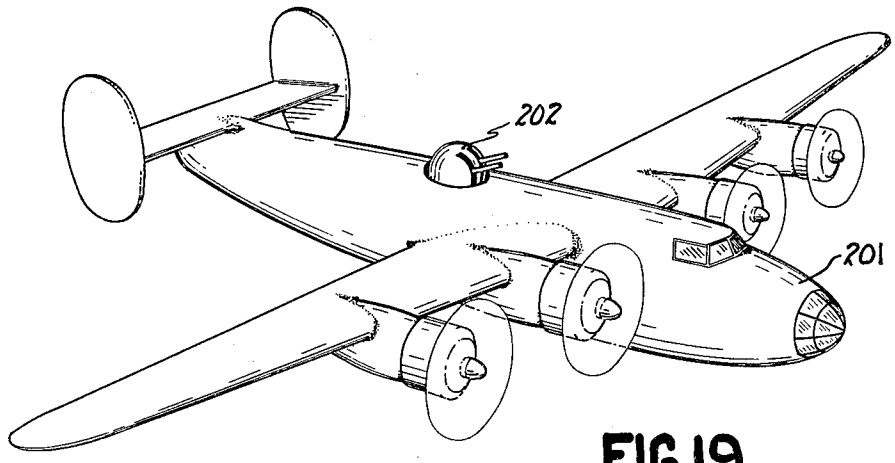


FIG.19

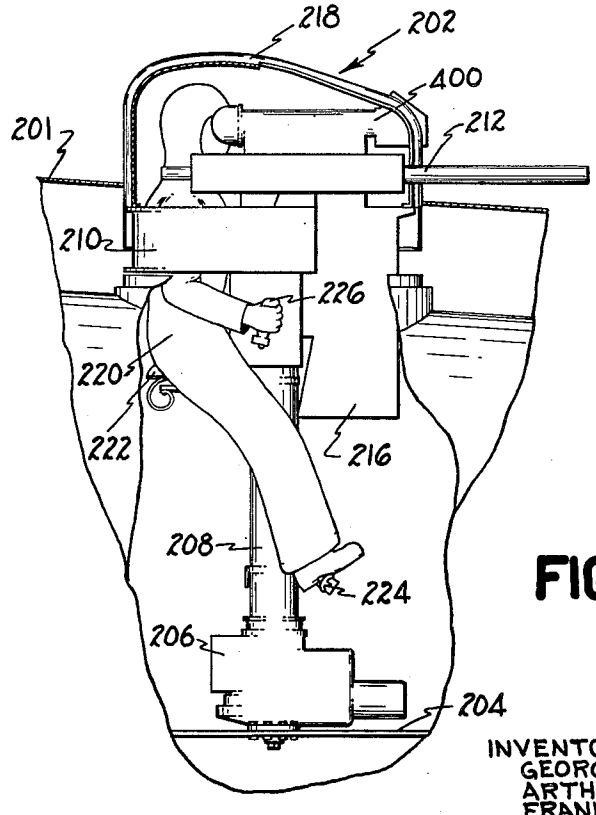


FIG.20

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GUN TURRET SIGHTING COMPENSATION SYSTEM

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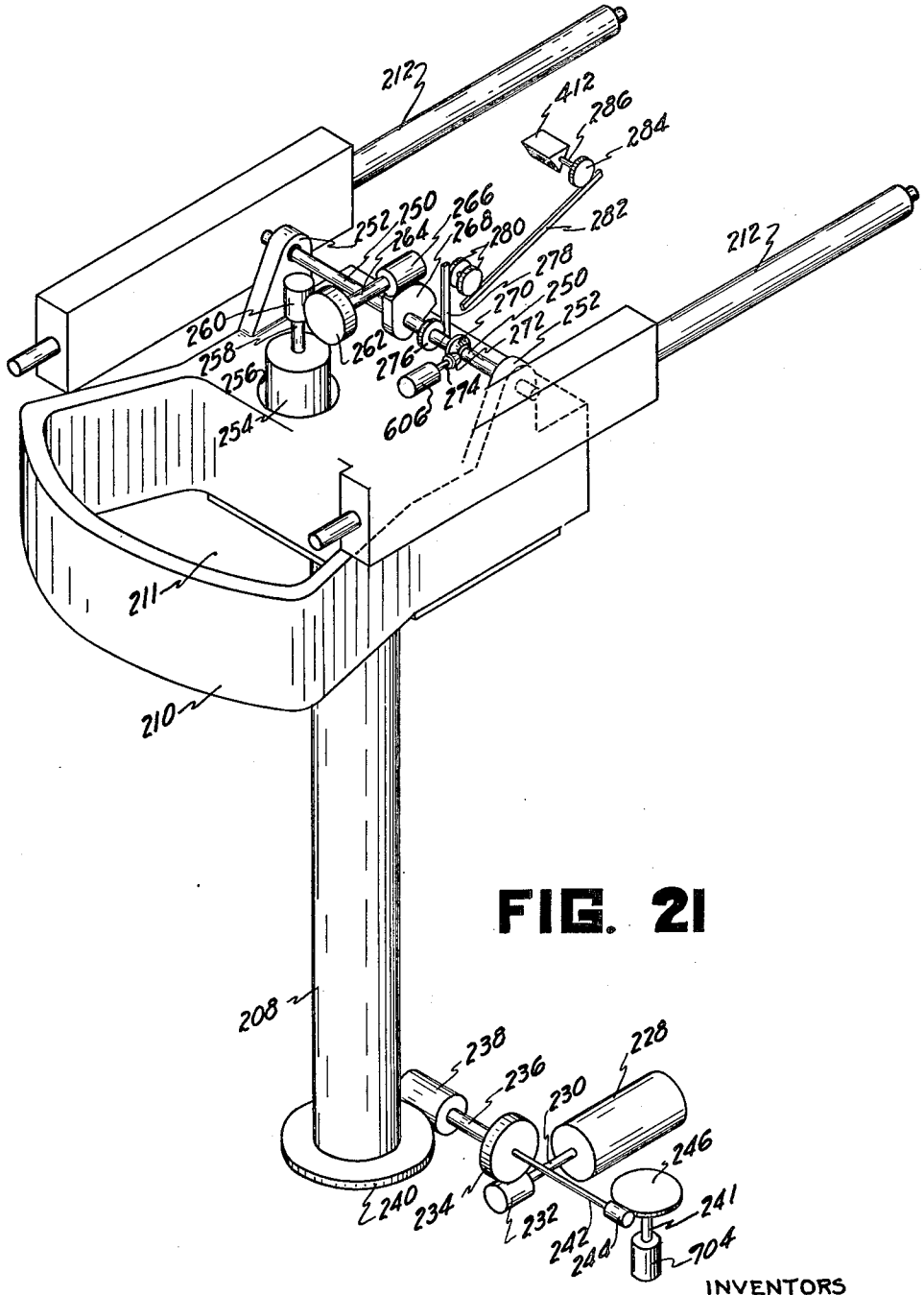


FIG. 21

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GUN TURRET SIGHTING COMPENSATION SYSTEM

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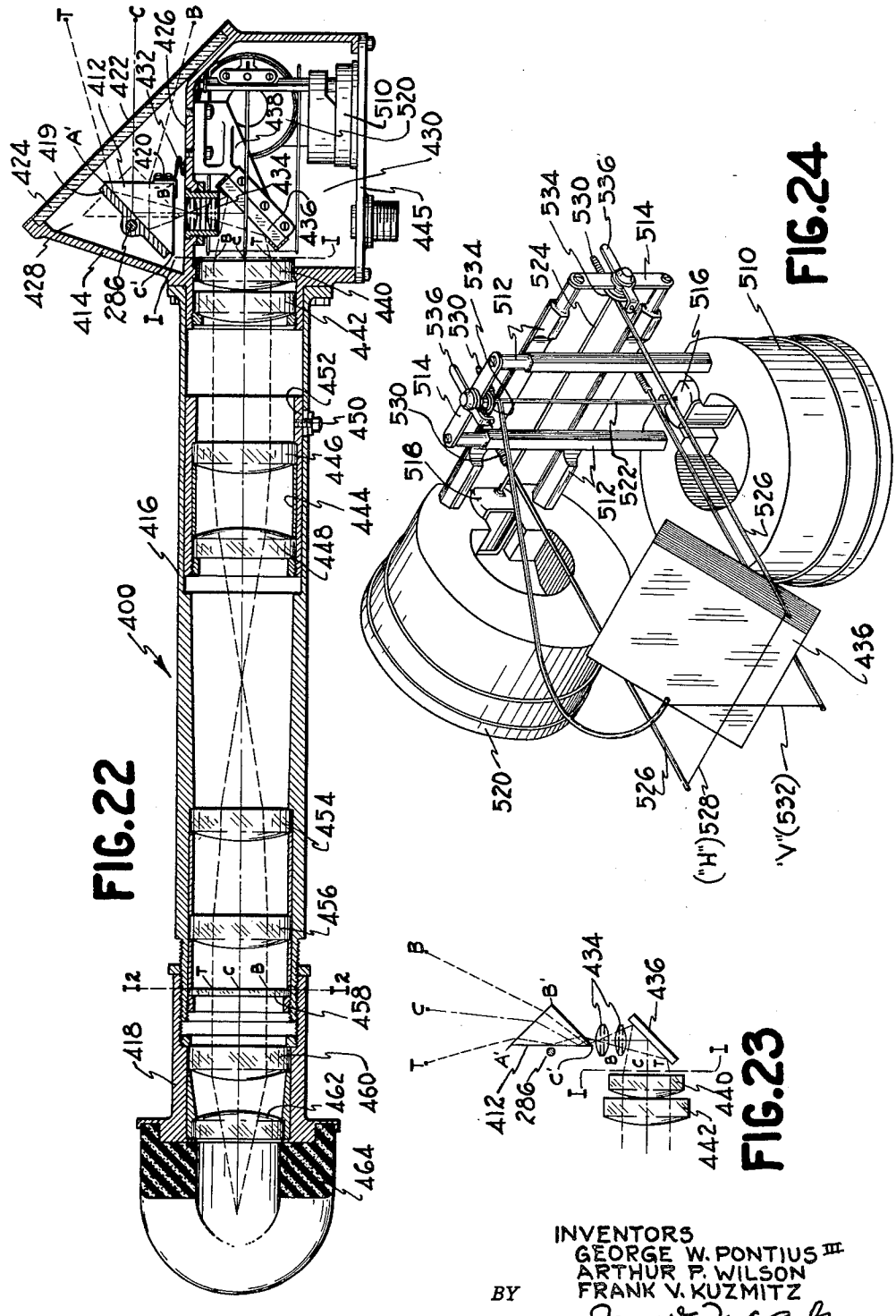


FIG.22

FIG.24

FIG.23

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GUN TURRET SIGHTING COMPENSATION SYSTEM

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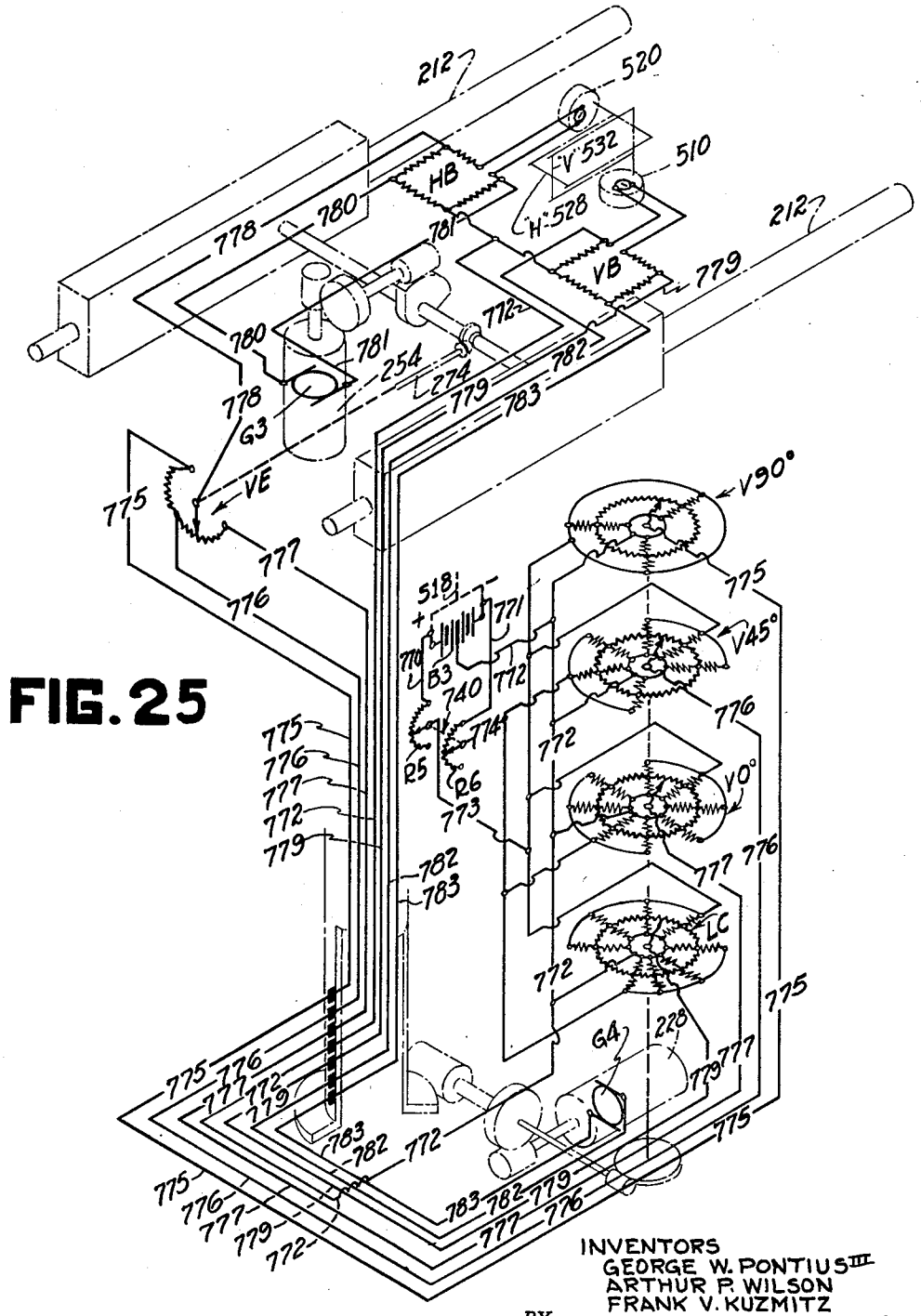


