Feb. 18, 1947. G. W. PONTIUS, 3D 2,415,967

GUN TURRET

Filed Feb. 4, 1942 13 Sheets-Sheet 1

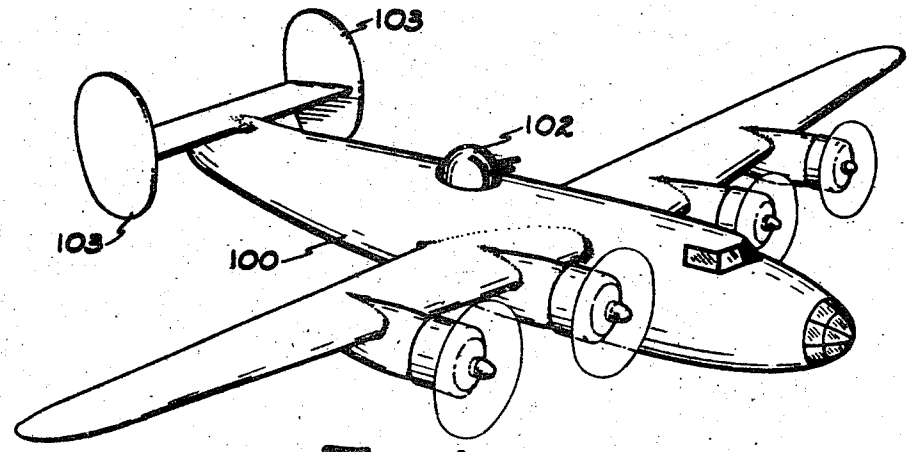


FIG. 1

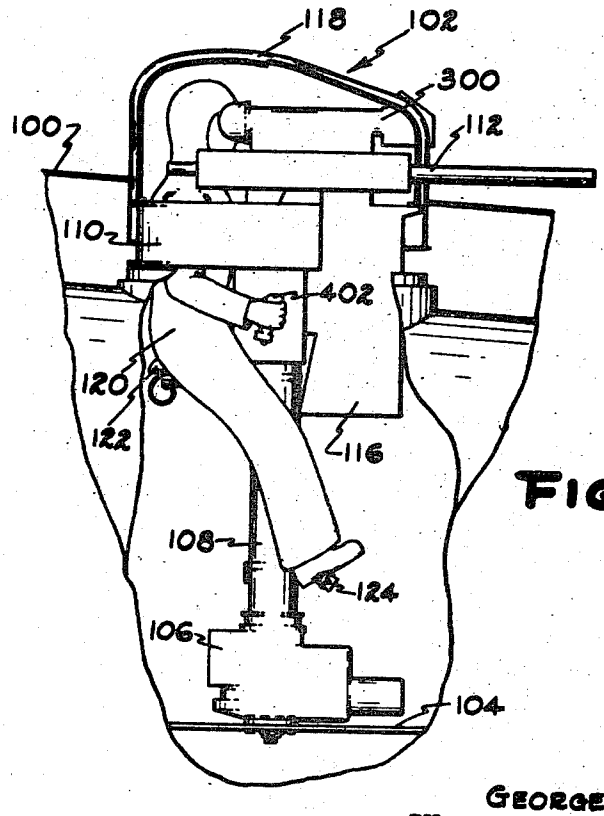


FIG. 2

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GUN TURRET

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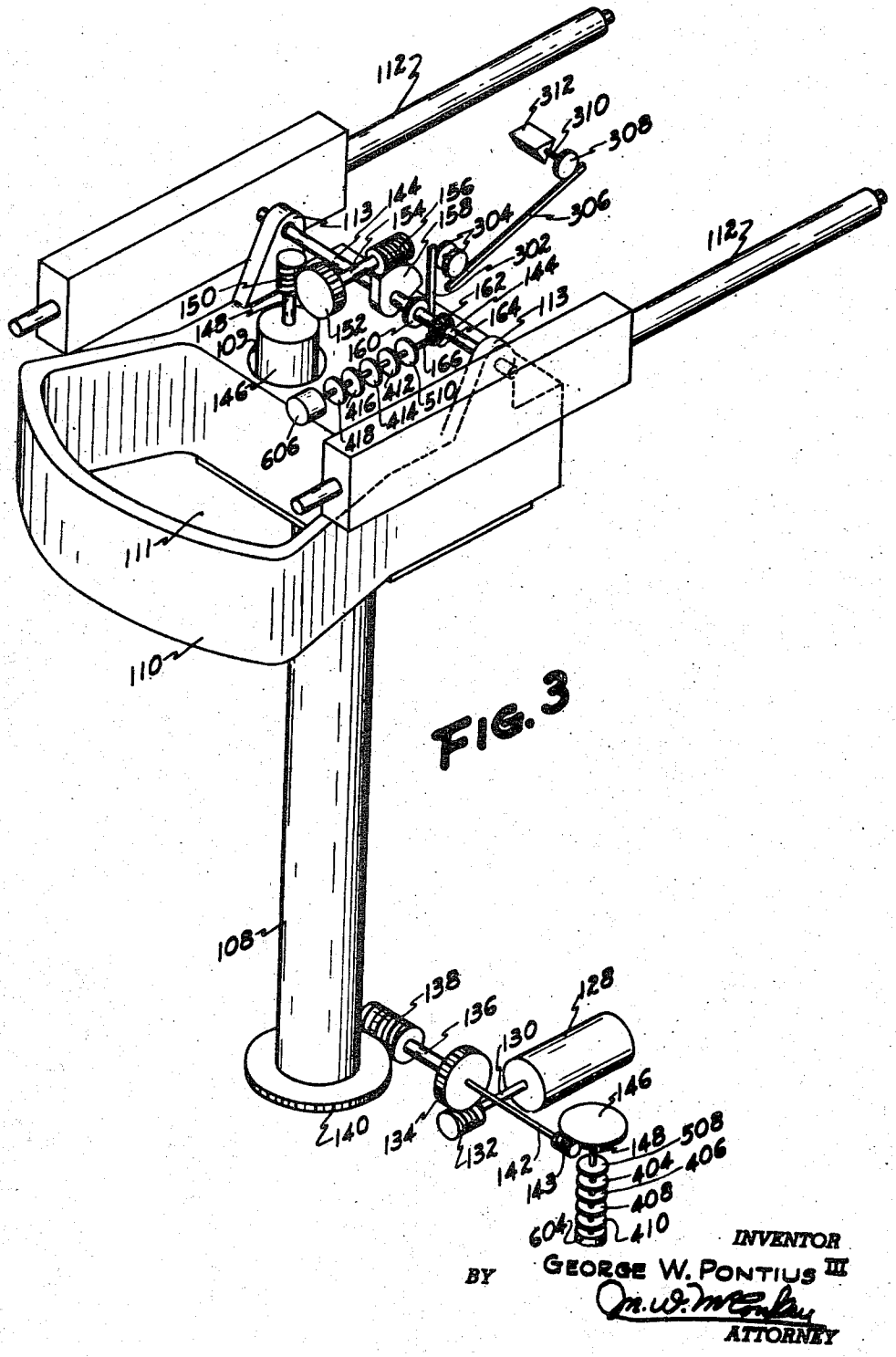


FIG. 3

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GUN TURRET

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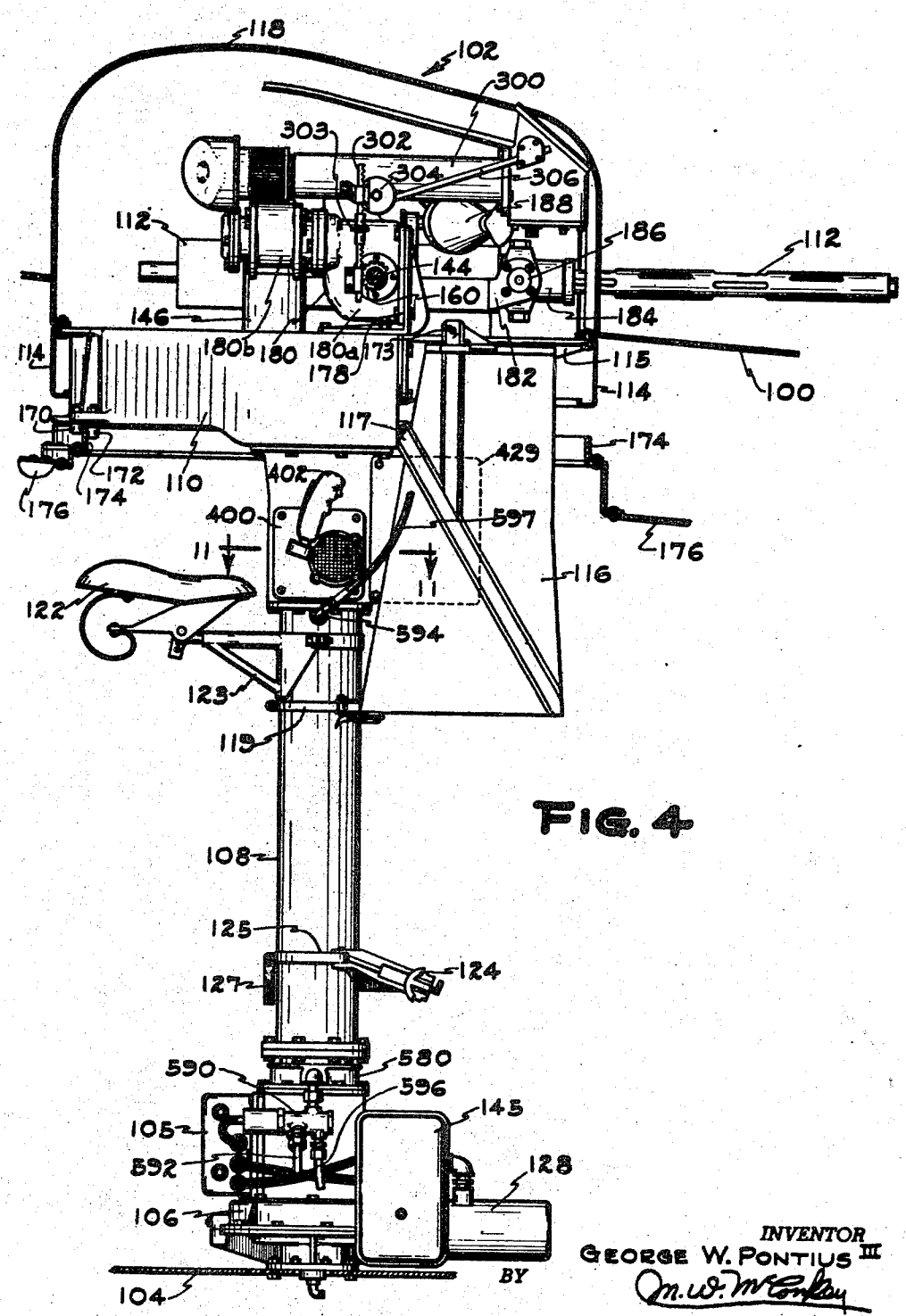


FIG. 4

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Feb. 18, 1947. G. W. PONTIUS, 3D 2,415,967