FIG. 25

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Patented Oct. 1, 1946

2,408,681

UNITED STATES PATENT OFFICE

2,408,681

GUN TURRET SIGHTING COMPENSATION SYSTEM

George W. Pontius, III, Arthur P. Wilson, and Frank V. Kuzmitz, South Bend, Ind.

Application April 9, 1942, Serial No. 438,236

13 Claims. (Cl. 33—49)

1

This invention relates to gun turrets and more particularly to a sight for aircraft gun turrets wherein compensation is made for: (1) the ballistics deflection of a projectile; and (2) lead with respect to a relatively moving target.

The invention will be described as applied to gun turrets for the upper and lower surfaces of an airplane, although it is not limited to such applications. A lower turret to which the invention is applied is described more completely in Pontius application Serial No. 391,911 filed May 5, 1941.

It is an object of the invention to provide a sighting device for guns which indicates lead on a target.

It is another object of the invention to provide a sighting device for guns which corrects for the deflection of a projectile caused by windage, gravity and magnus effect.

It is another object to provide a sighting device which makes a single correction combining lead and ballistics deflections.

It is another object to provide a sight in the field of an optical instrument wherein cross hairs or other reference media move relative to the field of an optical instrument to give an automatic correction.

It is an object to provide an automatic ballistic correction system for sights wherein the correction is obtained from electrical bridges dependent upon the position of the guns in their field of fire.

Other objects and advantages of the invention will be apparent from the following specification and drawings in which:

Figure 1 is a side view of an airplane having a lower turret in a retracted position and having a sight compensation system or mechanism made according to the present invention;

Figure 2 is an enlarged sectional view of the airplane of Figure 1 in the region of the lower turret, showing the turret in an extended or operative position and being at the instant controlled and fired by a gunner;

Figure 3 is an isometric, schematic sketch of the lower turret in an extended position, partly in section and showing the mechanical parts and movements;

Figure 4 is a view in vertical section, partly schematic, of a periscope of the lower turret, showing the path taken through the periscope by light rays reflected horizontally from an object;

Figure 5 is a fragmentary view in elevation of a detail of the adjustable fastening means for holding the erector lens housing;

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Figure 6 is a schematic view showing the path taken through the periscope by light rays reflected vertically from an object;

Figure 7 is a schematic drawing to illustrate the various images of target airplanes seen by the gunner at the respective positions of the target airplanes with relation to the airplane in which the turret is mounted;

Figure 8 is a view in vertical section through the sight box or bottom part of the periscope of Figure 4, showing the parts and their relation in more detail;

Figure 9 is a sectional view showing the top of the sight box along the line 9—9 of Figure 8;

Figure 10 is an isometric view of the cross hair mechanism of the sight box and the actuating galvanometers therefor as well as the position of the periscope mirror, as seen from above and from the right with reference to Figure 9;

Figure 11 is an isometric view of the periscope prism mounting, with part of the sight box housing broken away as well as part of the prism housing to show the details of construction;

Figure 12 is a diagram showing correction angles for lateral deflections of a bullet for various points in a portion of the hemisphere of fire of the lower turret;

Figure 13 is a diagram illustrating an electrical cam producing a voltage curve corresponding to the correction angles for lateral deflection of Figure 12 for any given point on the herispherical field of the lower turret and used in the sight correction system for the turret;

Figure 14 is a diagram illustrating the correction movements of the cross hairs of the lower turret for various azimuth positions of the turret when the guns are pointing straight down at 180° zenith;

Figure 15 is a diagram of an electrical cam for producing a voltage curve corresponding to the correction movements of the horizontal cross hair shown in Figure 14;

Figure 16 is a diagram of the correction angles for the vertical deflections of a bullet for various points in the hemisphere of fire of the lower turret;

Figure 17 is a diagram of an electrical circuit forming electrical cams and producing a voltage curve corresponding to the correction angles for vertical deflection of Figures 14 and 16 for vertical deflection for any given point on the hemispherical field of fire of the turret;

Figure 18 is a phantom view showing the lower turret in dotted lines and having superimposed thereon the complete sight correction circuit for

moving the cross hairs of the periscope, and including the electrical cams of Figures 13, 15 and 17;

Figure 19 is a perspective view of an airplane having an upper turret including a compensated sight made in accordance with the invention;

Figure 20 is a vertical section through the airplane of Figure 19 and the canopy of the turret showing a gunner operating the turret with the guns pointed toward the rear of the airplane;

Figure 21 is an isometric projection of the mechanical parts and movements of the upper turret;

Figure 22 is an elevational view in section of the periscope of the upper turret showing the path of light rays therethrough;

Figure 23 is a view of the prism, lens and mirror of the periscope showing the paths taken by rays of light from a vertical direction;

Figure 24 is an isometric view of the galvanometers controlling the cross hairs of the sighting mechanism included in the periscope, and showing the periscope mirror; and

Figure 25 is a phantom view of the upper turret in broken outline having superimposed thereon in full lines the complete electrical compensation circuit.

The placement of the lower turret in an airplane is shown in Figure 1. Airplane 100 retains a turret 102 in a retracted position in the bottom of the fuselage. When thus retracted the bottom of the turret is substantially flush with the surface of the fuselage and offers little resistance to the airstream.

The turret 102 is shown on an enlarged scale in an extended position in Figure 2. A gunner 104 kneels on a cushion 106, his chest supported on a rest 108 attached to the turret. The gunner looks through a periscope in the turret to sight the guns, and with his right hand operates the electrical power controls for the movements of the turrets and guns, while with his left hand he operates a trigger control. Gun wells 112 are provided in the airplane 100 at the rear of the turret as a housing for the guns when the turret is retracted, at which times the guns 110 will be horizontal.

The mechanical parts relating to the movement of the turret are shown in diagrammatic form in Figure 3 wherein the turret is shown in an extended position. The turret 102 as a whole is supported on a four-armed spider 114 which is secured to structural members such as 115 of the airplane 100, and which has a central collar 116. Ball bearings such as 118 rotatably support an internally threaded sleeve 120 within collar 116, which sleeve has an upper ring gear portion 122. A threaded column 124 is threaded into sleeve 120 and is thereby supported within spider 114. A head unit 126 rotatably rides on the upper end of column 124 and is itself restrained from rotation by a telescoping yoke member 128 secured to the outer end of one arm of spider 114.

A single power source is used to rotate the sleeve 120 in order to rotate the turret in azimuth or optionally to retract and extend the turret. This power source is an electric motor 130 suitably secured to the spider 114. The motor 130 drives a motor shaft 134 to which is secured a worm 136. Worm 136 engages a worm wheel 138 which is secured to a drive shaft 140 journalled in suitable bearings which will be later described. A worm 142 on shaft 140 engages ring gear 122, causing the sleeve 120 to rotate within central collar 116, when electric motor 130 is operated. The motor 130 can be reversed by reversing the field current, thus reversing the direction of rotation of sleeve 120. The gear train provides a large reduction in rotation allowing the use of a very high speed motor, to provide a high power to weight ratio.

Also shown in Figure 3 is a shaft 149 driven by motor worm wheel 138 and having a worm 151 on the other end thereof. Worm 151 drives a worm wheel 604 which in turn drives a compensator shaft 602 having a series of electrical cam followers secured thereto and adapted to contact electrical compensation cams encased in a housing 610 as shown in Figures 3 and 18. The gear reduction at worm 151 is the same as that of driving worm 142 at the column resulting in compensator shaft 602 making a complete rotation for every rotation of column 124. In other words, the movement of electrical cams in housing 610 is synchronized with the azimuth movement of the turret.

The column 124, and thereby the turret also, may be rotated in azimuth or retracted and/or extended, by selectively connecting column 124 with sleeve 120 or with non-rotatable head 126. This selective connection is performed by an L-shaped key 144 held in a hole through column 124 and selectively engaging an internal notch 150 in sleeve 120, or an external notch 152 in non-rotatable head 126. The mechanism for moving key 144 has been completely described and claimed in Pontius et al. application Serial No. 407,468, filed August 19, 1941, entitled "Gun turret."

When key 144 engages notch 152 in non-rotatable head 126, column 124 is restrained from rotation. If motor 130 now rotates ring gear 122, and thereby sleeve 120, the column 124 will be raised or lowered according to the direction of rotation of sleeve 122. The head 126 is lowered or raised with column 124, and the yoke member 128 will telescope and extend and will act at all times to keep head 126 from rotating. In this way the extension and retraction of turret 102 is accomplished. When the turret 102 is extended the key 144 may be moved to engage notch 150 in sleeve 120 and the column 124 will rotate as sleeve 120 rotates, and thus provide the operative movement of rotation in azimuth. It will be noted that in such case the key 144 will be out of notch 152 and there is no restriction on the movement in azimuth. The column 124 can be rotated continuously in either direction for any given number of rotations.

Certain parts of the turret are fastened on the lower end of column 124. These parts include a rotatable shaft 156 to which the guns 110 are secured. The details of construction for affixing the guns to shaft 156 has been described, Pontius application Serial No. 391,911, filed May 5, 1941, entitled "Gun turret." A worm wheel sector 160 is secured to shaft 156 and is engaged by a worm 162 fastened to a drive shaft 164. Drive shaft 164 in turn is driven by a worm wheel 166 secured thereto, which is driven by a worm 168 secured to a motor shaft 170 of an electric elevation motor 172. The driving mechanism described is preferably positioned within a frame or housing which will be described later.

Also shown in Figure 3 is an elevation gearing system for electrical compensation cams. Connected to motor worm wheel 166 is a shaft 177 having a worm 177a secured to the outer end thereof. Worm 177a drives a compensator worm wheel 612 which is secured to a compensa-

tor shaft **614**. Fastened to the end of shaft **614** is a zenith electrical cam in housing **616**. The gear reduction at worm **177***a* is not the same as at worm wheel sector **160**, and shaft **614** rotates approximately three times faster than gun shaft **156** but in synchronism with it. This is permissible since the greatest movement of the guns in zenith is about 95°, and the increased movement of shaft **612** gives greater sensitivity.

The elevating gear train and its actuating motor are adapted to elevate or depress the guns, depending upon the direction of rotation of motor **172**, which is reversed by reversing the field. The guns **110** can be elevated above horizontal as far as is permitted by the shape of the airplane in which the turret is mounted, and can be depressed to point straight down. The zenith arc as will be described for purposes of illustration, will be limited to a 90° arc from horizontal to straight down.

The mechanism for synchronizing the periscope of the turret with the guns is also shown in diagrammatic form in Figure 3. A pinion **190** is secured to shaft **156**, and engages a rack **192** on the upper end of a bar **194**, suitably positioned by means which will later be described. A rack **196** on the lower end of bar **194** engages a gear sector **198** secured to a shaft **200** which rotatably supports a prism **301** forming a part of the optical system of the periscope. When guns **110** are elevated or depressed by rotating with shaft **156**, the prism will be rotated, not an equal amount, but in proportion thereto, thus synchronizing the line of sight of the periscope with the direction in which the guns point.

The periscope system **300** of the turret is shown in Figures 4 through 7, and is shown in longitudinal section in Figure 4. The periscope comprises in the main a periscope tube **306**, and a sight box **302**. The periscope tube **306** is formed in three pieces. At the top is an eyepiece tube **310** retaining eyepiece lenses **312** and **314**. Eyepiece tube **310** rotates within cushion **304** on bearings **311**, which insure that there will be no binding of the two parts.

The lower portion of periscope tube **306** comprises an upper spacer member **316** and a lower spacer member **318** in each of which there are positioned lenses having an "erector" function to invert the image to an upright or normal position for views directly to the rear of the airplane. The upper end of spacer member **316** retains a plate glass piece **320** on the bottom side of which is focused the image viewed by the eyepiece lenses **312** and **314**. A lens **322** is also placed near the upper end of spacer tube **316** and helps to focus the image on the bottom of plate **320**. The lower spacer tube **318** retains erector lenses **324** which are held by snap rings **325** in a perforated housing **326** secured to the upper end of spacer member **318**. Housing **326** is held in lower spacer tube **318** by screws **327** fitting in longitudinal slots **328** in tube **318**, as shown in detail in Figure 5. Slots **328** allow adjustment of the erector housing **326**. Lower spacer tube **318** also retains a fixed diaphragm or stop **329** for eliminating ambient; rays of light. The lower end of spacer tube **318** is screwed into sight box **302**.

The sight box **302** is also shown in longitudinal section in Figure 4. It includes the rotatable prism **301** whose transverse section is that of an isosceles right triangle. Light entering prism **301** is refracted and reflected into a compound objective lens **330**. Objective lens **330** is made up of two plano-convex lenses with a spaced intermediate double-concave lens of material having a different index of refraction from the outer lenses, to form an achromatic lens group. A diaphragm or stop **331** is placed over the outer side of lens **330** to stop ambient light from entering that lens.

Light which passes through lens **330** from prism **301** is reflected by a mirror **332** placed at an angle of 45° to the axis of the objective lens **330** and to the axis of the periscope tube **306**. The light so reflected forms an image in the plane I—I, just above the mirror **332**. Two lenses **340** are placed in sight box **302** above this image plane and they help to bend light rays passing through them from the image to the erector lenses **324**.

The path taken by rays of light is shown in Figure 4. The ray T represents a ray on the upper side or top of the cone of the field of the periscope system, which cone has an angle of approximately 40° or greater. Ray C represents a horizontal center ray in the field cone, and ray B represents a bottom ray in the field cone. The window surface A'B' of the prism **301** refracts all of these rays to the hypotenuse surface A'C' where they are reflected and then refracted out of the prism at one end of the surface C'B', and into the objective lens **330**. The fixed diaphragm **331** is placed over the outer surface of the plano-convex lens nearest the prism, causing all rays of light that enter the lens **330** to cross in or near the outer lens. The objective lens **330** causes the rays of light to form an image, and because of the interposition of mirror **332**, this image is formed in a plane parallel to the axis of objective lens **330**.

Assuming that the sight box **302** is pointed toward the rear of the airplane **100**, the gunner will be crouched facing toward the rear also, as in Figure 2. If there were no lenses in periscope tube **306**, the image on plane I—I would appear upside down to the gunner on plane I—I since the ray T will be at the left in Figure 4, and therefore to the bottom of the gunner's image, and the ray B will be at the right in Figure 4, or to the top of the image seen by the gunner. In order to make this image appear right side up, or erected, erector lenses **324** are interposed between image I—I and the eyepiece **310**. Erector lenses **324**, with the aid of lenses **340** and **322** form an erect image of the objects to the rear, in the plane I_2—I_2. The ray T is to the right or the top of the image seen by the gunner in plane I_2—I_2, and ray B is to the left, or to the bottom in plane I_2—I_2. The eyepiece takes rays from the image I_2—I_2 and concentrates them for the gunner's eye at the top of the cushion **304** where the gunner's head will be resting. It will be noted that the convergence of the rays at the top of the eyepiece is at an angle approximately equal to that of the field rays T and B, resulting in practically no magnification of the image which gives a "natural" size image, allowing the gunner to estimate the range of a target.

Figure 6 shows the prism **301** in the other extreme position, taking in a vertical cone of field. As in Figure 4, the prism **301** will refract and reflect the light into the lens **330** which condenses it for forming an image on the plane I—I. Figure 6 shows the path of light for this straight down position, as compared to Figure 4 which shows it for the horizontal position. Any intermediate position of the prism **301** would give rays of light in paths intermediate those shown in Figures 4 and 6.

The periscope of this application with a field

of about 45° gives a larger field than prior periscopes designed for gunfire which have fields not to exceed 30°. The larger field obtained by the present periscope is due first, to an objective lens that will take in at least a field of 45°, and second, to a prism that will transmit a 45° field to such a lens at all positions of rotation and at the same time give an exit pupil not less than ¼" in diameter without transmitting double images. The lens must have a relatively short focal length and relatively wide angle of field, and must be well corrected over this field when the image produced by this lens is used for compensation. Camera lenses of relatively short focal lengths have been found satisfactory for this purpose because of their wider angles and well corrected small images which in turn desirably limits the diameter of the tube.

The prism **301** must be relatively large as compared to those in use in prior periscopes. A three inch prism, for example, is required in the present periscope. The shaft about which the prism rotates must be placed so that when the prism rotates the prism will be as close as possible to the lens **330**. This placement of the axis of rotation is very important as otherwise the prism cannot transmit the necessary field to the lens. The placement of the pivot shaft for the prism with regard to synchronism with the guns is unimportant as long as the prism rotates near lens **330**. All that is required, once a given position of the prism is found to include a field into the center of which the guns will fire, is that the prism will rotate only one-half as much as the guns rotate in elevation above or below such a position. This limitation to one-half the rotation of the guns is due to the mirror function of the prism, wherein the included angle of reflection of a fixed ray of light will increase or decrease twice as much as the angle the mirror surface itself is rotated.

The sight box **302** also retains two movable cross hairs for sighting purposes, the details of which will be described later. Both cross hairs are in the image plane I—I, so that they will appear to be a part of the image viewed by the gunner, and will not appear to move if the gunner should move his head about on the cushion **304**. One cross hair appears to be vertical in an upright field, and the other appears to be horizontal in an upright field. They are both movable laterally to their axes by automatic electrical means for ballistic corrections, and thus move about on the round image field viewed by the gunner.

The plate glass member **320** has a dot DC impressed in its center for orienting the initial position of the cross hairs relative to the field. There is also a dot DT impressed on plate glass **320** which would appear to be on the upper part of the vertical hair when the hair is in a normal position and the field is toward the rear of the plane. This dot is to relate the turret to the cross hairs so that the gunner will know which way to move the turret to train the cross hairs on the target.

It will be noted that a passage **341** in the upper part of sight box **302** communicates the right hand part of the sight box with the periscope tube **306**, and that a passage **342** communicating said right hand part of the sight box with the left part of the sight box. These passages and the holes formed through perforated housing **326** allows the communication of air between the sight box **302** and the tube **306**. By providing a water absorbing cell or unit in the sight box, which cell will be described later, the major part of the periscope can be dehydrated to prevent the condensation of moisture on the optical pieces as they become chilled due to climatic or altitudinal changes in temperature. Elimination of condensation is very important and the means just described to eliminate condensation forms a feature of the invention.

The views of an object as seen by the gunner through the periscope are shown in Figure 7. The gunner **104** is shown in a top view looking down the periscope as he crouches facing toward the rear of the plane. Target airplanes **344** flying in the horizontal plane including the sight box of the periscope in the middle thereof are shown in four positions: to the rear (to the right in Figure 7); to the side toward the gunner's left (top in Figure 7); to the front of the plane (left in Figure 7); and to the side toward the gunner's right (bottom in Figure 7). The view the gunner would see if the periscope were properly orientated in each case is opposite each of the target airplanes **344**, and is a round field having a side view of the airplanes **344** therein. The cross hairs are in the middle of the field, and the orientation dot DT appears to be on the vertical cross hair in every case.

It will be noted that the only upright or exact image relative to the gunner himself is at the rear of the airplane. As he looks at the airplane to his left the target airplane **344** appears to stand on its nose. Likewise, the target airplane to the front of the plane appears to be upside down relative to the gunner, and the airplane to his right appears to be standing on its tail. In every view, however, the orientation dot DT indicates to the gunner the true position and direction of flight of the target airplane relative to the cross hairs and the field. From this it is apparent that the gunner must not aim and fire the gun relative to himself as he would be hopelessly confused by the various positions and directions that a target plane would assume for a given "cross hair" position of the target on the field. The gunner must completely detach himself from consideration, and follow the target and aim the guns by association of the target with dot DT in the field. The gunner will train himself to a given muscular reaction for a given position and direction of the target in the field, regardless of the direction in which the guns are pointed with relation to the airplane in which they are mounted. The erector lenses are provided chiefly for conventional reasons and also because the most important job which this gunner has is to protect against an attack from the rear.

The details of construction of the sight box **302** are shown in Figures 8, 9, 10 and 11. The sight box itself is divided into two main parts, a hood **350** for the prism **301**, and an image box **352**. These two parts are separated by a wall **351**, which wall also supports the objective lens **330** and has the de-hydrating hole **342**. The prism **301** is mounted on shaft **200**, as is shown generally in Figure 3 but specifically as is shown in more detail in Figures 9 and 11. In Figures 8 and 11 it will be noted that shaft **200** supports prism **301** by means of a housing **354** which covers the top and the sides of prism **301**. The prism **301** is held in the housing **354** by a clamp bar **356** which presses a notched rubber cushion **358** against the apex of the prism **301** (Figure 8). Shoulders **355** (Figure 11) contact the upper

edges of prism **301** and thereby hold the prism without danger of scratching the central part of the upper surface which is the reflector surface A'C' of the prism. Shaft **200**, as shown in Figure 9, is essentially two stubs screwed into housing **354** and journalled in hood **350**.

The details of construction of the gear sector **198** which rotates prism shaft **200** are also shown in detail in Figures 9 and 11. As already explained, the prism **301** needs to rotate only one-half as much as the guns **110** are elevated or depressed to be in synchronism with them, because of the mirror function of the prism. As shown in Figure 3, the gear sector is of twice the radius (and consequently sector circumference) as the driving gear **190** on gun shaft **156**, thus providing a 2 to 1 reduction in rotation. Referring to Figure 11, it is pointed out that gear sector **198** is mounted freely on shaft **200**, but drives it through an adjustment member **199** secured to shaft **200** and having adjustment screws **201** bearing on sector **198**. This arrangement of parts allows for the very minute adjustments necessary to synchronize the prism **301** with the guns **110**.

A piece of flexible opaque sheeting **360** (Figure 8) of leather or rubber is attached to housing **350** by clamping against cushion **358** by clamp bar **356**. The other end is fastened by screws to wall **351**. Sheeting **360** prevents light from directly entering lens **330** or the face B'C' of prism **301**.

Hood **350** is closed by a window of glass **362** clamped against a gasket **364** by a rim **366** screwed to hood **350**. All rays of light entering the periscope must pass through this window, and for this purpose it must be large enough to pass a full field to the prism **301** for all positions of rotation.

The details of construction of the cross hairs are shown best in Figure 10. Two permanent magnets **370** of "horseshoe" shape, each has a rotor **372** of any well known construction such as are used in galvanometers. Each rotor is attached to a U-shaped member **374** having a fine metal cross hair wire **376** across the upper ends. The U-members **374** with rotor attached are suitably supported on each end by hardened, pointed pins **378** journalled in a recess in hardened heads **380** held in image box **352**. Electric current is supplied to the galvanometer units by wires leading from socket **277** (Figure 8) which wires are connected as shown in Figure 10 to hair springs **382** (only two of which are seen) at the journals for both U-members **374**. Current flows into one hair spring, goes through the associated rotor **372** and through the bottom leg of U-member **374** to the other hair spring where the current leaves the member. Hair springs **382** help to center the U-members **374** as well as pass current through the rotors **372**. The journals and hair springs at the rotor end of the U-members are not shown, but they are of the same construction as those shown. It will be noted that one leg of one U-member is curved over part of its length to accommodate the casing of objective lens **330**. Counterweights **384** help to balance the U-members.

Referring still to Figure 8 it may be seen that the mirror **332** is mounted on a standard **334** attached to the bottom of image box **352**. The mirror reflects the light rays so that an image is formed in plane I—I just above it. It will be noted that the cross hairs **376** are very near this plane so that they appear to be a part of the image viewed by the gunner.

The cross hairs are placed at right angles to each other, and can move either side of dead center, depending upon the direction of the current going through rotors **372**. The magnitude of the movement depends upon the voltage across rotors **372**. These two factors, magnitude and direction of the current, cause the cross hairs to move independently and to move relative to the field of the periscope, in correcting for ballistics deflection and lead. The gunner has merely to move the turret and guns so that the intersection of the cross hairs is superimposed on the image of the point on the target which he desires to hit. The electrical circuit and its parts for moving these cross hairs will be later described.

As shown in Figures 8 and 9, a tubular cell of screen or perforated metal **386** is screwed into the bottom of image box **350**. This cell is filled with silica gel, calcium chloride, or other moisture absorbent material and is used to de-hydrate the periscope. Water vapor can pass through perforated housing **326** (Figure 4) to cell **386**. In this manner the major part of the periscope can be rid of water vapor and thus freedom from condensation on the optical system is assured.