GUN TURRET

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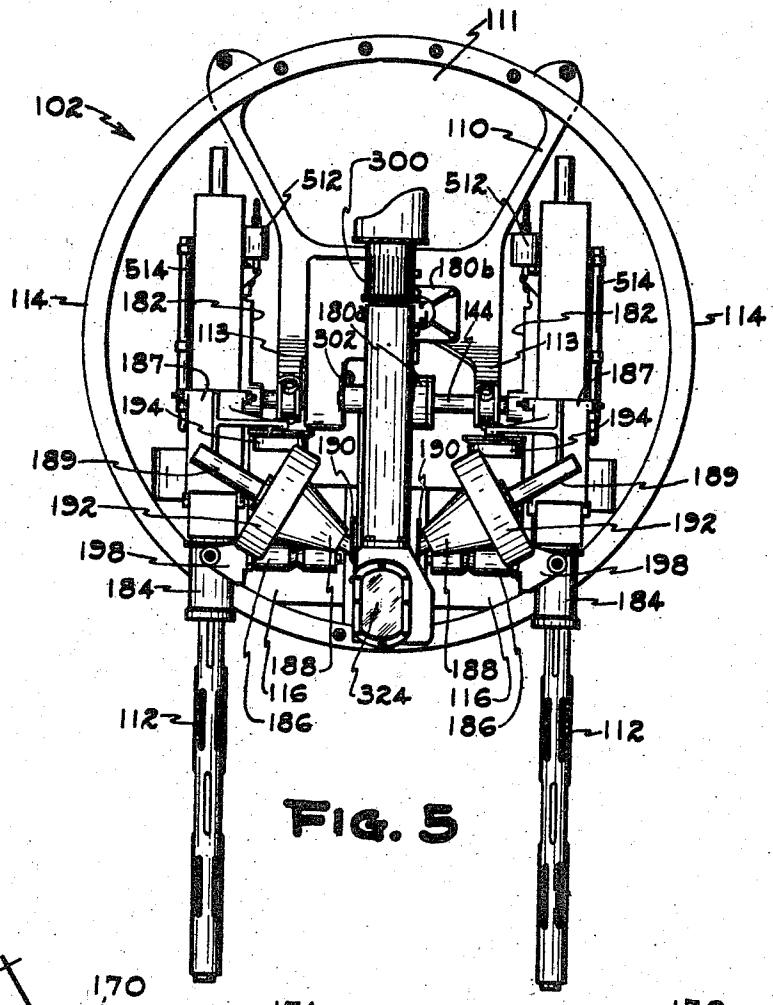


FIG. 5

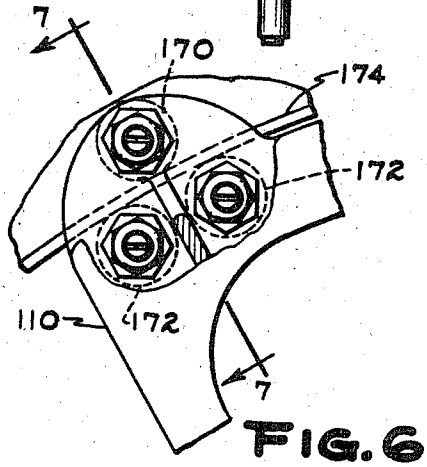


FIG. 6

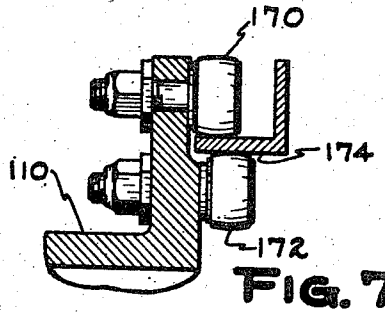


FIG. 7

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Feb. 18, 1947. G. W. PONTIUS, 3D 2,415,967

GUN TURRET

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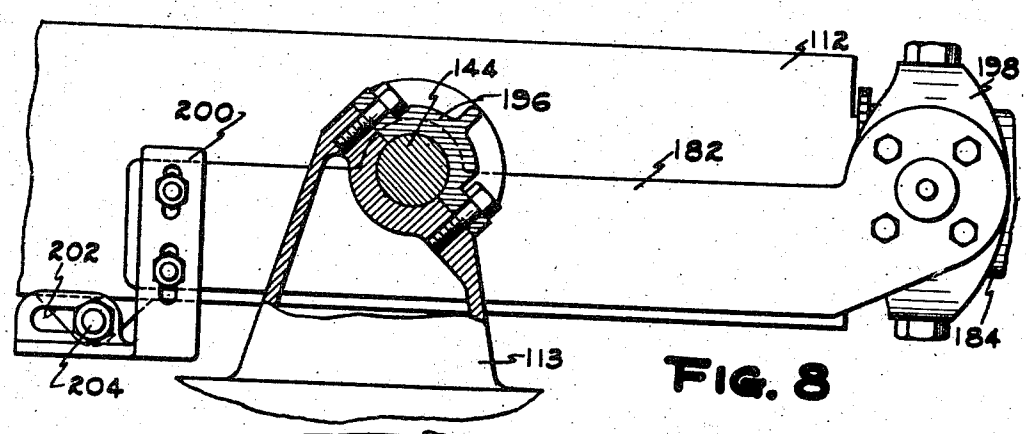


FIG. 8

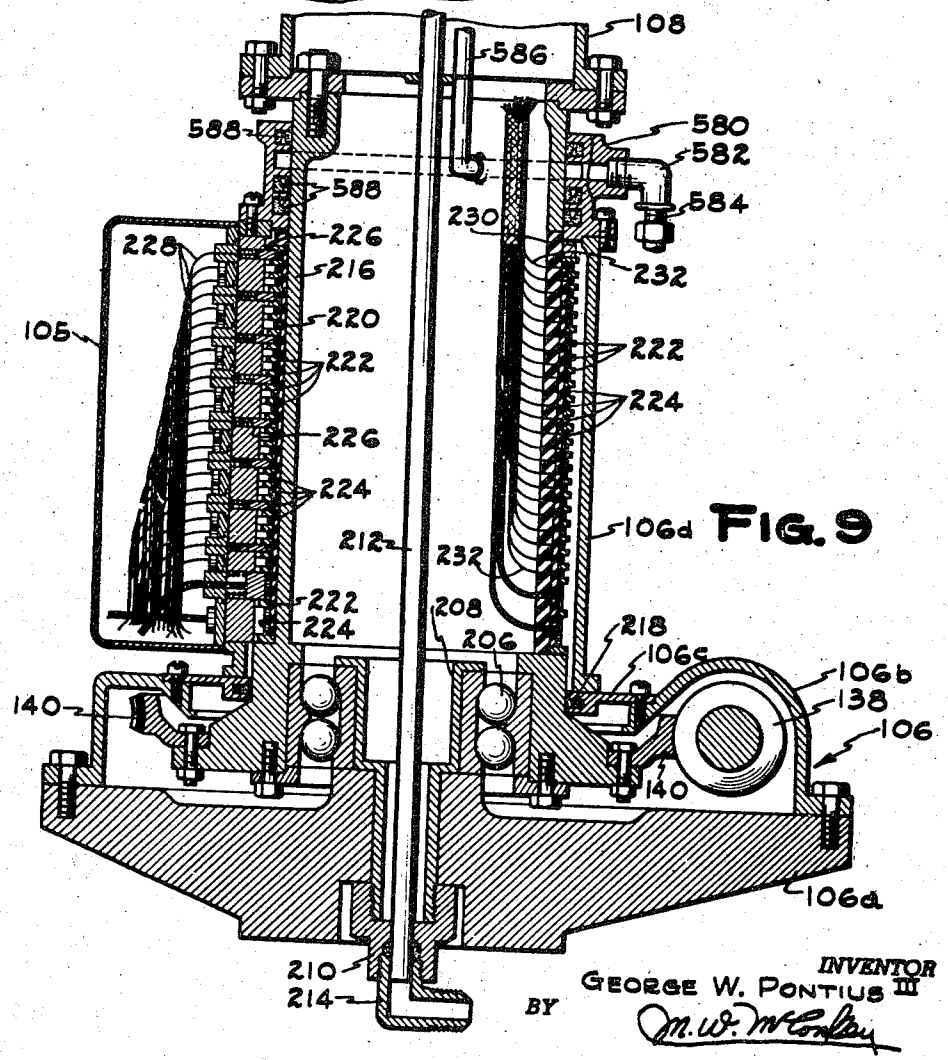


FIG. 9

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Feb. 18, 1947. G. W. PONTIUS, 3D 2,415,967

GUN TURRET

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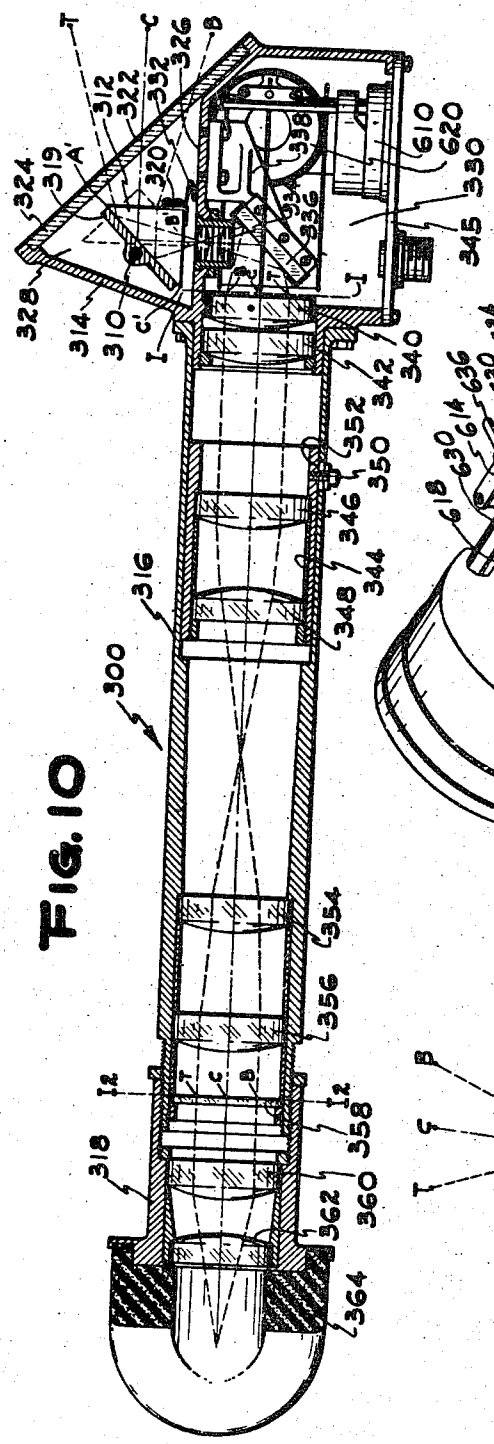