Having explained the nature of the turret and the sighting device, the sight compensation will now be explained. As explained with reference to the periscope in Figures 8 and 10, the cross hairs **376** move with relation to the field of the periscope and the point of intersection of the two when superimposed on the image of the target in the periscope will represent a condition of the guns whereby they are so compensated that when fired the projectiles will strike the target at a point corresponding to the image point as seen in the periscope. The electrical system for passing current through the rotors **372** (Figure 10) of the galvanometers to move the cross hairs is entirely independent of the power current and circuits and has its own source of power and ground wires.

If a target were stationary and if the trajectory of projectiles were on the exact line of the axis of the gun barrels, there would be no need for sight correction. In all firing however, the effect of gravity causes the bullet to drop from the path of the axis of the gun toward the center of the earth. Also if a wind is blowing at an angle to the axis of the gun barrel, the bullet will be blown up or down or sideways depending upon the direction of the relative wind. If the relative wind is of any appreciable velocity it causes magnus effect, i. e., the tendency of the bullet to rise or fall from its normal path depending upon the direction of the wind. The magnus phenomenon is caused by the formation of a low pressure area on a part of a spinning object when moving through a transverse wind, causing the object to rise or fall depending upon the direction of the wind with relation to the spin of the object. Still another consideration in sighting a gun is lead; i. e., the amount in front of a moving target that a gun must be aimed in order to hit the target considering the time consumed in trigger actuation and flight of the bullet to the target.

The compensation system shown in this application is designed to compensate for all the predictable factors affecting the deviation of a bullet from the axis of the gun from which it is fired. The factors for which there is compensation in-

clude lead, magnus effect, gravity effect, and windage deviations.

Since the deviation of a bullet from the axis of its gun usually increases with the distance it travels, the corrections must be determined for a definite range, because corrections effective for all ranges would involve prohibitive complications of the correcting system. Rather, it is more expedient to choose the range at which most of the shooting can be done with relation to the calibre and type of gun used. For a .50 calibre machine gun this range is preferably about 600 yards. If the target is at a point inside this range the over corrections will not cause appreciable inaccuracies, for although there will be error, the target is closer and will intercept a larger angle of fire than a more distant target. For targets at a range greater than that chosen the guns may not be effective. Therefore the gunner will not normally shoot at such ranges and the errors are of little importance.

The deflection of the bullets from the axis of the guns, caused by gravity, magnus effect and windage are herein called ballistic deflection. Such deflection is preferably determined by empirical methods. The deflection data are then reduced pictorially by means of graphs and curves and broken down into elements of azimuth and zenith measurements to correspond with the mechanical movements of the guns in the turret, and the sight compensation system is designed accordingly. In operation, electrical currents are sent to the rotors **372** of the galvanometers, depending generally upon the position of the guns in zenith and azimuth, and the cross hairs **376** are moved automatically an amount depending upon the position in zenith and azimuth.

The relative lead of a gun upon a moving target with respect to the gun is a direct function of the speed of the target, and, where trigger actuation may be considered to be practically instantaneous, of the speed of the bullet or projectile. For a given gun the projectile speed is substantially constant and the relative speed of the target need be the only variable correction. In the present turret an electrical current responsive to the speed of the target is obtained by generators geared to or mounted on the shafts of the zenith and azimuth motors. Inasmuch as the turret must be moved to keep the target in the periscopic field, the rotation of the motors which move the turret and guns will directly reflect speed of the target, and therefore reflect the lead in azimuth and zenith. This lead current is sent to the galvanometer rotors **372** and is superimposed on the correction current for windage, magnus effect and gravity as described above.

The ballistics deflection of the guns of the turret, which deflection is the algebraic summation of the effects of windage, magnus effect and gravity, can best be broken up into vertical and lateral components with respect to the airplane in which the turret is mounted. The lateral deflections are corrected by advancing or retarding the rotation of the turret in azimuth which advances or retards the axis of the guns with relation to the target. The vertical deflections are corrected by elevating or depressing the guns of the turret with relation to the target.

These lateral and vertical components of ballistics deflection are correlated with the movement of the cross hairs **376** of the periscope. As shown in Figure 7, and as explained with reference thereto, the cross hairs intersect the field of the periscope vertically and horizontally. As best shown in the right hand field diagram of Figure 7, which is at the rear and is an upright image with respect to the gunner, the cross hair which intersects the gunner's image up and down is the vertical cross hair, and the hair that intersects the image from the gunner's left to right is the horizontal cross hair.

These hairs can be correlated with the rays of light of Figure 6, the cross hair intersecting the upper ray T and the lower B in the image plane I—I being the vertical hair and the other being the horizontal hair. Thus the hair parallel to the axes of the guns is the vertical hair hereafter designated as "V" and the hair transverse to the axes of the guns is the horizontal hair designated hereafter as "H." From the foregoing it is evident that the V hair corrects for lateral ballistics deflections because it moves sideways and that the H hair corrects for vertical ballistics deflection because it moves up and down with regard to the image.

Before describing the lateral and vertical ballistic deflections of the bullets the terminology used herein expressing the correlated azimuth and elevation positions will be explained. Azimuth is expressed in degrees of a full 360° circle, with 0° as straight forward and the angular measurement being clockwise when looking down on the airplane. Thus when the turret is pointing at 0° azimuth it is pointing straight forward, at 90° it is to the right, at 180° to the rear and at 270° to the left. Zenith is expressed in terms of degrees of a half circle with 0° as straight up. Thus if the upper turret of an airplane be at 0° zenith it would be pointing straight up and if pointed at 90° would be horizontal. When the lower turret is pointing at horizontal it is at 90° zenith and when pointing straight down it is at 180° zenith. It will be remembered that the zenith arc of the lower turret is from 90° to 180° i. e. from horizontal to straight down.

Lateral ballistic corrections

The correction for lateral ballistic deflection of a bullet is shown diagrammatically in Figure 12. The airplane **100** in which the turret is mounted is shown in the center of its range circle C**1** which may be taken at 600 yards, assuming that the turret has .50 calibre machine guns. The 0° mark of the circle C**1** in azimuth is straight ahead as explained before.

The airplane can be assumed to be flying straight ahead, for example at 250 miles per hour. A target airplane T**1** is assumed to be traveling in the same horizontal plane as airplane **100** and straight ahead at 250 miles per hour to remove considerations of lead from the ballistics compensation. If the guns were pointed straight at the airplane T**1** the projectiles would not hit it. The 250 miles per hour wind would blow the bullet laterally backwards. (Magnus effect and gravity doo not cause lateral deflections at 90° zenith. The vertical error of magnus and gravity does not show in Figure 12 and will be considered later.) To correct for the lateral deflection with regard to plane T**1** the turret must be rotated so that the guns point in advance of the target T**1** by an angle A**1**. The wind will blow the bullets backward and they will travel in the dotted path from airplane **100** to airplane T**1** and hit airplane T**1** squarely.

The size of the angle A**1** for each position of the target plane T**1** is indicated by the length of the radial lines A**1** between the range line C**1** and the lighter 90° zenith line or curve C**2**. The

length of these lines, as will be appreciated, are merely a linear measurement of an angular quantity and therefore have no measurement value except relative or as compared to a scale. No scale is given however, as this description is merely qualitative and the data varies for various guns and is elsewhere available. By regarding these radial lines as relative measurements only, it will be noted that the lateral deflection at 90° zenith is greater at 90° azimuth than at 45° azimuth, and that at 0° and 180° in azimuth the deflection is zero because bullets fired at those azimuth angles are not exposed to a side force from the wind.

In order for the cross hairs to reflect this correction angle A1 for the target T1, the V hair would have to move to the right of the true center of the periscopic field. If the turret is now turned so that the V hair intersects the target on the periscopic field, the guns will now lead the target T1 a correct amount so that the wind will "blow" the bullets to hit target T1 squarely. It will be realized that this V hair movement must be very small on a non-magnified field, and that the actual correction angles involved are very minute.

Also shown in Figure 12 is the target airplane T2, to the left of the airplane 100. As with the case of target T1, the guns of the turret must lead plane T2 so that when the wind blows the bullets backward they will strike the plane T2 squarely. In order to reflect this correction in the periscope, the V hair will have to move to the left of the center of the field to enable the guns to lead the plane T2, rather than move to the right as was the case with target T1. This difference in direction of movement must be indicated and for present purposes we can call the movement to the left of center positive and movement to the right of center negative. The change in sign is expressed by the radial distance from the range line C1 to the 90° zenith line C2. On the 0° to 180° part of the azimuth circle these radial distances are inside the range line C1 or negative, and from 180° to 0° the distances are on the outside of the range line C1 or positive.

If a target airplane were flying on the range circle C1 at 135° zenith instead of 90°, the corrections will vary but slightly. The corrections for 90° and 135° zenith are nearly similar because there is little difference in the angle at which the wind strikes the bullets. The chief difference at 135° zenith is near 0° and 180° azimuth where the spinning bullet is exposed to a side wind causing a magnus effect which diverts the bullet to the left at 0° azimuth with reference to Figure 12, and diverts the bullet to the right at 180° azimuth with reference to Figure 12. The angular correction at any point in azimuth for 135° zenith is the radial distance between the 135° zenith line, C3 and the range line C1.

The 90° zenith line C2 and the 135° zenith line C3 are so close together, that for practical purposes a common line can be drawn between them which will adequately represent both lines. Accordingly a single composite line C4 is drawn to represent both the 90° and the 135° line for all points in azimuth. This line is drawn in most places between the two lines. The greatest divergence of the composite line C4 from the mean of lines C2 and C3 is near 180° azimuth where the composite line C4 follows the 90° line closely. This is to render the firing at the tail area near 90° zenith as nearly accurate as possible because this is a vital area.

The actual correction therefore between 90° zenith and 135° zenith is incorporated in the composite line C4. The corrections at any point in azimuth are indicated by the radial lines between the composite line C4 and the range line C1. The sign of the correction is indicated by the nature of the radial lines. On the left part of Figure 12 between 180° azimuth and 0° azimuth, the positive correction is shown by solid lines; on the right part of Figure 12, the negative correction between 0° azimuth and 180° is shown by broken radial lines.

The composite line C4 is not an irregular curve, but rather a curve made up of arcs having the same radius as the range circle C1. One arc is from 0° azimuth to 45° azimuth and is negative, another from 45° to 90°, another from 90° to 118°, another from 118° to 157°, another from 157° to 237°, which crosses the range line C1 from negative to positive, another is from 237° to 270°, still another from 270° to 319°, and finally one from 319° to 0°. If the composite 90° and 135° line C4 were plotted on rectilinear coordinate paper, plotting degrees azimuth against correction angles, the arcs would show up as straight lines as will be described with relation to Figure 14.

The lateral deflections for 180° zenith are shown in Figure 14. In the middle part of the figure are shown the periscopic fields for the various azimuth positions when the guns are pointed at 180° zenith. The central dot DC appears in the middle of the field and marks the position toward which the guns are pointed. Wind will blow the bullets backward however, and magnus effect will cause the bullet to deflect to the left with reference to the dot DC, to hit the target airplane in the periscopic field. This deflection is constant in amount and direction relative to the airplane 100, regardless of rotation of the turret in azimuth, because the bullets are all exposed to the same wind forces when shooting straight down.

The V and H cross hairs at all positions in azimuth must intersect at the point at which the bullets hit when the guns are pointed at 180° zenith. For purposes of illustration a target airplane is shown in this position, and for purposes of illustration its size at 600 yards range is greatly exaggerated with relation to the field, which is a 45° field. The orientation dot DT is shown on field vertically above central dot DC. When the turret is pointed at 0° azimuth, the V hair is to the left of true center (shown by the dot DC) by an amount sufficient to compensate for the magnus effect. Although the H hair will be discussed later, it will be noted that it is below true center by an amount sufficient to compensate for wind blow. The correction of the V hair, which compensates for lateral deflections, is shown on a curve C5 to the left of the field illustrations, wherein the ordinate represents degrees azimuth and the abscissa represents the deflection angle. Since movement of the V hair to the left of center is a positive correction, this movement is marked positive (+) on the curve. Thus for 0° azimuth the abscissa is a small plus quantity.

At 45° azimuth the V hair must move to the right of center, or in a negative direction to intersect the target. This movement is shown on the curve C5 by a large negative deflection. At 90° azimuth the V and H hairs are interchanged as compared to the 0° azimuth positive. In this position the V hair movement reaches its greatest negative correction and this is reflected by a negative high point on the curve C5. At 135° azi-

muth the V hair is still at a negative correction but of slightly less amount than at 90°.

When the turret is rotated to 180° azimuth, the V hair again assumes a "0° azimuth" position as at 0° azimuth, but of reverse sign. This correction is reflected on the curve as a negative correction of an amount equal to that at 0° azimuth. The correction is negative because it is to the right of center using the orientation dot DT a basis. At 225° azimuth the V hair must move to the left of center to intersect the target, a positive correction. Thus the curve C5 will cross the zero deflection line from negative to positive between 180° and 225° azimuth.

At 270° azimuth the V hair reaches its greatest positive deflection, reflecting the full wind blow of the bullet. At 315° the correction is still positive but smaller in amount than at 270° azimuth. From a consideration of the V hair movement as the turret turns in azimuth, with relation to the fixed deflection, it will be apparent that the curve C5 is a sine curve.

For purposes of comparison, the composite curve C4 of Figure 12 may be drawn on the same azimuth-deflection axes as the curve C5 of Figure 14. As explained with reference to Figure 12, the composite curve C4 is not an irregular curve, but a series of regular segments. These show up on Figure 14 as straight line lengths plotted at the azimuth position noted in Figure 12. It can be seen that the composite curve C4 follows the curve C5 so closely that at 180° elevation, the composite adequately represents the true curve of the V hair movements.

From the foregoing it is evident that the composite curve C4 adequately represents V hair movements at 90° zenith, 135° zenith, and at 180° zenith. Further, it can be assumed with reasonable safety, that the curves in intermediate zenith positions correspond closely to the composite curve C4 for any given position in azimuth. This being true, all that remains is to produce a voltage curve corresponding to the curve C4, and impress this voltage on the galvanometer rotor 372 governing the V hair movement.

An electrical cam for producing a composite curve voltage wave is shown in Figure 13. To obtain positive voltages and negative voltages corresponding with the positive and negative correction angles, there is provided a source of positive and a source of negative voltage with reference to a source of zero voltage. This can be obtained by tapping the ends of a battery for the positive and negative voltage and tapping a midpoint in the battery for the zero source as will be described later.

Figure 13 shows a series of bridges for producing a voltage curve corresponding to the azimuth composite curve C4 for the lateral deflection, and will be referred to as the lateral composite or LC cam. For illustration, the voltages of 1.5 volts and of —1.5 volts are taken as the maximum voltage corrections corresponding to the maximum angular corrections, which are practically equal though opposite in sign as at 90° and 270°. Positive voltage is supplied to the LC cam by wire 54 which is connected to a supply wire 57 supplying voltage and current to the various positive cam angles at the ends of arc segments of the composite curve C4 of Figure 12; namely 237°, 270°, 319° and 0° azimuth. Negative voltage and current is supplied to cam LC by a wire 53 connected to a supply wire 58 supplying the various negative cam angles at the ends of arc segments of the curve C4 of Figure 12; namely, 45°, 90°, 118° and 157° azimuth. A zero voltage wire 52 is connected to a grounding conductor 59 which in turn is connected to resistances at all of the arc segment ending angles, both positive and negative, of the composite curve C4 of Figure 12.

The actual voltage curve is formed on a series of resistances forming a circle 60. The cam LC is stationary in the airplane and voltage is taken off from circle 60 by a take-off arm 61 synchronized with the movement of the turret in azimuth. Thus when the turret is pointed at 0° azimuth the arm 61 is at the zero degree mark on cam LC, and as the turret is rotated the arm 61 moves with it for any given number of rotations. The voltages at the various points are indicated in Figure 13. At zero degrees the .055 v. corresponds to the small positive correction angle at 0° in Figure 12. At 45° the voltage is a negative .943 v. and at 90° is negative 1.5 v. corresponding to the maximum negative correction in Figure 13. Between 157° and 237° the voltage again changes sign from negative to positive and approaches the maximum at 270° again with plus 1.5 v.

The voltage circle 60 is formed by a series of simple bridges, and for purposes of illustration the formation of the voltage points at 270° and 319° will be described. At 319° the voltage drops from plus 1.5 v. in wire 57 to zero at wire 59. All that is necessary is to place a resistance between these two wires, and pick off an intermediate point on the resistance giving plus 1.106 v. A resistance R6 of 52.6 ohms connecting wire 57 and the voltage point gives the correct voltage of 1.106 v. when in series with a resistance R7 of 152 ohms connecting the voltage point and ground wire 59. This can be approximated mathematically by multiplying the fraction R7 over the quantity R6 plus R7 by the maximum voltage 1.5 v., which equals 1.116.

The same considerations obtain at the 270° point. Since the maximum voltage of 1.5 v. is desired at the voltage point a conductor 62 leads from wire 57 to the voltage point. A resistance R9 is connected between the 270° voltage point and ground wire 59 and is approximately equal to the sum of the radial resistances connected at any voltage point or about 200 ohms. A resistance R8 connects the voltage points of 270 and 319 to give a straight line graduation of voltage between the two. This resistance R8 is relatively high because the current taken off by arm 61 is very small, as will be explained later. The details of calculation of the correct resistance, for circle 60 between voltage points are dependent upon resistance in the circuits supplied by arm 61, and these calculations are well known in the electrical art and need not be explained here. The single bridge circuit just described is duplicated between all other supply points on the circle 60 and by connecting the whole together the voltage circle 60 is formed. In this manner an accurate voltage wave may be formed for the composite curve LC, and yield voltages at any point in azimuth which are satisfactory for all points in zenith from 90° to 180°.

Vertical ballistics correction

The correction angles for the vertical ballistics deflection of a bullet are shown in Figure 16. The airplane 100, in which the lower turret is mounted is shown in the center of its hemisphere of fire. The range line for 90° zenith is shown as line C6. The correction angles for any point in azimuth

on the line C6 is shown on a correction curve C7. The range line for 135° zenith is the line C8, and correction angles for azimuth points on line C8 are measured by a correction curve C9. The corrections for 180° zenith will be explained later with reference to Figure 14.

The amount of correction at an azimuth point on a range circle is shown by the "longitude" lines on the hemisphere between the range line and its respective correction curve. For example at 90° azimuth and 90° zenith the correction angle is much greater than at 270° azimuth and 90° zenith. Magnus effect causes the bullet to "dive" when fired at 90° azimuth, and to "climb" when fired at 270° azimuth, but even at 270° azimuth the effect of gravity is greater than magnus effect and the guns must be aimed above the 90° zenith range line C6 to hit an airplane on that 90° zenith line. The target airplane T3 is shown on the 90° zenith line, and in order for the bullets to hit the target the guns must be elevated an angle A3 above the target to offset magnus effect and gravity. In order to point the guns above the target plane T3, the horizontal or H cross hair must move below the center of the field of the periscope. When the target plane T3 is then sighted on the H hair the guns will be elevated above the target. The angular correction, and the corresponding movement of the H hair below center will be referred to as a positive correction.

A target plane T4 is shown to the rear of airplane 100 at 180° azimuth and 135° zenith on the line C8. If the guns were pointed directly at this target plane the wind would blow the bullets relatively upward from the axis of the guns and they would never hit the target. The guns must accordingly be pointed below the target T4 by an angle A4 as determined by the longitudinal correction lines (drawn dotted) below the 135° zenith range line C8 to the correction curve C9. The bullets now fired will be blown upwardly from the axis of the guns in the path shown by the heavier dotted line, and will hit the target airplane T4 squarely.

In order to point the guns below the target plane T4, the H hair must be raised above the center of the periscopic field, and the turret guns then depressed to sight the cross hairs on the target plane T4. It is understood, of course, that in actual operation the cross hairs move automatically and the pilot merely sights on the target. The movement of the H hair above center, being opposite from the movement for target T3, will be called negative, and is indicated by longitudinal lines below the range line. Positive corrections are indicated by longitudinal lines above the range lines.

A target T5 is shown in Figure 16 directly below the airplane 100 at 180° zenith. The guns must be pointed in advance of the target T5 at an angle A5, so that when the bullets are blown backwardly by the wind they will hit the target. This correction is illustrated to bring out the corrections for the H hair movement which will be discussed with relation to Figure 14.

The movements of the H hair when the guns are pointing at 180° zenith are shown in Figure 14. The periscopic fields for the various azimuth positions are shown in the central part of the figure. The curve corresponding to the movements of the H hair is a curve C10 shown on the right part of the figure. The abscissa measurements reflect angle of correction, and the ordinate measurements represent degrees in azimuth. As stated before, the deflection for 180° zenith is constant in amount and direction with relation to the airplane in which the turret is mounted. The dot DC marks the center of the field, the direction in which the guns are pointed. The bullets are blown backwardly as described in Figure 16, and magnus effect causes them to deflect to the left so that they hit the airplane in the field squarely. The V and H hairs must move according to azimuth position so as to intersect on the target at all times.

At 0° azimuth the H hair is below the center of the periscopic field as shown by the dot DC. This movement by prior definition has been termed positive, and is accordingly reflected on the curve C10 as a positive quantity. At 45° azimuth the H hair is below center by a less amount and this is reflected on the curve C10 accordingly.

Between 90° azimuth and 135° azimuth the H hair crosses the center of the field so that it is "above" center, (i. e. toward the dot DT). This change is reflected on the curve C10 by a change of sign from positive to negative. At 180° the negative correction is the greatest and gradually diminishes until it again changes sign near 270° azimuth. The positive correction increases at 315° azimuth to connect with the negative peak at 0° were the curve completed on a circular path as are the curves of Figure 12.

Having now determined the nature of the curves which reflect correction movement of the H hair at 90° zenith, curve C7; at 135° zenith, curve C9, and at 180° zenith, curve C10, it must now be considered by what means these curves can be duplicated electrically to move the H hair in a path corresponding with the curves. In the case of lateral deflection, the curve at 90° zenith, curve C2, at 135° zenith, curve C3, and at 180° zenith, curve C5, were so similar that one composite curve C4 could adequately represent all three curves. In the case of vertical deflection, however, the curves are all radially different. In Figure 16 it can be seen that curve C7 for 90° zenith is always positive and that curve C9 for 135° has positive and negative positions. By comparing Figure 14 with Figure 16 it can be seen that the curve C10 for 180° crosses the zero line at different points from the 135° curve C9. Manifestly no one curve can adequately represent all three curves in vertical deflection.

The three curves C7, C9 and C10 must therefore all be duplicated electrically and connected with the position of the guns in zenith to make the curve nearest the zenith position of the guns most effective at that instant. The three curves are accordingly duplicated by electrical cams and connected together in zenith, so that a take-off member following the guns in zenith can pick off the curve nearest the zenith position of the guns.

The 180° zenith curve C10 for the H hair is duplicated electrically by the electrical cam shown in Figure 15. Since this cam reflects movements of the H hair at 180° zenith, which hair corrects for vertical deflections, this cam will be referred to as the V180 cam. The construction of the V180 cam is based on the same principles as the DC cam shown in Figure 13, the construction of which has been explained. The wire 54 supplies positive voltage to the positive points of the curve, 315°, 0°, 45° and 90° azimuth. The wire 53 supplies negative voltage to the negative points on the curve, 135°, 180°, 225° and 270° azimuth. The wire 52 supplies zero voltage to the cam. A take-off arm 65 traverses the circle of the cam, rotating as the turret rotates in azimth. Take-

off arm 65 delivers current to a wire 55 which is connected to a cam VE which will be explained later. The actual electrical curve created by cam V180 is shown in dotted lines on Figure 14 as the curve V180. It will be noted that the electrical curve V180 follows the theoretical curve C10 very closely.

The correction curves for vertical deflection curves C7 for 90° zenith and curve C9 for 135° zenith are duplicated by voltage curves at any point on the hemisphere of fire, by the cams shown in Figure 17. In Figure 17 is shown an azimuth cam V90 for the 90° curve C7, and an azimuth cam V135 for the 135° curve C9, and a zenith cam VE for correlating the azimuth curves to the zenith position of the guns. It can safely be assumed that the corrections in zenith between the curves vary in a straight line relation for any given azimuth position, that is, between curves C7 and C9 for 90° zenith and 135° zenith, and between curves C9 and C10 for 135° zenith and 180° zenith.

The actual construction of the 90 degree cam V90 and the 135 degree cam V135 is similar in principle to the lateral deflection composite cam LC of Figure 13. The correction curves are electrically formed by a series of "straight line" electrical segments which follow the actual curves very closely. Wire 54 is a source of positive voltage for cam V90, and since there are no negative portions on the correction curve C7 for 90° zenith the only other supply wire is the ground or zero potential wire 52. The 0° azimuth mark on cam V90 corresponds with the 0° azimuth position of the turret with relation to a wiper arm 67 which rotates in synchronism with the azimuth rotation of the turret. The resistances used give the proper voltages to correspond to the correction angle curve C7 of Figure 16. The voltage at 0° is small, is greatest at 120° and smallest at 255°.

The cam V135 has a positive and a negative portion to correspond with the correction curve C9 of Figure 16. Wire 54 supplies the positive voltage, wire 53 supplies the negative voltage, and wire 52 the zero voltage. The cam V135 is greatest in positive voltage near 0° azimuth and greatest in negative voltage near 205° azimuth. A wiper arm 68 takes current off of the circle of cam V135, the arm 68 moving in synchronism with the turret in azimuth.