FIG. 10

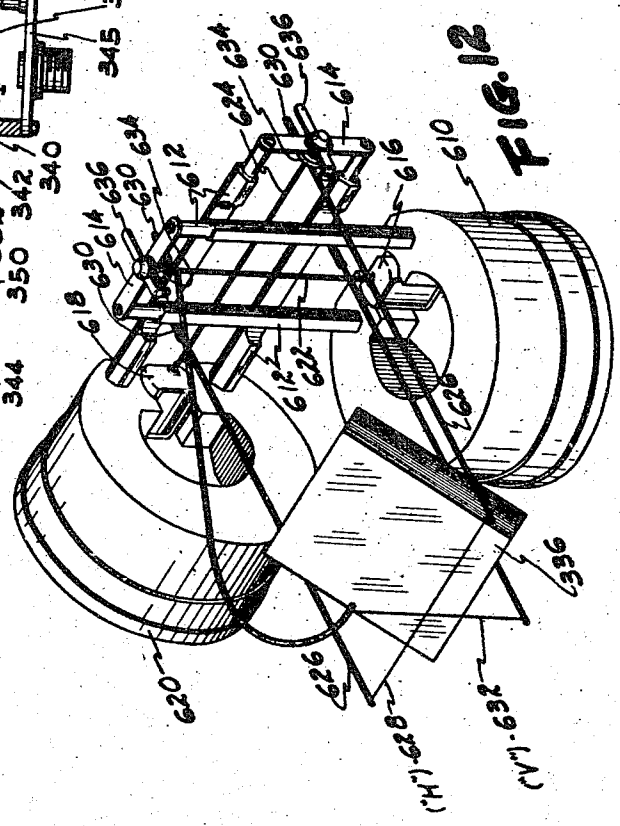


FIG. 12

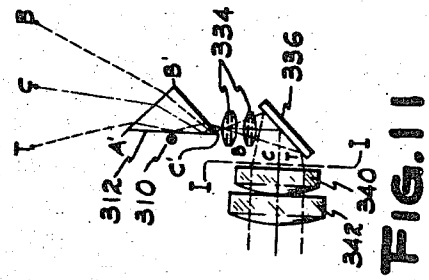


FIG. 11

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Feb. 18, 1947. G. W. PONTIUS, 3D 2,415,967

GUN TURRET

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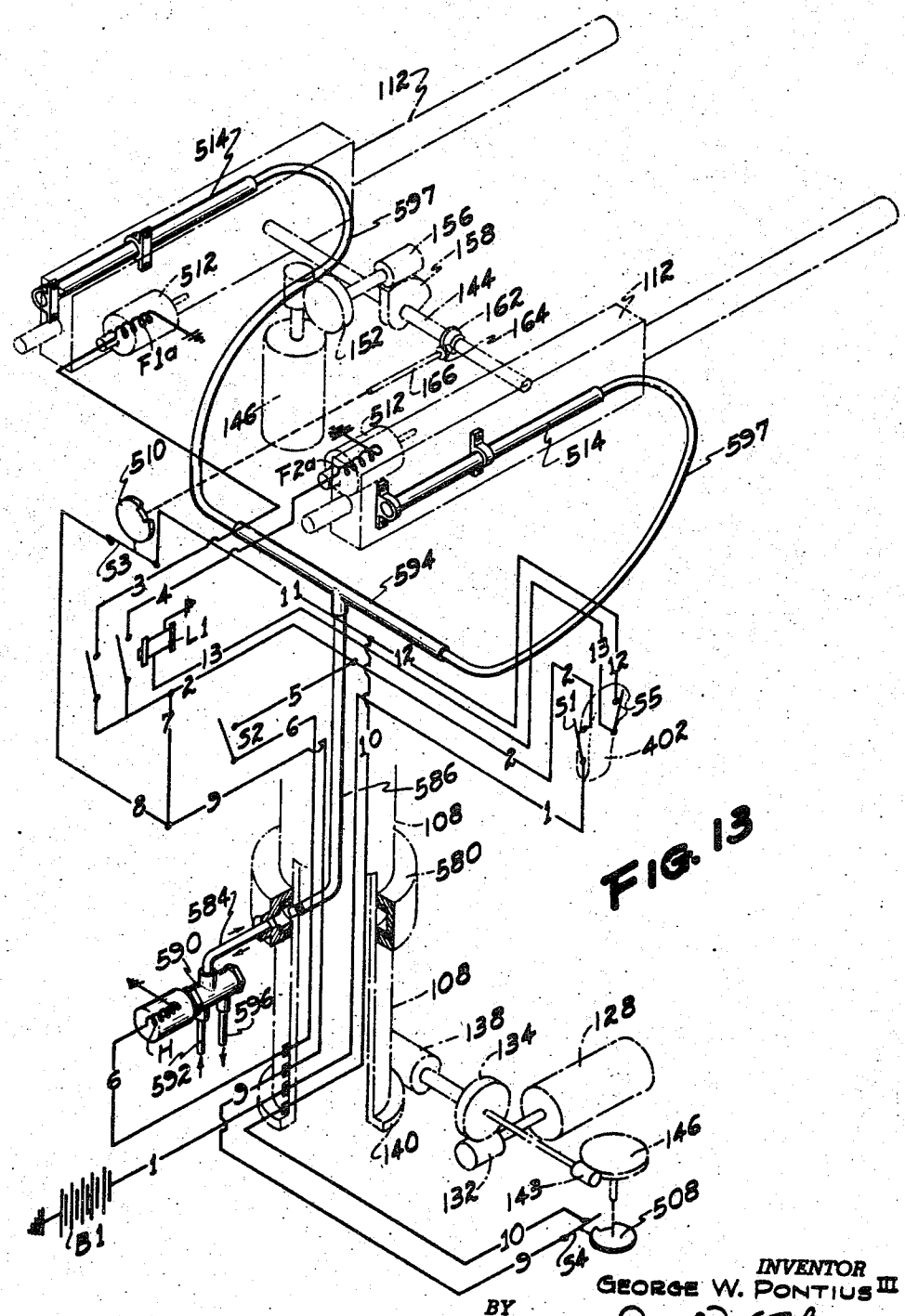


FIG. 13

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Feb. 18, 1947. G. W. PONTIUS, 3D 2,415,967

GUN TURRET

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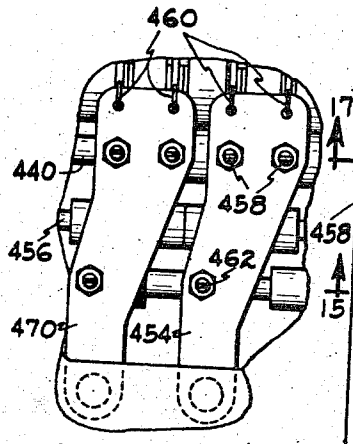