A wire 69 receiving the current from wiper 67 of cam V90 leads to the 90° zenith point of a resistance R11 forming a part of cam VE and curved to form a 90° to 135° zenith arc. A wire 70 receiving the current from wiper 68 of cam V135 leads to the 135° end of resistance R11 at which point another resistance R12 forming another part of the cam VE is attached to form a 135° to 180° arc of the zenith arc. The 180° end of resistance R12 is connected to wire 55 which receives current from cam V180 as shown on Figure 17.

Both resistances R11 and R12 are of several thousand ohms. A wiper arm 71 forming another part of cam VE is synchronized with the guns of the turret in zenith, and wipes the resistances R11 and R12, passing the azimuth voltage from cams V90, V135 and V180, as modified by resistances R11 and R12, to a wire 72 leading to the H cross hair circuit.

The operation of the circuit of Figures 15 and 17 depends entirely on the movements of the turret. Cams V90, V135 and V180 are in the azimuth compensator housing 610 (Figure 3) and the wiper arms 67, 68 and 65 are secured to compensator shaft 602, making one complete rotation every time the turret rotates. The cam VE including the resistances R11 and R12 and the wiper arm 71 is in the zenith compensator housing 616 (Figure 3) and arm 71 is fastened to zenith compensator shaft 614. The combination of the azimuth and zenith movements covers every point in the hemisphere of fire of the turret, correcting for vertical deflection through movement of the H hair. The position of the turret in Figures 13, 15 and 17 is indicated by the position of the arms 61, 65, 67, 68 and 71 to be about 60° in azimuth and 105° in zenith. Cam V90 is producing a voltage intermediate .28 v. and .49 v. and supplying this voltage to the top of resistance R11. Cam V135 is producing a voltage intermediate +1.107 v. and −.49 v. and supplying this voltage to the bottom end of R11. Since wiper 71 is about one-quarter of the way between 90° and 135°, the effective voltage will be one-quarter of the difference between the voltage at the 90° and 135° ends of R11 added to the voltage at the 90° end of R11.

Complete compensation electrical circuit

The compensation circuit as a whole is applied to the turret in Figure 18. The source of current for the lateral and vertical correction cams is obtained from a battery B2. A two-throw switch S15 controls power flow from the battery B2 at each end. A wire 50 is attached to switch S15 at the positive end of battery B2 and leads to a resistance R2 of a manual rheostat 625. A wire 51 is attached to switch S15 at the negative end of the battery and leads to rheostat resistance R3. Zero voltage wire 52 taps a mid point in the battery B2. An arm 53*a* of rheostat 625 connected to wire 53 takes current from negative resistance R3, and an arm 54*a* connected to wire 54 takes current from positive resistance R2. The rheostat 625 is manually controlled in response to air speed, because the ballistics deflections described vary substantially in accordance with air speed.

The wires 52, 53 and 54 supply current to the azimuth cams LC, V90, V135 and V180 as described with relation to Figures 13, 15 and 17. The respective take-off arms of these cams are attached to the azimuth compensator shaft 602 which rotates once for every rotation of the turret in azimuth. It will be noted that the takoff arms for the cams are all pointing in the same direction, approximately 180° azimuth, and from a comparison of the respective azimuth and elevation drive parts the turret can be seen to be pointing toward the rear of the airplane 100 or near 180° azimuth in which it is mounted.

The azimuth cam take-off wires 69, 70 and 55 for the vertical deflection cams lead down the central column to the zenith compensator box 616 containing resistances R11 and R12. Wire 69 from cam V90 leads to the 90° end of resistance R11, and wire 70 from cam V135 leads to resistance R12 at the 135° elevation point. The take-off arm 71 secured to elevation compensator shaft 614 is synchronized with the movement of the guns in elevation, but it will be recalled that the rotation of the elevation compensator shaft 614 is multiplied about three times over the movement of the guns in elevation, to increase sensitivity. Thus the representation in Figure 18 of the 90° arc traveled by the elevation arms 71 is reduced and was used merely for purposes of illustration.

The take-off wire 63 from the LC cam in the

azimuth compensator leads down the central column to a balanced square bridge circuit for the vertical cross hair or V hair and this bridge will be referred to as bridge VB. The V hair, as stated above, corrects for lateral deflections. The opposite corner of square bridge VB is connected to wire **52** which is the ground or zero voltage wire. The bridge VB has the V hair rotor **372** in one leg, and both branches of the bridge are balanced including the resistance of the V hair rotor **372**. Although the resistances of the bridge VB may be of the order of several hundred thousand ohms, enough current is passed to the V hair galvanometer, which is sensitive to very small currents, to effect its movements. The V hair will move to the right or to the left in the periscopic field depending upon whether the voltage is negative or positive through the bridge VB.

The resultant current from take-off arm **71**, which is the current from the V90 cam (wire **69**) the V135 cam (wire **70**) and V180 cam (wire **55**), all relating to vertical deflections, passes to wire **72** which leads to a square balanced bridge HB. The H hair rotor **372** is inserted in one leg of the bridge HB and current flowing through the bridge causes the H hair rotor to move in accordance therewith. Although the resistances of the bridge HB may be of the order of several hundred thousand ohms, enough current is passed to the H hair galvanometer, which is sensitive to very small currents, to effect its movement. The opposite corner of bridge HB is connected to wire **52** which is the zero voltage or ground wire. The H hair will move above or below the center of the periscopic field depending upon whether the voltage is negative or positive.

The compensation for lead is accomplished by generators built into the azimuth and elevation motors **130** and **172** respectively. A generator G1 in the azimuth motor causes current to flow in wires **73** and **74**, the direction depending upon the direction of rotation of the azimuth motor **130**. Since azimuth lead is controlled by movement of the vertical cross hair V, the wires **73** and **74** lead to the bridge VB being attached to opposite corners. Depending upon the direction of the rotation of the turret, the V hair will move to the right or to the left in lead compensation. The lead current is superimposed upon the ballistics correction current through the bridge VB and the V hair moves in response to the algebraic sum of the two currents at any one time. In general, the lead current is several times as large as the ballistics correction current through the bridge.

Lead in elevation is accomplished by a generator G2 built into elevation motor **172**. This causes current to flow through wires **75** and **76**, the direction depending upon the direction of rotation of elevation motor **172**. Since lead in elevation is accomplished by movement of the H hair the wires **75** and **76** lead to opposite corners of the bridge HB. The effective current on the H hair rotor **372** is the algebraic sum of the ballistic correction current and the lead current.

In operation, with relation to Figure 18, the gunner learns from the pilot of the airplane through the intra-plane phone or otherwise, the speed of the airplane and sets the rheostat **625** to correspond thereto. He then closes switch S15 and current flows to the azimuth cams which regulate ballistic corrections. Lateral deflections in azimuth between 90 and 180° in zenith are corrected by cam LC having the take-off wire

63 leading down the central column to bridge VB. The cam V90 corrects for vertical deflection at 90° zenith. The cam V135 corrects for vertical deflections at 135° zenith. The cam V180 corrects for V hair movements at 180° zenith. The respective take-off currents flow through wires **69**, **70** and **55** to zenith cam VE in the elevation compensator, to be modified by the position of the guns in elevation. Lead correction is accomplished through generators G1 and G2 built into the azimuth motor **130** and the elevation motor **172** respectively. The direction of flow from these generators is dependent upon the direction of rotation of the respective motors. Lead in azimuth is corrected on the V hair, and wires **73**, **74** from generator G1 consequently lead to bridge VB controlling the V hair. Lead in elevation is controlled by the H hair and wires **75** and **76** from generator G2 consequently lead to bridge HB controlling the H hair. The lead currents are superimposed on the ballistics correction currents at the respective bridges, and the V and H hairs move in response to the algebraic sum of the two currents.

It has been assumed that lead is directly dependent upon the relative rate of movement of the target plane with respect to the airplane **100**, which is reflected by the rate of angular movement of the turret in keeping the target in the periscopic field. Actually, however, lead varies according to the position of the target airplane in azimuth and zenith and varies somewhat in the same manner as ballistic correction according to gun position. This lead variation is so small as compared to the total lead and as compared to the ballistic corrections, that it can be ignored for practical purposes and for this reason lead correction cams are not shown.

It has been stated that ballistics correction varies according to air speed, which is reflected by moving rheostat **625** to the proper position. Actually, however, ballistics correction varies in accordance with air speed and density of the air. The correction obtained by movement of rheostat should reflect air speed and density, as determined by the speed and altitude at which the airplane is flying. This dual correction can be made automatically by having a wind driven generator as the source of current rather than a battery. Air speed and density then determine total voltage, although a wind driven generator adds weight and air resistance compared to a battery.

The mounting of the upper turret is illustrated in Figure 19. An airplane **201** has mounted on the rear part of the fuselage an upper turret **202**, which is adapted to rotate through 360°.

The mounting of the turret is shown in detail in Figure 20. Secured to longitudinal members **204** of the airplane **201**, is a base member **206** which rotatably supports a column **208**. Secured to the top of rotatable column **208** is a frame member **210** to which the guns **212** are mounted for rotation in zenith. Also secured to frame **210** is a periscope **400** and an ammunition can **216**. A transparent canopy **218** covers the top of the turret and is secured to frame **210**.

The turret is operated by a gunner **220** sitting on a seat **222** secured to the column **208**, the gunner placing his feet on a rest **224** also secured to the column **208**. With his right hand the gunner **220** grips a control handle **226** which he manipulates to rotate the turret in azimuth in either direction or to elevate or depress the guns. The gunner sights the guns by looking through

periscope 400, moving the turret and guns in alignment with the target. All the mechanism mounted on the column 208 rotates in azimuth, and the guns 212 and the movable part of the periscope 400 rotate in zenith.

The mechanical parts and movements of the upper turret are shown schematically in Figure 21. At the bottom of the figure a high speed electrical motor 228 drives a motor shaft 230 to which is secured a worm 232, which drives a worm wheel 234 secured to a drive shaft 236 to which is secured at the other end a driving worm 238. Drive worm 238 engages a worm wheel 240 secured to rotatable column 208, and drives column 208 in rotation in either direction depending upon the direction of rotation of azimuth motor 228.

Also secured to worm wheel 234, is a compensator drive shaft 242 to which is secured a compensator worm 244. Worm 244 drives compensator worm wheel 246 to which is connected compensator shaft 241. Mounted on compensator shaft 241 is an azimuth electrical cam 704.

The gear reduction between compensator worm wheel 246 and worm 244 is the same as that between column worm wheel 240 and driving worm 238, resulting in compensator shaft 241 rotating one revolution for every revolution of column 208 and rotating in synchronism.

Rotatable column 208 is preferably made of aluminum or magnesium to reduce weight. The frame 210 secured to the top of column is also preferably magnesium or aluminum and may be made by casting. An opening 211 in the frame 210 provides a place in which the gunner may place his body for operating the turret. The guns 212 are secured to a rotatable gun shaft 250 supported near each gun by frame brackets 252.

Referring again to Figure 21 gun shaft 250 is driven in zenith by a high speed electrical motor 254 positioned within a well 256 in frame 210. Motor 254 drives a motor shaft 258 to which is secured worm 260 engaging driving worm wheel 262 mounted on a drive shaft 264. Secured on the other end of drive shaft 264 is a driving worm 266 engaging a worm wheel sector 268 secured to gun shaft 250. The gun shaft is rotated in either direction by reversing elevation motor 254, elevating or depressing the guns according to direction of rotation of motor 254.

The zenith compensator drive is obtained through a bevel gear 270 secured to shaft 250, and driving a matching bevel gear 272 which drives zenith compensator shaft 274. Fastened to compensator shaft 274 is a compensator cam 606. Since the zenith movement of the guns is about 90°, the rotation of compensator shaft 274 is multiplied about three times to increase sensitivity of the cam control.

Shown in Figure 21 also is the mechanism for synchronizing the periscope 400 (Figure 20) with the zenith movement of the guns. A spur gear 276 is fastened to gun shaft 250 and engages the teeth of a double rack 278, the other end of which engages a double spur gear 280. The other part of spur gear 280 engages a second double rack 282 the other end of which drives a gear 284. Gear 284 is secured to a prism shaft 286 on which is mounted for rotation the periscope prism 412. Through mechanism which will be later described, the rotation of prism 412 in synchronism with the zenith movement of the guns enables the gunner to observe at all times the field into which the guns are firing at any given time.

The periscope is shown in detail in Figures 22, 23 and 24. The periscope 400 includes three main parts, a sightbox 414, a central tube 416, and an eyepiece 418. The sightbox 414 has rotatably mounted therein the prism 412 (Figure 21) held against a plate 419 by a clamp bar 420 and having corners A', B' and C'. The prism rotates on shaft 286 through an angle of about 45° from the position in Figure 22 shown in solid lines to that shown in broken lines. On the upper face of sightbox 414 is a window 422 in which is placed a pane of plate glass 424. A horizontal partition 426 divides sightbox 414 into an upper prism compartment 428 and a lower meter compartment 430.