FIG. 16

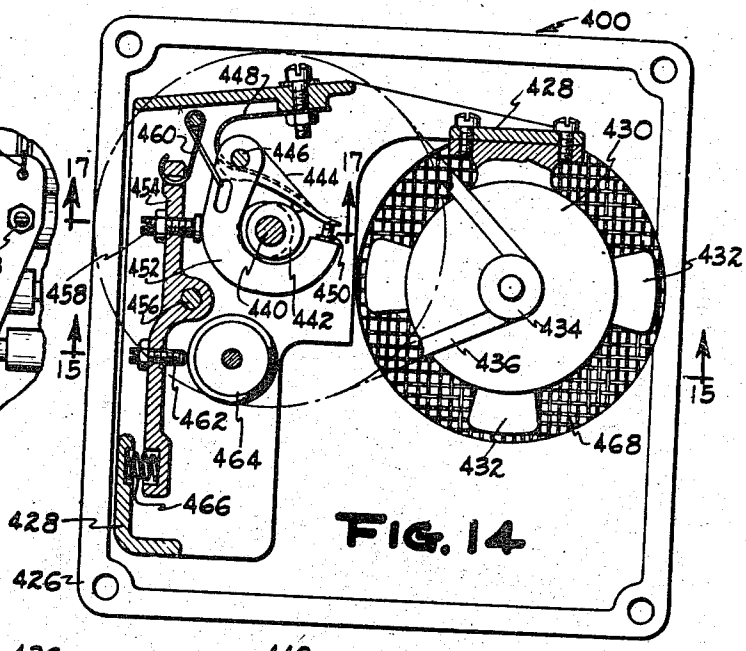


FIG. 14

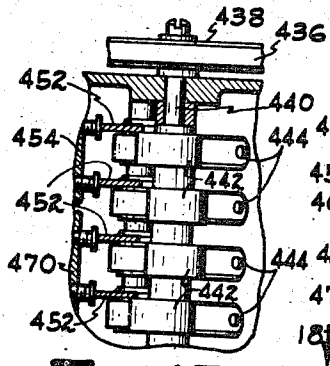


FIG. 17

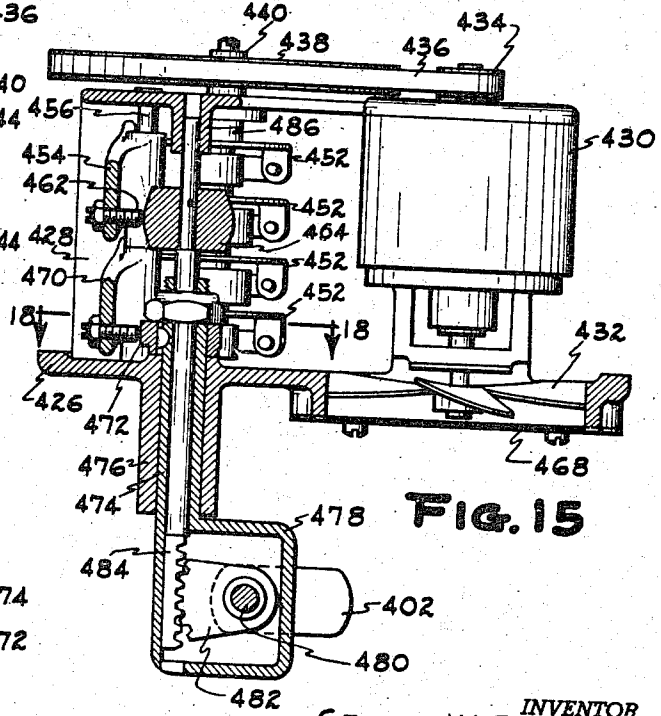


FIG. 15

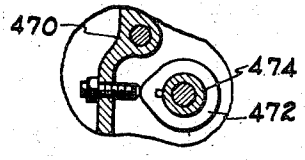


FIG. 18

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GUN TURRET

Filed Feb. 4, 1942 13 Sheets-Sheet 9

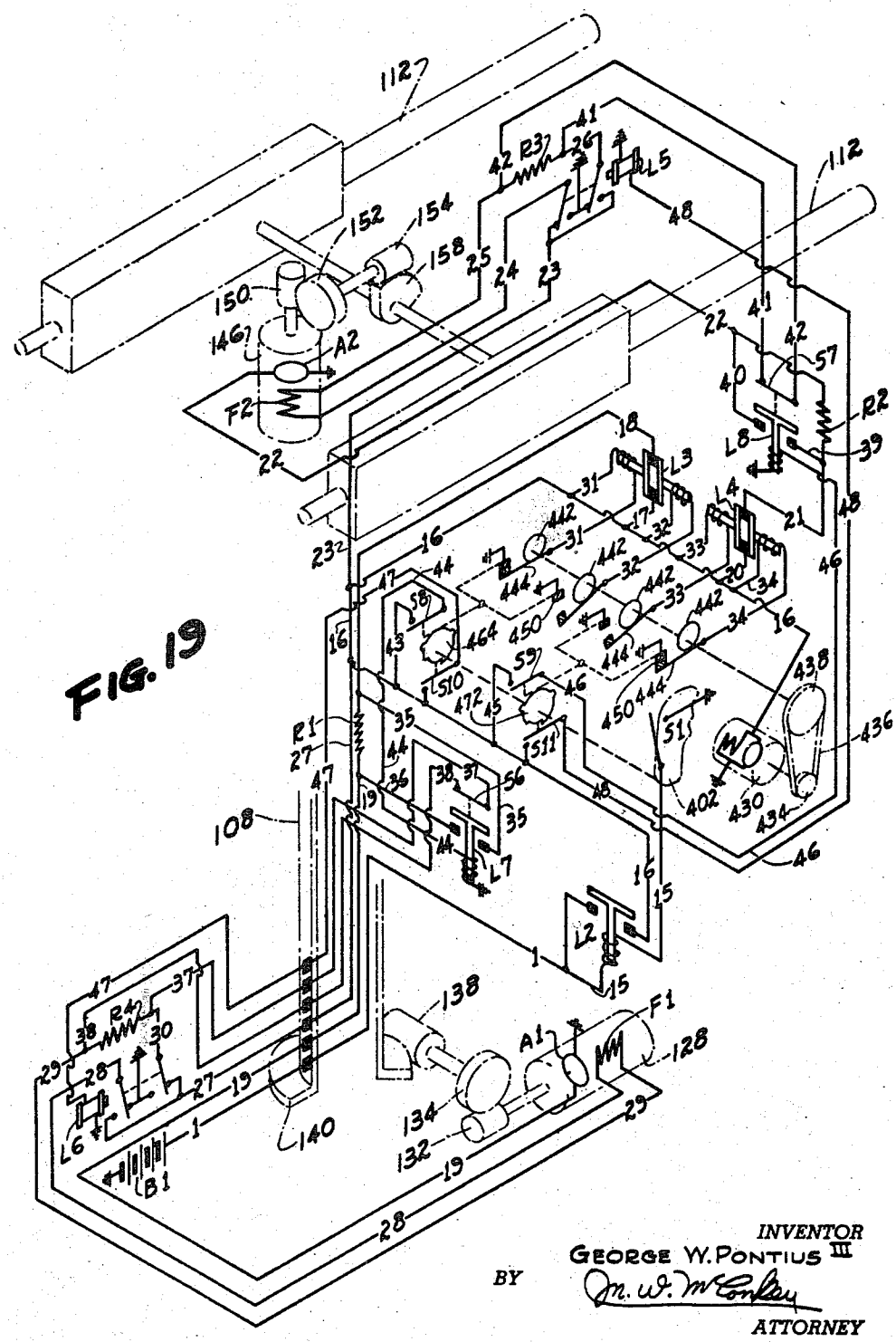


FIG. 19

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GUN TURRET

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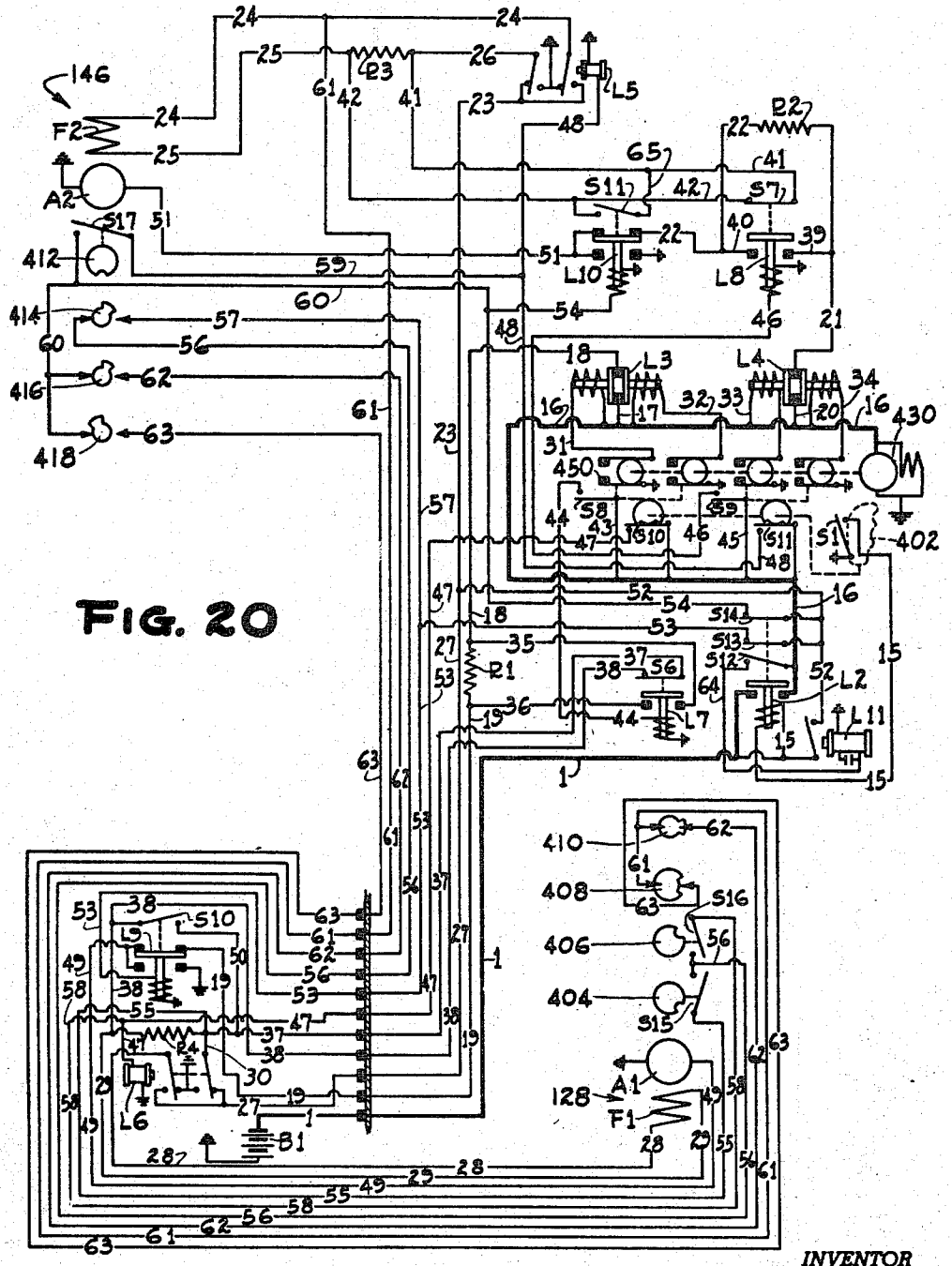


FIG. 20

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Feb. 18, 1947. G. W. PONTIUS, 3D 2,415,967