A flexible opaque sheet 432 secured to prism clamp 420 and partition 426 prevent light entering window 422 from striking the lower surface of prism 412.

Referring to Figure 22 light entering through window 422 to prism 412 is refracted and reflected from prism 412 to an objective lens unit 434 held in partition 426. After passing through lens 434 the light is reflected from a periscope mirror 436 held in position by a standard 438 secured to partition 426. The light thus reflected forms an image on the plane I—I just to the left of mirror 436. Rays of light from the image on plane I—I pass through two convex lenses 440 and 442 which aid in the "erector" function of making the image appear upright to the gunner using the periscope. Secured to the bottom of sightbox 414 is a cover plate 444 to which are secured a cross hair actuating mechanism including galvanometers 510 and 520. The cross hairs are in the image plane I—I and therefore form an integral part of the image viewed by the gunner. The cross hair actuating mechanism will be more fully explained with reference to Figure 24.

Again referring to Figure 22, secured to sightbox 414 is the central tube 416. This tube retains two sets of two lenses each, which lenses cooperate with the lenses 440 and 442 of sight-box 414 in making the image appear upright. One set of lenses 446 and 448 are mounted in a longitudinally movable housing 444 placed in the right part of tube 416. A screw 450 passing through a slot 452 in central tube 416 is threaded into housing 444 and is tightened adjustably to position the housing 444 in the tube 416 to obtain the proper focus. In the left end of tube 416 are secured two additional lenses 454 and 456 to complete the erector function of the various lenses. The erected image is projected or focused on plane I2—I2 which is at the right face of a plate glass member 458 also held in the left part of central tube 416.

The eyepiece 418 is screwed to the left end of tube 416, and retains two lenses 460 and 462 respectively for viewing the image on plane I2—I2. A hollow sponge rubber cushion 464 is fastened to the left end of eyepiece 418 for the gunner to rest his head against while looking through the periscope.

The paths of the light rays through the periscope are also shown in Figure 22. The prism takes in a field of about 45° in which T is a top ray, C a center ray, and B a bottom ray of the field. The center ray C is parallel to the axis of the guns for any given position of the guns in elevation and by this means the gunner may sight his guns while looking through the periscope. The rays enter face A', B' of the prism 412 and are refracted to the reflecting surface

A', C' of the prism. The rays then leave the prism through the face C', B' and enter the objective lens **434**. The guard **432** prevents light entering window **432** from striking face C', B' of the lens. After passing through the objective lens **434** the rays are reflected at right angles by mirror **436** and form an image in the plane I—I.

It will be noted that the top ray T is at the bottom of the image in plane I—I and that the bottom ray B is at the top. From this it is apparent that the image is inverted, and to aid the gunner in training the guns on a target the inverted image is erected. Light from the image of the plane I—I passes through lenses **440**, **442**, **446**, **448**, **454** and **456** which invert the image of plane I—I, giving an upright image on plane I2—I2. That the image on plane I2—I2 is upright is shown by the fact that the top ray T is at the top of the image and the bottom ray B is at the bottom. The rays from image I2—I2 pass through eyepiece lenses **460** and **462** to the point where the eye of the gunner would normally view the image. There is substantially no magnification of the image in the eyepiece **418**, so that the field will be as large as possible.

The other extreme position of the lens **412** is shown in dotted outline in Figure 22. In this position the center ray C will be vertical corresponding to a vertical or 0° zenith position of the guns. It will be noted that the rotation of prism **412** from one extreme to the other is only half of the angular movement of the guns. This is due to the mirror function of prism face A', C' of the prism **412**, resulting in the field rotating twice as much as the mirror rotates.

The path of the rays in the 0° zenith position is shown in Figure 23. The left ray T and the right ray B correspond to the top and bottom rays T and B respectively of Figure 22. The rays refract into the prism, are reflected and refracted to the lens **434**, and after passing through lens **434** are reflected by mirror **436** and form an image on the plane I—I. The image on plane I—I of Figure 23 is inverted as in Figure 22. For intermediate position of the prism **412** between the two extremes the rays of light follow intermediate paths from those shown.

The cross hair mechanism is shown in detail in Figure 24. The two galvanometers **510** and **520** are fastened to cover plate **445** as shown in Figure 22 so that the cross hair mechanism may be inserted or removed as a whole by merely removing plate **445**. Each galvanometer **510** and **520** is a permanent magnet and has secured thereto two uprights **512** of hexagonal bar stock, joined at the top by a connecting member **514**. The galvanometers **510** and **520** each have a rotor **516** and **518** respectively to which are secured shafts **522** and **524** respectively. The shafts **522** and **524** are journalled on one end in connecting members **514** and the other ends are similarly journalled in mechanism not shown. Secured to the rotor shaft **524** of H hair galvanometer **520** are two transverse members **526** preferably made of fine aluminum tubing or magnesium to reduce weight. Between the left ends of members **526** is stretched a fine wire **528** which is the H hair or the cross hair intersecting the field of the periscope horizontally. The opposite or right ends of members **526** project beyond shaft **524** and have mounted thereon weights **530** to counterbalance the longer left end. The transverse members on shaft **522** which support a vertical cross hair **532** are similar in construction to the transverse members

526 of shaft **524** except that the upper cross arm is curved to reach around the lens unit **434** (Figure 22).

Each rotor shaft **524** and **522** is centered by a hair spring **534** secured to each end of the shaft and to adjustable arms **536** mounted on each cross member **514**. Only one hair spring for each shaft is shown in Figure 24, but the construction (not shown) on the other ends of the rotor shafts is similar. The current for actuating the galvanometer passes through the hair springs of each shaft and in passing through the rotor, causes the rotors **516** and **518** to react against the field of the permanent magnets **510** and **520**. The electrical system for supplying current to the galvanometers to supply automatic sight correction will be described later.

From the foregoing description it will be noted that the mechanical parts and movements of the upper turret are similar in many respects to those of the lower turret. Also, the periscopes are similar, and as a matter of practice, the same construction of periscope is used in both upper and lower turrets. Also it will be recognized that the same problems of ballistic correction and lead are present in the upper turret as are found in the lower turret.

For these reasons the complete compensation circuit of the upper turret is practically identical with that of the lower turret and therefore will not be discussed in detail. The complete wiring diagram for the sight compensation circuit of the upper turret is shown in Figure 25.

The lateral deflection for a given point in azimuth is relatively independent of the elevation position of the gun. It is therefore possible to make an electrical cam producing a voltage wave corresponding to the composite lateral deflection curve. This cam is cam LC of Figure 25 indicating "lateral composite."

Vertical deflections vary greatly for a given position in azimuth depending upon position in zenith. Accordingly an electrical cam V90° is provided to produce a voltage wave corresponding to a deflection curve for all azimuth positions at 90° zenith. An electrical cam V45° is provided to produce a voltage wave corresponding to a vertical deflection curve for all azimuth positions at 45° zenith. A third cam V0° is provided to give a voltage curve corresponding to the movement of the V hair for all azimuth positions when following the fixed ballistics deflection at 0° zenith.

These three electrical cams for vertical deflection are combined electrically so that each exerts a proportionate effect upon the H hair. This is done by means of an electrical cam VE driven by the elevation compensator shaft **274**.

Referring to Figure 25, the resultant vertical deflection current is passed to a bridge HB controlling the horizontal cross hair, the reference letters indicating "horizontal bridge." The resultant current from the lateral composite cam LC is passed to a bridge VB for controlling the vertical cross hair V, the reference letters indicating "vertical bridge." The bridges VB and HB are also connected respectively to two lead generators the operation and construction of which will be later described.

Current is furnished by a battery B3 having the terminals connected to a double switch S18. The positive end of switch S18 is connected to a wire **770** leading to a resistance R5 of a manual potentiometer **740** and the negative end is connected to a wire **771** leading to a resistance R6 of the potentiometer **740**. The potentiometer **740**

is provided to give an available voltage for the compensation circuit depending upon the speed of the airplane which largely controls ballistics deflections. The battery is center tapped by a wire **772** to provide a source of zero potential and the positive end of the battery is positive with respect thereto and the negative end is negative with respect thereto.

Leading from resistance R5 is a wire **773** for positive potential, and leading from resistance R6 is a wire **774** for negative potential. The three wires **772**, **773** and **774** lead to the four azimuth cams V90°, V45°, V0° and LC supplying respectively zero, positive and negative potential where needed. The wire **772** continues up the column to connect to corners of bridges HB and VB. The azimuth cams are made up of a series of bridges in circular form, as is well known in the electrical art and described with relation to the lower turret, to produce a positive and/or negative voltage of the desired wave form. Each cam has a wiper which picks off the desired voltage according to the position of the turret in azimuth.

Connected to the wiper of cam V90° is a wire **775** leading down to the brush box and up the column to one end of cam VE. Leading from the wiper of cam V45 is a wire **776** leading to a central point of cam VE, and a wire **777** leading from the V0° wiper leads to the other end of cam VE. The VE wiper arm is driven by elevation cam shaft and has a wire **778** connected thereto leading to a corner of bridge HB opposite to the connection of wire **772**.

The wiper of azimuth cam LC is connected to a wire **779** which leads up the column to bridge VB where it is connected to a corner opposite to the connection of wire **772**.

Lead in a vertical direction is furnished by a generator G3 built into the elevation motor **254**. The amount of lead necessary depends upon the speed with which a target is moving and the faster the gunner moves the guns by elevation motor **254**, the greater will be the lead current generated. Wires **780** and **781** are connected to the generator G3 and lead to opposite corners of bridge HB to move the H hair up or down depending upon the direction of the lead. Lead in a horizontal direction is furnished by a generator G4 having wires **782** and **783** leading up to column to opposite corners of bridge VB.

The operation of the sight compensation system shown in Figure 25 is entirely dependent upon movement of the guns in zenith and azimuth. As the turret moves in azimuth the lateral deflection correction is made by cam LC and is positive or negative according to azimuth position to swing the vertical cross hair V to the right or left of the center of the field. At the same time V cross hair is affected by lead generator G4 supplying current according to speed of movement in azimuth. The resultant cross hair movement will be the algebraic sums of the ballistics and lead corrections.

The H hair is actuated by cam V90, V45 and V0° as modified by the zenith position of the guns on cam VB. The lead connection is furnished by generator G3 and the resultant movement of the H cross hair is dependent upon the algebraic sum of the two currents.

Thus has been described a novel and unique construction comprehending a sighting device which is corrected for windage, gravity and magnus deflections of a projectile, and which is also corrected for the necessary lead on a moving target. There has also been provided a sight wherein reference media move relative to the field of the sight to give automatic correction.

Although this invention has been described with reference to particular embodiments thereof, it is not limited to these embodiments or otherwise except by the terms of the following claims.

What is claimed is:

1. In a sighting mechanism for guns movable in azimuth and zenith, a sighting means synchronized with the movement of the guns, a first electric meter positioned near said sighting means and moving a vertical cross hair laterally in said sighting means, and a second electric meter positioned near said sighting means and moving a horizontal cross hair laterally in said sighting means, a first balanced square bridge including the first said meter in one leg thereof, a second balanced square bridge including the said second meter in one leg thereof, a source of positive voltage, a source of zero voltage, and a source of negative voltage, a conductor connecting the source of zero voltage to one corner of both of said bridges, an electric cam mechanism connected to the positive and negative and zero voltages and to the first bridge at the opposite corner from the zero voltage connection of said first bridge, said cam adapted to pass measured amounts of positive or negative voltage to said bridge dependent upon the position of the guns in azimuth and zenith to actuate said vertical cross hair to correct for lateral ballistics deflection, and a second electrical cam mechanism connected to said positive, negative and zero voltages and to the corner of the second bridge opposite to the zero voltage connection and adapted to pass measured amounts of negative voltage to said second bridge dependent upon the position of the guns in azimuth and zenith to actuate said horizontal cross hair to correct for vertical ballistics deflection.

2. In a sighting mechanism for guns movable in azimuth and zenith, a sighting means synchronized with the movement of the guns, a first electric meter positioned near said sighting means and moving a vertical cross hair laterally in said sighting means, and a second electric meter positioned near said sighting means and moving a horizontal cross hair laterally in said sighting means, a first balanced square bridge including the first said meter in one leg thereof, a second balanced square bridge including said second meter in one leg thereof, a source of positive voltage, a source of zero voltage comprising a resistance and a neutral point connected to said source of positive voltage, and a source of negative voltage, a conductor connecting the source of zero voltage to one corner of both of said bridges, an electric cam mechanism connected to the positive and negative and zero voltages and to the first bridge at the opposite corner from the zero voltage connection of said first bridge, said cam adapted to pass measured amounts of positive or negative voltage to said bridge dependent upon the position of the guns in azimuth and zenith to actuate said vertical cross hair to correct for lateral ballistics deflection, a second electrical cam mechanism connected to said positive, negative and zero voltages and to the corner of the second bridge opposite to the zero voltage connection and adapted to pass measured amounts of negative voltage to said second bridge dependent upon the position of the guns in azimuth and zenith to actuate said horizontal cross hair to correct for vertical ballistics deflection, a direct

current generator connected to respond to the speed of the movement of the guns in azimuth, the output wires from said generator being connected to the remaining opposite ends of the first square bridge, and a second direct current generator connected to respond to the speed of movement of the guns in zenith, the output wires of the generator being connected to the remaining corners of the second square bridge.