GUN TURRET

Filed Feb. 4, 1942 13 Sheets-Sheet 11

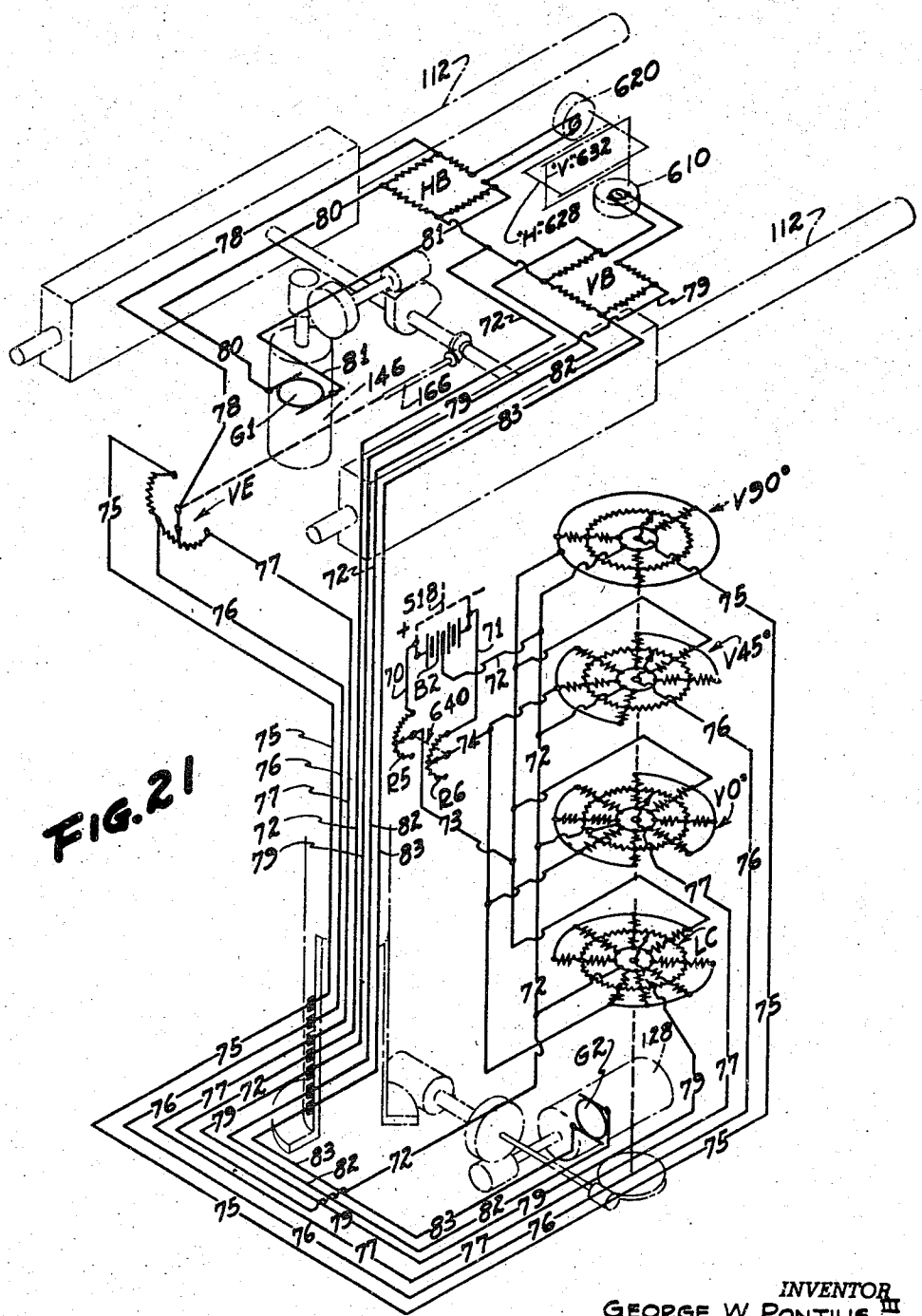


FIG. 21

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GUN TURRET

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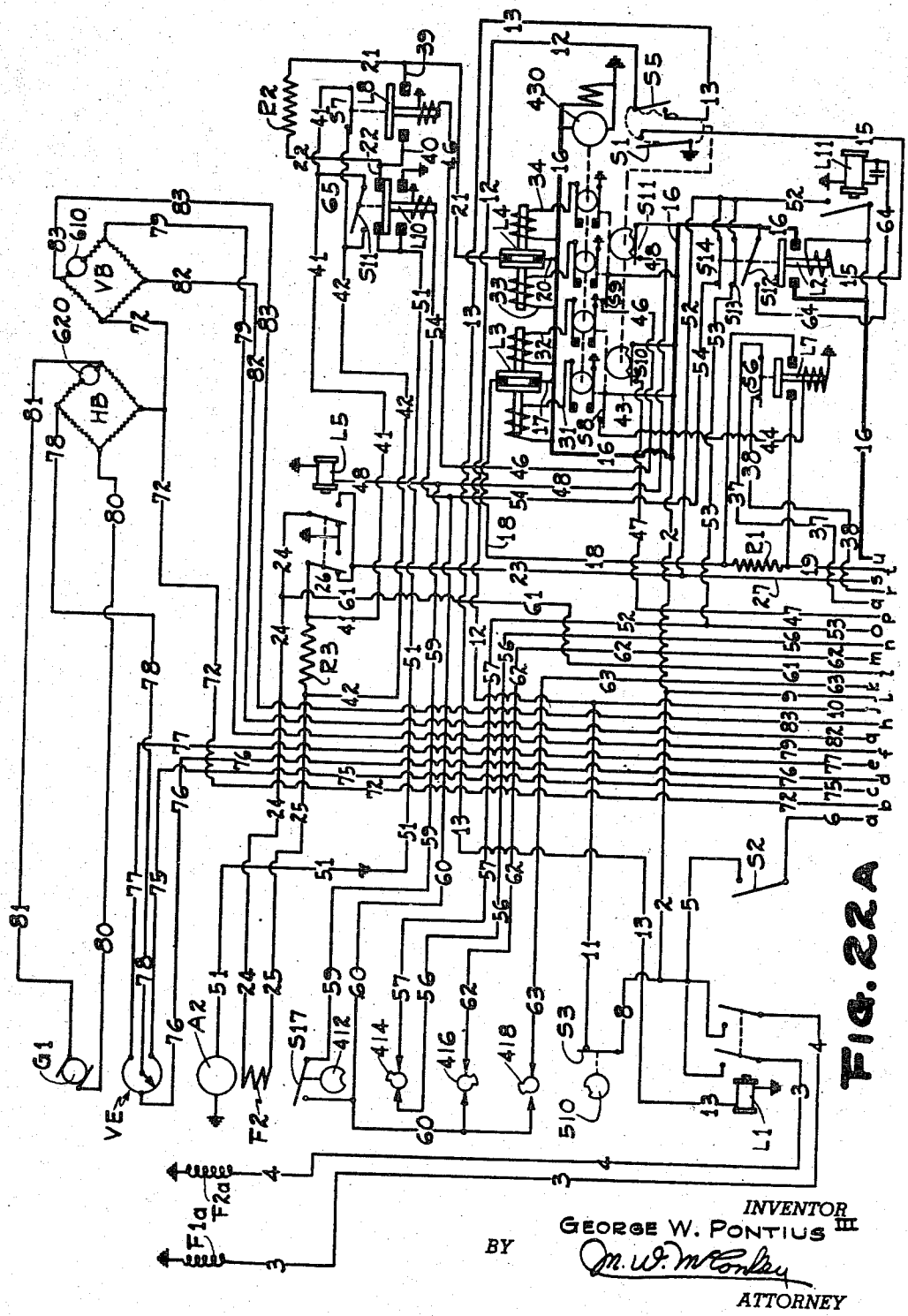


Fig. 22A

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GUN TURRET

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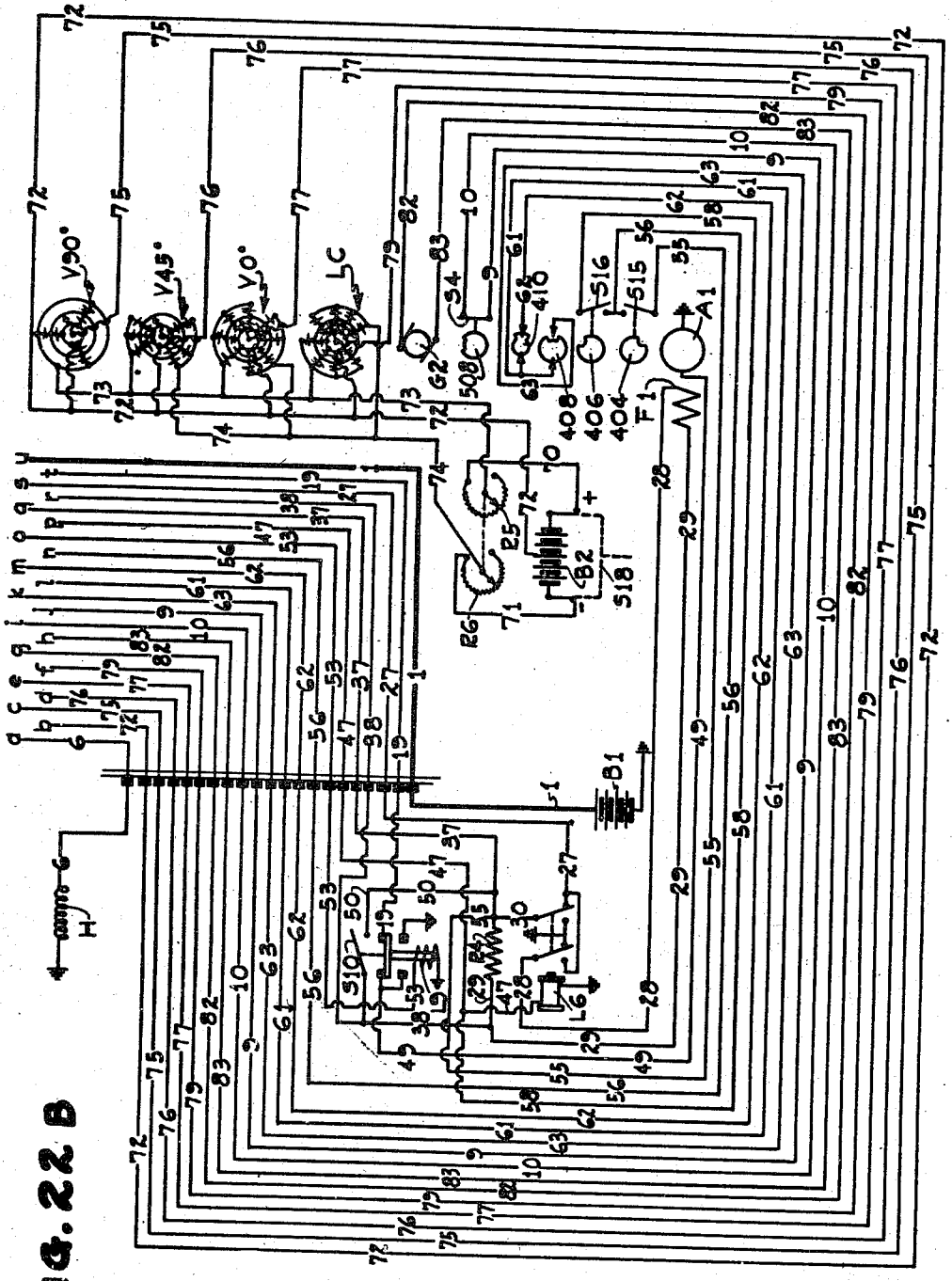


FIG. 22 B

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Patented Feb. 18, 1947 2,415,967

UNITED STATES PATENT OFFICE

2,415,967

GUN TURRET

George W. Pontius, III, South Bend, Ind., assignor to Bendix Aviation Corporation, South Bend, Ind., a corporation of Delaware

Application February 4, 1942, Serial No. 429,439

6 Claims. (Cl. 89—37.5)

1

This invention relates to gun turrets and more particularly to a gun turret for protecting the upper surfaces of land, sea or air vehicles.

The turret shown in this application is applicable to tanks, trucks, torpedo boats, airplanes or land fortification. The turret will be described, however, but for purposes of illustration only and not as a limitation of the invention, as designed for use with an airplane.

The defense of military airplanes, particularly bombers, involves the defense of separate areas with relation to the airplane. One area of defense is the area above the airplane and the present invention is described with reference to an upper turret to defend this area. When a tail gunner is not used, the upper turret must defend this vital spot also. For this purpose the vertical fins of the tail are separated to allow firing in the "straight back" zone.

An upper turret must be able to cover a complete hemisphere of fire to properly protect the upper portions of an airplane. I have accordingly designed an electrically driven turret which has two synchronizing guns that move in elevation through a 90 degree arc, the turret itself rotating 360 degrees in azimuth. The gunner moves in azimuth with the turret and sights the guns in elevation. To allow use of the turret as an observation post as well, a transparent canopy, streamlined as far as practicable, is placed over the top of the turret and projects above the general surface of the airplane fuselage.

The movements of the turret in azimuth and elevation are controlled by the gunner. The turret is rotatably secured at its lower end inside the airplane, and the azimuth drive is applied to the turret at that lower end. This type of drive is advantageous over the usual ring gear drive at the top of the turret, since an airplane is essentially a flexing structure to accommodate the high stresses necessary in light weight construction. Any driving member secured to or near the "skin" of the airplane is therefore subject to relative movement and is not as accurate a driving unit as one secured to the interior of the airplane. The upper part of the turret is supported on a central rotatable column and is guided horizontally by rollers contacting a circular rim at the fuselage surface.

I have also provided a novel type of control box for the electrical motors driving the turret in azimuth and in elevation. This control box allows sensitive control of speed in two or more distinct speed ranges for either the azimuth or elevation motor. Movement in azimuth is independent of movement in elevation and vice versa, and both movements are controlled by a single control handle gripped by the gunner.

The lower limit of movement of the guns in elevation is dependent upon the shape of the fuselage adjacent to the turret. The turret is

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usually mounted toward the rear of the fuselage where the surface slopes downward. In such installations the guns can point horizontally or below horizontal to the rear without striking the fuselage, whereas when pointing forward the guns point above horizontal in their lowest position. I have therefore provided automatic lower limits for movement in elevation which are dependent upon position of the turret in azimuth. Also I have provided an automatic upper limit at the "straight up" or zenith position. Another feature of the control system is the use of dynamic braking in stopping or reversing movement in elevation or azimuth.

The guns are fired by power units comprising solenoid motors controlled by a button switch. Automatic cutouts for the firing system are provided to prevent the guns from shooting at parts of the airplane such as wings or tail members. Each gun is provided with hydraulic chargers controlled by a solenoid valve and operated by a button switch. If either gun becomes jammed due to a dud, the gunner merely presses the switch charging both guns.

In most turrets the gunner must change his physical position from time to time to allow his eyes to sight along the guns. This has proved unsatisfactory because a gunner cannot train his guns upon rapidly moving targets when he must at the same time move his body. This defect has been overcome in the present turret by the provision of a periscope sight which has a movable member allowing the field of sight to move through an arc of 90 degrees. The movable member rotates in synchronism with the elevation movement of the guns thus taking in a field of sight in the direction the guns are pointing. The periscope rotates in azimuth with the turret, and allows the gunner to sit or stand in a fixed comfortable position and sight the guns at any point in the hemisphere of fire.

The periscope is provided with intersecting cross hairs which move relative to the field of sight for ballistics compensation and lead. These cross hairs are automatically moved by electrical devices in response to position of the guns in elevation and azimuth and in response to the relative speed of the target. The intersection point of the cross hairs marks the point in the field of sight which the bullets will hit at a chosen range, air speed, air density and lead. In order to hit the target the gunner merely moves the guns and consequently the periscope so that the cross hairs intersect on the target.

Objects

It is therefore an object of this invention to provide an upper or top turret having at least a full hemisphere of fire.

It is an object to provide a turret having a transparent canopy permitting use as an observation post.

It is an object to provide a turret mounted on a central column and driven in azimuth through this central column.