3. In an electrical cam for correlating the movement of a vertical cross hair in a sighting mechanism with the lateral corrections for a bullet of a gun fired into a wind stream, a source of positive voltage, a source of zero voltage comprising a resistance and a neutral point connected to said source of positive voltage, a source of negative voltage, a main resistance wire, resistance wires intersecting said main resistance wire, said intersecting wires connected to zero voltage on one end and having the other ends connected to positive voltage over a part of said main resistance wire, and connected to negative voltage over another part of said main resistance wire, the resistances of the intersecting wires being varied to give a selected positive or negative voltage at the point of contact with said main wire, and means responsive to the azimuthal movement of the guns for traversing said main resistance wire to pick off a voltage to thereby cause movement of said vertical cross hair.

4. A sight compensation system for guns adapted to be moved in zenith and azimuth to follow a target moving relative to the gun comprising a sight movable synchronously with the guns, a source supplying positive, negative and zero voltages, a pair of bridges, electric means connected to said voltages and to one of said bridges to pass measured amounts of positive or negative voltage to said bridge dependent upon the position of the guns in azimuth and zenith, a second electric means connected to said voltages and to the other of said bridges to pass measured amounts of positive or negative voltage to the bridge dependent upon the position of the guns in azimuth and zenith, a first element in said sight connected to one of said bridges and movable in response to the voltage impressed on said bridge to move the first element for ballistic correction in azimuth, and a second element in said sight connected to the other of said bridges and movable in response to the voltage impressed on said bridge to move the second element for ballistic correction in zenith.

5. A sight compensation system for a gun adapted to follow a target moving in azimuth and zenith with respect to said gun comprising a plurality of electrical cams each having a member connected for actuation by and proportional to the movement of the gun in azimuth, an electrical cam having a member connected for actuation by and proportional to the movement of the gun in zenith, an electrical connection between said plurality of cams and said second named cam, a source of electrical current connected to said plurality of cams, vertical and horizontal cross hairs movable with the gun and shiftable relatively thereto to vary the angular relationship between the gun bore and a line of sight defined by a point of intersection of said cross-hairs on a target, an electrical meter having electrical connections to said plurality of cams and connected to said vertical cross hair to thereby move said cross hair in a direction dependent upon the direction of the current through said meter, and an electrical meter connected to said horizontal cross hair and having electrical connections to at least one of said plurality of cams and to second named cam to thereby move said horizontal cross hair in a direction dependent upon the direction of the current through said meter.

6. A sight compensation system for a gun adapted to follow a target moving in azimuth and zenith with respect to said gun comprising a plurality of electrical cams each having a member connected for actuation by and proportional to the movement of the gun in azimuth, an electrical cam having a member connected for actuation by and proportional to the movement of the gun in zenith, an electrical connection between all but one of the actuated members of the plurality of cams and said last named cam, a source of electrical current connected to said plurality of electrical cams, a rheostat connected to the source and the plurality of cams to thereby regulate the current to said plurality of electrical cams to a predetermined amount dependent upon the air speed, cross hairs movable with the gun and shiftable relatively thereto to vary the angular relationship between the gun bore and a line of sight passing through a point of intersection of said cross-hairs on a target and responsive to current from said source to thereby correct for lateral and vertical deflection of a projectile to be fired from said gun, an electrical meter having electrical connections to said plurality of cams and connected to the cross hair adapted to correct for lateral deflection of a projectile to be fired from said gun to thereby move said cross hair in a direction dependent upon the direction of the current through said meter, and an electrical meter connected to the other of said cross hairs and to the first and second named cams and adapted to move said other cross hair in a direction dependent upon the direction of the current through said meter to thereby correct for vertical deflection of a projectile to be fired from said gun.

7. A sight compensation system for a gun movable in azimuth and zenith to follow a target moving relative to said gun comprising a plurality of electrical cams each having a member connected for actuation by and proportional to the movement of the gun in azimuth, an electrical cam having a member connected for actuation by and proportional to the movement of the gun in zenith, an electrical connection between all but one of the actuated members of the plurality of cams and said last named cam, a source of electrical current connected to said plurality of electrical cams, a rheostat connected to the source and the plurality of cams and adapted for manual adjustment to thereby regulate the current to said plurality of electrical cams a predetermined amount dependent upon the air speed, cross hairs movable with the gun and shiftable relatively thereto to vary the angular relationship between the gun bore and a line of sight passing through a point of intersection of said cross-hairs on a target and responsive to current from said source to thereby correct for lateral and vertical deflection of a projectile to be fired from said gun, an electrical meter having electrical connections to said plurality of cams and connected to the cross hair adapted to correct for lateral deflection of a projectile to be fired from said gun to thereby move said cross hair in a direction dependent upon the direction of the current through said meter, and an electrical meter connected to the other of said cross hairs and to the first and second named cams and adapted to

correct for vertical deflection of a projectile to be fired from said gun to thereby move said other cross hair in a direction dependent upon the direction of the current through said meter.

8. A sight compensation system for a gun movable to follow a target in azimuth and zenith with respect to said gun comprising a plurality of electrical cams each having a member connected for actuation by and proportional to the movement of the gun in azimuth, an electrical cam having a member connected for actuation by and proportional to the movement of the gun in zenith, an electrical connection between said first and second named cams, a source of electrical current connected to said first named cams, cross hairs movable with the gun and shiftable relatively thereto to vary the angular relationship between the gun bore and a line of sight passing through a point of intersection of said cross-hairs on a target and responsive to current from said source to thereby correct for lateral and vertical deflection of a projectile to be fired from said gun, an electrical meter connected to said cross hair adapted to correct for lateral deflection and to said first named cams to move said cross hair in a direction dependent upon the direction of the current through said meter, an electrical meter connected to said cross hair adapted to correct for vertical deflection and to the second named cam to move said cross hair in a direction dependent upon the direction of the current through said meter, a first resistance bridge connected to said first named meter and to said first named cams, a second resistance bridge connected to said second named meter and to said second named cam, and a separate generator connected to each of said first resistance bridge and said second resistance bridge and adapted to supply a current to the respective resistance bridge to which the generator is connected, said generators being driven in proportion to the angular rates of movement of the gun in azimuth and zenith.

9. A sight compensation system for a gun movable to follow a target in azimuth and zenith with respect to said gun comprising a plurality of electrical cams each having a member connected for actuation by and proportional to the movement of the gun in azimuth, an electrical cam having a member connected for actuation by and proportional to the movement of the gun in zenith, an electrical connection between said first and second named cams, a source of electrical current connected to said first named cams, cross hairs movable with the gun and shiftable relatively thereto to vary the angular relationship between the gun bore and a line of sight defined by a point of intersection of said cross-hairs on a target and responsive to current from said source to thereby correct for lateral and vertical deflection of a projectile to be fired from said gun, an electrical meter connected to said cross hair adapted to correct for lateral deflection and to said first named cams to move said cross hair in a direction dependent upon the direction of the current through said meter, an electrical meter connected to said cross hair adapted to correct for vertical deflection and to the second named cam to move said cross hair in a direction dependent upon the direction of the current through said meter, a first resistance bridge connected to said first named meter and to said first named cams, a second resistance bridge connected to said second named meter and to said second named cam, and a separate generator connected to each of said first resistance bridge and said second resistance bridge and adapted to supply a current to the respective resistance bridge to which the generator is connected, said generators being driven in proportion to the angular rates of movement of the gun in azimuth and zenith, the effective current acting to move said cross hairs adapted to correct for lateral and vertical deflection of a projectile to be fired from said gun being the algebraic sum of the current from the source and from each generator connected to its respective bridge.

10. A sight compensation system for a gun movable to follow a target in azimuth and zenith with respect to said gun comprising a single electrical cam having a member movable in azimuth by and in proportion to corresponding angular movement of said gun and adapted to correct for lateral deflection of a projectile to be fired from said gun, a plurality of electrical cams each having a member movable in azimuth by and in proportion to corresponding angular movement of said gun and adapted to correct for vertical deflection of a projectile to be fired from said gun, an electrical cam having a member movable in zenith by and in proportion to corresponding angular movement of said gun and adapted to correct for vertical deflection of a projectile to be fired from said gun, an electrical connection between said plurality of cams and said last named cam or zenith cam, a source of electrical current connected to said single cam and to said plurality of cams, a first cross hair responsive to current from said single cam, a second cross hair responsive to current from said plurality of cams and said zenith cam, a meter having connections to said first named cross hair and said single cam and responsive to current from said cam to move said cross hair, and a meter having connections to said last named cross hair, to said plurality of cams and to said zenith cam and responsive to current from said cams to move said cross hair, said cross-hairs intersecting to define a line of sight movable with the gun and shiftable relatively thereto to vary the angular relationship between the gun bore and said line of sight.

11. A sight compensation system for a gun movable to follow a target in azimuth and zenith with respect to said gun comprising a single electrical cam having a member movable in azimuth by and in proportion to corresponding angular movement of said gun and adapted to correct for lateral deflection of a projectile to be fired from said gun, a plurality of electrical cams each having a member movable in azimuth by and in proportion to corresponding angular movement of said gun and adapted to correct for vertical deflection of a projectile to be fired from said gun, an electrical cam having a member movable in zenith by and in proportion to corresponding angular movement of said gun and adapted to correct for vertical deflection of a projectile to be fired from said gun, an electrical connection between said plurality of cams and said last named cam or zenith cam, a source of electrical current connected to said single cam and to said plurality of cams, a first cross hair responsive to current from said single cam, a second cross hair responsive to current from said plurality of cams and said zenith cam, a meter having connections to said first named cross hair and said single cam and responsive to current from said cam to move said cross hair, a meter having connections to said last named cross hair, to said plurality of cams and to said zenith cam and responsive to

current from said cams to move said cross hair, said cross-hairs intersecting to define a line of sight movable with the gun and shiftable relatively thereto to vary the angular relationship between the gun bore and said line of sight, a resistance bridge connected to said first named meter and to said single cam, a resistance bridge connected to said second named meter and to said zenith cam, a generator driven in proportion to the angular rates of movement of the gun in azimuth and connected to the first named resistance bridge to supply a current to said bridge commensurate with the movement of said gun in azimuth, and a generator driven in proportion to the angular rates of movement of the gun in zenith and connected to the second named resistance bridge to supply a current to said bridge commensurate with the movement of said gun in zenith.

12. A sight compensation system for a gun movable to follow a target in azimuth and zenith with respect to said gun comprising a plurality of electrical cams each having a member connected for actuation by and proportional to the movement of the gun in azimuth, an electrical cam having a member connected for actuation by and proportional to the movement of the gun in zenith, an electrical connection between said first and second named cams, a source of electrical current connected to said first named cams, vertical and horizontal cross hairs movable with the gun and shiftable relatively thereto to vary the angular relationship between the gun bore and a line of sight defined by a point of intersection of said cross-hairs on a target, an electrical meter having electrical connections to said first named cams, said meter being responsive to current from said first named means and connected to said vertical cross hair to thereby move said cross hair in a direction dependent upon the direction of the current through said meter, said vertical cross hair adapted to correct for the lateral deflection of a projectile to be fired from said gun, only one of said plurality of electrical cams having a winding thereon adapted to produce a resultant electrical current commensurate with the position of the gun in azimuth to correct for lateral deflection, and an electrical meter having electrical connections to at least one of said first named cams and to said second named cam, said meter being responsive to current from said cams to thereby move said horizontal cross hair in a direction dependent upon the direction of the current through said meter.

13. In a sighting mechanism for guns movable in azimuth and zenith, a sighting means synchronized with the movement of the guns, a first electric meter for moving a vertical cross-hair laterally in said sighting means, a second electric meter for moving a horizontal cross-hair laterally in said sighting means, a first balanced square bridge including the first said meter in one leg thereof, a second balanced square bridge including the said second meter in one leg thereof, a source of positive voltage, a source of zero voltage, and a source of negative voltage, a conductor conducting the source of zero voltage to one corner of both of said bridges, a voltage proportioning mechanism connected to the positive and negative and zero voltages and to the first bridge at the opposite corner from the zero voltage connection of said first bridge, said voltage proportioning mechanism adapted to pass measured amounts of positive or negative voltage to said bridge dependent upon the position of the guns in azimuth and zenith to actuate said vertical cross-hair to correct for lateral ballistics deflection, and a second voltage proportioning mechanism connected to said positive, negative and zero voltages and to the corner of the second bridge opposite to the zero voltage connection and adapted to pass measured amounts of negative voltage to said second bridge dependent upon the position of the guns in azimuth and zenith to actuate said horizontal cross-hair to correct for vertical ballistics deflection.

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