It is an object to provide an electrically driven and operated turret.

It is an object to provide a control box for the turret which gives sensitive speed control through a large range.

It is an object to provide a power operated turret having automatic limit stops for the movement of the guns in elevation.

It is also an object of the invention to provide a turret having automatic stops for movement in elevation which vary in accordance with the azimuth position of the turret.

It is an object to provide a turret having dynamic braking for cessation of movement.

It is an object to provide power firing for the guns of a turret.

It is an object to provide the firing control of a turret with automatic cutouts to prevent shooting at parts of the vehicle in which the turret may be mounted.

It is a further object to provide a turret having power operated charging mechanisms.

It is a further object to provide electrical controls for the charging mechanism.

It is an object to provide a turret with a periscope whereby the gunner may observe the field in the elevation arc without moving his head.

It is an object to provide a periscope having a movable member synchronized with the elevation movement of the guns to enable a gunner to observe the field at which the guns are firing.

It is an object to provide a periscope with automatically movable sighting means.

It is also an object to provide a turret with an automatic correction for ballistic deflection and lead of guns on a target.

Other objects and features of the invention will be apparent in the following description and claims.

In the drawings forming a part of this specification:

Figure 1 is a perspective view of an airplane having an upper turret made in accordance with the invention;

Figure 2 is a vertical section through the airplane and the canopy of the turret showing a gunner operating the turret with the guns pointed toward the rear of the airplane;

Figure 3 is a schematic sketch in isometric projection of the mechanical parts and movements of the turret;

Figure 4 is an elevational view of the turret mounted in an airplane, with the airplane broken away, the canopy in section, and one gun removed, to show the construction and arrangement of parts;

Figure 5 is a plan view of the turret with the canopy removed to show more clearly the construction;

Figure 6 is a detail plan view with part of an overhanging flange broken away of the rollers positioning the turret horizontally with respect of the airplane in which it is mounted;

Figure 7 is a sectional view of the rollers along the line 7—7 of Figure 6;

Figure 8 is a detail elevational view of the hangar supporting one gun for movement in elevation and the relation to the rotatable gun shaft to which the hangars are attached;

Figure 9 is a view in vertical section through the bottom of the column on which the turret is mounted showing the rotatable column and driving gear mechanism, the brush assembly, electrical takeoffs, and the hydraulic gland;

Figure 10 is an elevational view in section of the periscope showing the path of light rays therethrough;

Figure 11 is a view of the prism, lens and mirror of the periscope showing the paths of the rays of light from a vertical direction;

Figure 12 is an isometric view of the galvanometers controlling the cross hairs of the sighting mechanism included in the periscope, and showing the periscope mirror;

Figure 13 is a diagram of the trigger circuit and electrical controls for the charging circuit, and the hydraulic conduits and mechanisms of the charger system, all superimposed in solid lines on parts of the turret shown in dotted outline;

Figure 14 is an elevational view of the rear of the control box for the turret;

Figure 15 is a plan view in section of the control box along the line 15—15 of Figure 14;

Figure 16 is a detailed side view of the control box showing the shape and construction of the rocker arms which vary the electrical impulses;

Figure 17 is a sectional view of the control box showing the breaker cams and taken along the line 17—17 of Figure 14;

Figure 18 is a detail sectional view of the control box showing the elevation control cam taken along the line 18—18 of Figure 15;

Figure 19 is a simplified wiring diagram of the power circuit, showing parts of the turret in dotted outline and having superimposed thereon in full lines a modified power circuit;

Figure 20 is a complete wiring diagram of the power circuit, showing parts of the turret in dotted outline and having superimposed thereon in full lines the complete power circuit;

Figure 21 is a wiring diagram of the sight compensation circuit showing parts of the turret in dotted outline and having superimposed thereon in solid lines the electrical circuit for varying the cross hairs in the periscope for sighting the guns; and

Figures 22A and 22B are each portions of the complete electrical turret and while Figures 22A is on one sheet and Figure 22B is on another sheet, they should be considered together. The two sheets will be referred to together as Figure 22.

Mechanical parts and movements

The mounting of the turret is illustrated in Figure 1. An airplane 100 has mounted on the rear part of the fuselage a turret 102. The turret is adapted to rotate 360° for a given number of rotations. The tail of the airplane 100 includes vertical fins 103 which are separated to permit the turret to fire toward the rear.

The mounting of the turret is shown in detail in Figure 2. Secured to longitudinal members 104 of the airplane 100, is a base member 106 which rotatably supports a column 108. Secured to the top of rotatable column 108 is a frame member 110 to which the guns 112 are mounted for rotation in elevation. Also secured to frame 110 is a periscope 300 and an ammunition can 116. A transpafent canopy 118 covers the top of the turret and is secured to frame 110.

The turret is operated by a gunner 120 sitting on a seat 122 secured to the column 108, the gunner placing his feet on a rest 124 also secured to the column 108. With his right hand the gunner 120 grips a control handle 402 which

he manipulates to rotate the turret in azimuth in either direction or elevate or depress the guns. The gunner sights the guns by looking through periscope 300, moving the turret and guns in alignment with the target. All the mechanism mounted on the column 108 rotates in azimuth, and the guns 112 and the movable part of the periscope rotate in elevation.

The mechanical parts and movements of the turret are shown schematically in Figure 3. At the bottom of the figure a high speed electrical motor 128 drives a motor shaft 130 to which is secured a worm 132. Worm 132 drives a worm wheel 134 secured to a drive shaft 136 to which is secured at the other end a driving worm 138. Drive worm 138 engages a worm wheel 140 secured to rotatable column 108, and drives column 108 in rotation in either direction depending upon the direction of rotation of azimuth motor 128.

Also secured to worm wheel 134, is a compensator drive shaft 142 to which is secured a compensator worm 143. Worm 143 drives compensator worm wheel 146 to which is connected compensator shaft 148. Mounted on compensator shaft 148 is a trigger cam 508 and azimuth limit stop cams 404, 406, 408, and 410. The word "compensator" is applied to several of the parts just identified because a cam unit 604, which forms part of the sight compensator circuit, is also driven by compensator shaft 148.

The gear reduction between compensator worm wheel 146 and worm 143 is the same as that between column worm wheel 140 and driving worm 138, resulting in compensator shaft 148 rotating one revolution for every revolution of column 108 and rotating in synchronism.

Rotatable column 108 is preferably made of aluminum or magnesium to reduce weight. The frame 110 secured to the top of column is also preferably magnesium or aluminum and may be made by casting. An opening 111 in the frame 110 provides a place in which the gunner may his body for operating the turret. The guns 112 are secured to a rotatable gun shaft 144 supported near each gun by frame brackets 113.

Gun shaft 144 is driven in elevation by a high speed electrical motor 146 positioned within a well 109 in frame 110. Motor 146 drives a motor shaft 148 to which is secured worm 150 engaging driving worm wheel 152 mounted on a drive shaft 154. Secured on the other end of drive shaft 154 is a driving worm 156 engaging a worm wheel sector 158 secured to gun shaft 144. The gun shaft is rotated in either direction by reversing elevation motor 146, elevating or depressing the guns according to direction of rotation of motor 146.

The elevation compensator drive is obtained through a bevel gear 162 secured to shaft 144, and driving a matching bevel gear 164 which drives elevation compensator shaft 166. Fastened to compensator shaft 166 is an elevation trigger cam 510, and limit cams 412, 414, 416 and 418, as well as a compensator cam 606. Since the elevation movement of the guns is about 90°, the rotation of compensator shaft 166 is multiplied about three times to increase sensitivity of the cam control.

Shown in Figure 3 also is the mechanism for synchronizing the periscope 300 (Figure 2) with the elevation movement of the guns. A spur gear 160 is fastened to gun shaft 144 and engages the teeth of a double rack 302, the other end of which engages a double spur gear 304.

The other part of spur gear 304 engages a second double rack 306 the other end of which drives a gear 308. Gear 308 is secured to a prism shaft 310 on which is mounted for rotation the periscope prism 312. Through mechanism which will be later described, the rotation of prism 312 in synchronism with the elevation movement of the guns enables the gunner to observe at all times the field into which the guns are firing at any given time.

A complete turret is shown in Figure 4 in which parts identified in Figures 2 and 3 are readily recognizable. Secured to stationary base 106 is the azimuth motor 128, and an azimuth compensator box 145 housing the compensator and cam mechanism. Also secured to base 106 is a solenoid operated charger valve 590 for regulating the flow of hydraulic fluid to the chargers for the guns. A brush box 105 encloses the electrical brush mechanism which will be later described.

The foot rest 124 is secured to column 108 by a band 125 tightened by a handle 127. Seat 122 is mounted on a triangularly shaped bracket 123 fastened to column 108. Secured within the top of hollow column 108 is the electrical control unit 400, to which is secured control handle 402. To the right of control box 400 is a relay box 429 also secured to the column 108. Just below control unit 400 is a hydraulic conduit outlet 594 to which is attached a conduit leading up to the gun chargers as will be explained later.

The frame 110, secured to the top of column 108 is guided axially by rollers 170 and 172. The rollers grip either side of a cylindrical rim 174 secured to longitudinal members 176 of the airplane 100. The construction and placement of the rollers will be more fully described later.

Secured to the top outer edge of frame 110 is a cylindrical fairing 114 having a channel cross section with inturned edges. This fairing continues the sides of the canopy 118 and presents a smooth surface on the otherwise exposed parts of the turret which would occur at the lateral edges of the turret where the rounded fuselage of the airplane 100 curves away from the high position shown in Figure 4. At the right in Figure 4, fairing 114 is supported by an arm 115 secured to frame 110.

Ammunition can 116 is held to frame 110 by a rod 117 passing through an ear (not shown) on the frame 110. The lower end of ammunition can 116 is held to column 108 by a band 119. Secured to the top of ammunition can 116 is a shaft 173 on which is mounted a roller (not shown) over which the belted ammunition is drawn during firing of the guns 112.

The elevation gear mechanism shown schematically in Figure 3 is also shown in Figure 4. An angle member 178 bolted to the top of frame 110 has fastened thereto a housing 180 comprising parts 180*a* and 180*b*. Part 180*a* houses gear sector 158 (Figure 3) and driving worm 156 and part 180*b* houses worm wheel 152 and motor worm 150. Elevation motor 146 is secured to housing 180*b*. Gun mounting shaft 144 is rotatably held in housing 180*a* and has secured thereto a gun arm 182 supporting a recoil absorbing unit 184 through which the gun barrel passes and receives its support. The details of gun arm 182 will be described later.

Also shown in Figure 4 is the gun feeding mechanism. Gun arm 182 has secured thereto a roller 186. Belted ammunition is taken from ammunition can 116 and passed over its roller

(not shown) mounted on shaft 173, and passed under and around the right side of roller 186 to the top of tapered roller 188. The belted ammunition then rolls around tapered roller 188 into the gun as more fully described in application Serial No. 401,574, filed July 9, 1941, now Patent No. 2,379,185, issued June 26, 1945, on behalf of Royal J. Reek.

The parts of the periscope 300 are also shown in Figure 4. The periscope as a whole is secured to the upper part of housing 180a. The prism operating mechanisms include the gear 160 secured to gun shaft 144 and the driven rack member 302 including a turnbuckle 303 for adjusting the lengths of the member 302. The actual structure of the gear 304 and the rack members 302 and 306 is shown in Figure 4 where it is apparent that the member 302 is outside the member 306 with relation to the periscope 300 where both contact spur gear 304. This showing differs from the schematic showing of Figure 3 where the positions of the two rack members on gear 304 were interchanged for purposes of clarity.

The turret is shown in a top view in Figure 5. It will be noted that each gun 112 has a firing solenoid 512 for firing the guns and a hydraulic charger cylinder 514 for charging the guns. The details of the gun feed mechanisms show clearly in this view. A plate 187 is fastened to the top of each gun and has secured to it a spindle 189 upon which tapered rollers 188 rotate. Secured on the ends of spindles 189 are guide plates 190. Near the large ends of rollers 188 are guiding hoods 192 and to the rear of tapered roller 188 is a rimmed roller 194 rotatably secured to plate 187 and used to align the cartridges with the ammunition opening in the guns 112, as is completely described in application Serial No. 401,574 mentioned above. The rollers 186 fastened to gun arms 182 are also shown in Figure 5, and the ammunition cans 116 are just below.

The placement of the guide rollers is shown in Figures 6 and 7. It will be noted that a set of rollers 170 and 172 is placed at each rear corner of the frame 110. The outer roller 170 is spaced between the two inner rollers 172 and the three are positioned to grip rim 174 without play. This structure permits free rotation of the turret even though the rim 174 might be momentarily deformed by extreme stresses in the airplane 100. The rollers 170 and 172 absorb all recoil of the guns as well as wind loads and other transverse loads to which the turret is subject.

The structure for supporting the guns 112 on the gun shaft 144 is shown in detail in Figure 8 which also shows the supporting bracket 113. Bracket 113 has a removable bearing plate 196 covering the forward and upper part of the bearing with reference to the gun 112. This permits an uninterrupted bearing surface on the bracket with the region absorbing the recoil impact of the guns. The gun arm 182 is preferably splined to gun shaft 144. Bolted to the forward or right end of arm 182 is a yoke member 198 which grips the recoil unit 184 through which the barrel of gun 112 passes as shown in Figure 4.

The rear part of gun 112 is supported by an L-shaped bracket 200 adjustably secured to arm 182 and having a slot 202 longitudinally of the gun 112. Placed in slot 202 is a transverse bolt 204 secured to the gun 112 which bolt in turn supports the gun. The bracket 200 may be moved up and down for alignment of the gun in elevation, and the bolt 204 may be adjusted in slot 202 to align the gun in azimuth. Slot 202 is just slightly longer than the recoil stroke of the gun, and permits the gun to reciprocate freely in recoil. Thus it appears from Figure 8 that the guns 112 are not directly fastened to gun shaft 144 as shown in Figure 3 but are mounted in a gun arm instead.

The construction of the lower part of the turret is shown in Figure 9. The base member 106 is formed in five sections, a base member 106a, a gear cover plate 106b, a cover ring 106c, a column cover 106d, and a hydraulic gland unit 580. A two-way thrust bearing 206 is secured to base 106a by a hollow bolt member 208 tightened against base 106a by a threaded fitting 210. An oxygen tube 212 passes through fitting 210 and into an elbow 214 screwed into fitting 210. The upper end of tube 212 is fastened to the frame 110 and has a convenient outlet for the gunner to supply oxygen at high altitudes. The tube 212 rotates with column 108 in fitting 210 and elbow 214.

Secured to the bottom of column 108 is a cylindrical member 216 which rests on the rotatable part of bearing 206. Secured to sleeve 216 is the ring gear 140 (Figure 3) through which the turret is driven in azimuth by worm 138. It will be noted that cover ring 106c retains an annular seal 218 to keep gear lubricant from leaking to other parts.

The structure of the electrical contacts at the base of column 108 are also shown in Figure 9. Electrical conductors are necessary for passing current to the control box 400, and from the control box to the azimuth motor. Also telephone, charger and trigger and compensator connections must be made between the rotatable part of the turret and the stationary base 106. A sleeve 220 of insulator material surrounds column sleeve 216. Alternately spaced on sleeve 220 are insulator rings 222 and slip rings 224 of conductor material. The brush box 105 retains brushes 226 which are, spring pressed against slip rings 224 and which are in several vertical rows to allow spacing of the brush units. Wires 228 are connected to each brush, and lead from brush box 105 to the various parts.

The takeoffs inside column sleeve 216 are also shown in Figure 9. A section of the sleeve 216 is replaced with an insulator piece 230. Passing through insulator 230 are wires 232 secured to the slip rings 224. Wires 232 rotate with column 108 and pass up through it to the various parts to which they are connected.

The hydraulic gland 580 is used to pass fluid to, and to receive fluid from the hydraulic chargers 514 (Figure 5). The gland has secured thereto an elbow fitting 582 to which is connected a conduit 584 leading to the solenoid valve 590 (Figure 4). Held in gland 580 against sleeve 216 are rubber sealing rings 588 to prevent leakage of fluid. A column tube 586 passes through sleeve 216 and communicates with the fluid space of gland 580. The upper end of tube 586 is connected to the fitting 594 (Figure 4) passing through column 108.

The periscope and its operation

The periscope is shown in detail in Figures 10, 11 and 12. The periscope 300 includes three main parts, a sightbox 314, a central tube 316, and an eye piece 318. The sightbox 314 has rotatably mounted therein the prism 312 (Figure 3) held against a plate 319 by a clamp bar 320

and having corners A', B', and C'. The prism rotates on shaft 310 through an angle of about 45° from the position in Figure 10 shown in solid lines to that shown in broken lines. On the upper face of sightbox 314 is a window 322 in which is placed a pane of plate glass 324. A horizontal partition 326 divides sightbox 314 into an upper prism compartment 328 and a lower meter compartment 330.

A flexible opaque sheet 332 secured to prism clamp 320 and partition 326 prevent light entering window 322 from striking the lower surface of prism 312.

Light entering through window 322 to prism 312 is refracted and reflected from prism 312 to an objective lens unit 334 held in partition 326. After passing through lens 334 the light is reflected from a periscope mirror 336 held in position by a standard 338 secured to partition 326. The light thus reflected forms an image on the plane I—I just to the left of mirror 336. Rays of light from the image on plane I—I pass through two convex lenses 340 and 342 which aid in the "erector" function of making the image appear upright to the gunner using the periscope. Secured to the bottom of sight box 314 is a cover plate 345 to which is secured a cross hair actuating mechanism including galvanometers 610 and 620. 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 12.

Again referring to Figure 10, secured to sight box 314 is the central tube 316. This tube retains two sets of two lenses each of which lenses cooperates with the lenses 340 and 342 of sight box 314 in making the image appear upright. One set of lenses 346 and 348 are mounted in a longitudinally movable housing 344 placed in the right part of tube 316. A screw 350 passing through a slot 352 in central tube 316 is threaded into housing 344 and is tightened to adjustably position the housing 344 in the tube 316 to obtain the proper focus. In the left end of tube 316 are secured two additional lenses 354 and 356 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 358 also held in the left part of central tube 316.

The eye piece 318 is screwed to the left end of tube 316, and retains two lenses 360 and 362 respectively for viewing the image on plane I2—I2. A hollow sponge rubber cushion 364 is fastened to the left end of eye piece 318 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 10. 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 312 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 334. The guard 332 prevents light entering window 332 from striking face C' B' of the lens. After passing through the objective lens 334 the rays are reflected at right angles by mirror 336 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 plane I—I passes through lenses 340, 342, 346, 348, 354 and 356 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 eye piece lenses 360 and 362 to the point where the eye of the gunner would normally view the image. There is substantially no magnification of the image in the eye piece 318, so that the field will be as large as possible.

The other extreme position of the lens 312 is shown in dotted outline in Figure 10. In this position the center ray C will be vertical corresponding to a vertical or zenith position of the guns. It will be noted that the rotation of prism 312 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 312, resulting in the field rotating twice as much as the mirror rotates.

The path of the rays in the zenith position is shown in Figure 11. The left ray T and the right ray B correspond to the top and bottom rays T and B respectively of Figure 10. The rays refract into the prism, are reflected and refracted to the lens 334, and after passing through lens 334 are reflected by mirror 336 and form an image on the plane I—I. The image on plane I—I of Figure 11 is inverted as in Figure 10. For intermediate positions of the prism 312 between the two extremes the rays of light follow intermediate paths from those shown.

The cross hair mechanism is shown in detail in Figure 12. The two galvanometers 610 and 620 are fastened to cover plate 345 as shown in Figure 10 so that the cross hair mechanism may be inserted or removed as a whole by merely removing plate 345. Each galvanometer 610 and 620 is a permanent magnet and has secured thereto two uprights 612 of hexagonal bar stock, joined at the top by a connecting member 614. The galvanometers 610 and 620 each have a rotor 616 and 618 respectively to which are secured shafts 622 and 624 respectively. The shafts 622 and 624 are journalled on one end in connecting members 614 and the other ends are similarly journalled in mechanism not shown. Secured to the rotor shaft 624 of "H" hair galvanometer 620 are two transverse members 626 preferably made of fine aluminum tubing or magnesium to reduce weight. Between the left ends of members 626 is stretched a fine wire 628 which is the H hair or the cross hair intersecting the field of the periscope horizontally. The opposite or right ends of members 626 project beyond shaft 624 and have mounted thereon weights 630 to counterbalance the longer left ends. The transverse members on shaft 622 which support a vertical cross hair 632 are similar in construction to the transverse members 626 of shaft 624 except that the upper cross arm is curved to reach around the lens unit 334 (Figure 10).

Each rotor shaft 624 and 622 is centered by a hair spring 634 secured to each end of the shaft and to adjustable arms 636 mounted on each cross member 614. Only one hair spring for each shaft is shown in Figure 12, but the construction on the other ends of the rotor shaft

(not shown) is similar. The current for actuating the galvanometer passes through the hairsprings of each shaft and in passing through the rotor, causes the rotors 616 and 618 to react against the field of the permanent magnets 610 and 620. The electrical system for supplying current to the galvanometers to supply automatic sight correction will be described later.

In operating the periscope, the gunner is positioned as shown in Figure 2, sitting on seat 122 sighting through the periscope and controlling the azimuth and elevation movements of the guns. In movement in azimuth the gunner and periscope rotate with the turret. In movement of the guns in elevation, the prism 312 of the periscope rotates one-half as much as the guns through the driving connection shown in Figures 3 and 4 of gear 160, rack 302, gear 304, rack 306, gear 308 and shaft 310. The center of the field of the periscope is aways at the point at which the guns are pointing and the gunner moves the turret and guns by observing his target through the periscope. The cross hairs 628 and 632 automatically move relative to the field of the periscope to indicate to the gunner the amount of lead and ballistics correction necessary for the bullets to hit the target. The gunner merely moves the guns and turret, and consequently the periscope, so that the cross hairs always intersect on the target. The electrical system for moving the cross hairs will be described later.

The trigger and charger circuits and their operation

The trigger circuit and charging circuit for the guns of the turret are shown in Figure 13. Parts of the turret already identified are shown in broken outline including the center post 108, the ring gear 140, the driving worm 138 and the azimuth motor 128. Also shown is the azimuth compensator drive including worm wheel 146 and the driven azimuth trigger cam 508. On the upper end of the turret the guns 112 are mounted on shaft 144 and driven in elevation by elevation motor 146. Also shown in dotted outline is the elevation compensator drive including shaft 166 on which is mounted elevation trigger cam 510.

The electrical trigger circuit and electrical and hydraulic charging circuit is superimposed in solid lines on the dotted outline of the turret. A battery B1 supplies current to a wire 1 leading through the brush box, up to the column, and to the control handle 402 where it connects to a switch S1. Switch S1 is the main power switch for passing all current to the turret and when the gunner grips control handle 402 he closes switch S1 by the act of grasping the control handle. Because of this type of grip control the power will automatically be cut off if the gunner is shot thus preventing injury to the turret or the airplane in which it is mounted.

When switch S1 is closed current flows to a wire 2 which is connected to both fingers of a double relay L1. Energizing relay L1 causes current to flow through wires 3 and 4 to firing solenoids F1*a* and F2*a* in housings 512 secured to the guns, causing the guns 112 to fire.

Branching from wire 2 near the center post is a wire 5 leading to a switch S2 the other end of which is connected to a wire 6 leading down the column 108 and out the brush box to a solenoid H of hydraulic valve 590. Switch S2 is manually operated by the gunner whenever either gun 112 jams. Closing switch S2 passes current to valve 590 causing it to open to pass hydraulic fluid from inlet pipe 592 to gland conduit 584, through the hydraulic gland 580 to conduit 586. Fitting 594 is connected to conduit 586 which passes fluid thereto at which point flexible tubing 597 is connected leading to the chargers 514. After the charging is completed switch S2 is opened deenergizing valve 590 and allowing it to return to normal at which time the hydraulic fluid in the charger will flow through the valve to exhaust conduit 596.

In certain positions of the turret, the guns 112 will be pointing at a part of the airplane and if firing were possible, injury to the airplane would result. For this purpose a cut out mechanism for the trigger system is provided, which will now be described.

Also branching from wire 2 is a wire 7 leading to two wires 8 and 9. Wire 8 leads to a switch S3 actuated by elevation cam 510. Cam 510 is notched in a portion corresponding to the elevation position of the guns at which the bullets will strike the airplane. When the guns move in elevation to this position the notch opens switch S3 and no current can pass at that point to supply a trigger switch.

The other branch wire 9 connected to wire 7 leads down the column and through the brush box to a switch S4 actuated by azimuth trigger cam 508. Cam 508 is notched in a portion or portions corresponding to the azimuth position of the turret at which the bullets will strike the airplane. When cam 508 rotates so that the notched portion is opposite the switch S4, no current will flow to the trigger switch at that point.

Connected to switch S4 is a wire 10 leading through the brush box up the central column to join a wire 11 leading from switch S3. Wires 10 and 11 are connected to a wire 12 leading to a trigger switch S5 in the control handle 402. When the gunner desires to fire he closes trigger switch S5 with his finger, passing current to a wire 13 leading to relay L1. If current passes through wire 13 the relay will be energized closing the circuit to the firing solenoids F1*a* and F2*a* causing the guns to fire.

In operating the charger circuit, the gunner will be seated in the turret gripping control handle 402 as shown in Figure 2. Gripping control handle 402 closes power switch S1 permitting current to flow from battery B1 up wire 1 to the switch S1 and through wire 2. Branch wire 5 is now energized, and if the guns should now jam, or if for other reasons the gunner should desire to charge the guns, he merely closes charger switch S2 with his left hand while gripping handle 402 in his right hand. Current then passes through wire 6 down column 108 to the solenoid valve 590. Valve 590 opens to permit hydraulic fluid under pressure to enter conduit 584, pass through gland 580, up column conduit 586 and out of fitting 594 to the hydraulic chargers 514. The chargers then retract the bolt of guns 112, charging them.

After the charging is completed the gunner releases switch S2 which opens, deenergizing the solenoid H of valve 590. The valve then returns to normal connecting tube 584 with the exhaust line 596. A quantity of liquid will then flow out of the chargers and connected conduits sufficient to allow the chargers to return to their starting position.

In operating the trigger system the gunner

grasps control handle 402 and in doing so closes power switch S1. This permits flow of current through wire 2 to wire 7 from there to the wires 8 and 9 forming part of a parallel circuit to firing switch S5. Current in wire 8 may be interrupted by a switch S3 actuated by cam 510 synchronized with the elevation movement of the guns 112. The other branch of the parallel circuit, wire 9 leads down the column and current flow is interrupted by switch S4 actuated by cam 508 synchronized with the azimuth movements of the turret. When either cam 510 or 508 rotates to a point corresponding to the point at which bullets would hit the airplane, the respective circuit is broken. When the azimuth and elevation positions both correspond to a position where the bullets will strike part of the airplane, no current will flow through either branch of the parallel circuit and closing the trigger switch S5 will have no effect.

When the position of the turret and guns is other than the cut out position, current will flow through one or both branches of the parallel circuit wires 8, 11 and 9 and 10 respectively to wire 12 passing current to firing switch S5. When the gunner desires to fire he merely presses switch S5 with his finger, passing current through wire 13 to relay L1 and actuating it. Current then flows from wire 2 to wires 3 and 4 to the firing solenoids F1*a* and F2*a* causing the guns to fire. Release of switch S5 breaks the circuit to relay L1, the power circuit to the firing solenoid is broken and the guns cease fire. A relay control of firing is used to reduce the size of the manual switch to a minimum and increasing ease of operation.

The power system

The power system is the electrical control circuit for starting, reversing, and stopping the azimuth and elevation motors and for varying their speed. The azimuth and elevation motors are direct current motors having a constant field. They are reversed by reversing their fields. The speed of the motors is controlled, not by varying the armature voltage, but by varying the duration of constant voltage "shots" to the armatures of the motors. The "shot" control consists of an interrupted direct current wherein the frequency of the interruptions is constant, and the duration of the interruptions is varied. The mechanism for obtaining this speed control is the control box 400.

The control box 400 for the power system is shown in Figures 14, 15, 16, 17 and 18. Figure 14 shows a rear view of the control box showing a cover plate 426 to which the mechanism of the entire box is affixed so that the whole unit may be removed from column 108 (Figure 4) in one unit. Secured to plate 426 is a frame 428 which supports the inner ends of the control mechanism. Secured to frame 428 is an electric motor 430 having a fan 432 secured to one end and a pulley 434 secured to the other. Through a drive which will be later explained, the motor 430 causes a shaft 440 to rotate at a constant speed. Mounted on shaft 440 are eccentric cams 442 which strike a breaker arm 444 pivoted to a rod 446 and urged in a clockwise direction by a spring 448 secured to frame 428.

Current is grounded through breaker arm 444 from relays which then act to interrupt the current as will be later explained. Breaker arm 444 breaks against a grounded contact 450 held in a curved arm 452 also pivoted to rod 446. Since the free stroke and the frequency of breaker arm 444 is a constant the duration of contact of breaker arm 444 and contact 450 is varied by varying the position of contact 450 with respect to the stroke of arm 444. In this way the breaker arm 444 may touch contact 450 at an intermediate point in its cycle of movement and remains in contact until the cycle of movement again lifts it free. As shown in Figure 14, the contact 450 is in the "neutral" position wherein there is continuous contact with the breaker arm 444, causing the actuated relays to remain continuously open so that no current flows to the motors.

The positioning of contact arm 452 is accomplished by a lever 454 pivoted on a rod 456 and having an adjustable screw 458 touching arm 452. Stretched between contact arm 452 and lever 454 is a spring 460 holding the two parts constantly against each other. Lever 454 is in turn positioned by an adjustment screw 462 contacting a double frustro-conical cam 464 which is axially movable to act as a cam. The axial position of cam 464 is controlled by the gunner and in this way the gunner controls the duration of the current shots to the azimuth motor. Between the lower end of lever 454 and frame 428 is a compression spring 466 urging adjustment screw 462 in contact with cam 464.

The control box 400 is seen in vertical section in Figure 15, which is a sectional view of the box from below looking upwardly. The cover plate 426 has an opening in front of fan 432, which is covered with metal screen 468. The fan 432 blows air through the screened covered opening to cool the motor and electrical contacts. The pulley 436 on the other end of motor 430, through a belt, drives a pulley 438 connected to the rotary cam shaft 440.

Lever 454 is shown in Figure 15 and adjusting screw 462 is shown contacting double frustro-conical cam 464. A similar lever 470 for operating the breaker arm for the elevation motor is also shown in Figure 15 pivotally mounted on rod 456. Lever 470 is similar in construction to lever 454 and operates in the same manner. It is positioned however by a rotary cam 472 mounted on a rotatable hollow shaft 474. This structure is shown in detail in Figure 18, where the elevation cam 472 appears in profile. Shaft 474 rotates in a bushing 476 integrally formed with cover plate 426. The outer end of shaft 474 is enlarged to form a housing 478. Control handle 402 is rotatably secured to housing 478 by a stem 480. When the gunner pushes or pulls on handle 402 transversely to the axis of shaft 474 he will cause the shaft to rotate, rotating cam 472 and changing the position of lever 470.

Secured to stem 480 of control handle 402 is a gear segment 482 contacting a rack 484. The azimuth cam 464 is secured to rack 484 and the inner end of the rack is positioned in a bushing 486 integrally formed in frame 428. Rack 484 rotates with shaft 474 and consequently causes cam 464 to rotate. Since cam 464 is circular, however, there is no effect on the azimuth adjustment due to rotation of the cam. When the gunner wishes to change the speed of the azimuth motor he merely rotates handle 402 on stem 480 causing gear segment 480 to move the rack 484 in or out, and thereby moving cam 464.

The outlines of the control levers 470 and 454 are shown in Figure 16. It will be noted that lever 454 has two screws 458 for positioning two contact arms 452. In all, there are four breaker

arms 444 controlling four relays interrupting the current supply, as will be later explained.

The arrangement of the cams 442 on shaft 440 is shown in Figure 17. Each cam is offset 180° from its mate, to get alternation in the relays operated by each breaker arm 444. Also shown in Figure 17 are the levers 454 and 470.

The control box is shown diagrammatically in Figure 19 as applied to a simplified version of the control system. The control box motor 430, the driving and driven pulleys 434 and 438 are shown in dotted outline as well as the cam shaft 440 on which cams 442 are mounted. During operation the shaft 440 is continuously rotating causing the breaker arms 444 to move regularly and to open and make contact when not in the neutral position. The control handle 402 is also shown in dotted outline and both rack 484 and shaft 474 are shown diagrammatically by a single broken line leading therefrom. The azimuth and elevation cams 464 and 472 are also shown diagrammatically as eccentric cams on a shaft. The function of cams 464 and 472 already described, that of varying the position of the grounded contact 450 against which the breaker arms strike, is also shown diagrammatically.

Current is supplied by the battery B1 to the wire 1 which leads up the column to a relay L2. A branch wire 15 leads through relay L2 to the main power switch S1 in the control handle 402. When the gunner grasps the control handle 402 he closes switch S1 grounding wire 15 and causing the relay L2 to close, passing current to the entire turret. Leading from relay L2 is a wire 16 which passes through the relay box and back to the control box where it supplies power to the control box motor 430. Thus when the gunner closes switch S1 he causes current to flow to motor 430 and the cams 442 start to rotate.

Branching from wire 16 near the cam 442 is a wire 17 leading to a double relay L3. Leading from relay L3 is a wire 18 which passes down the central column to a resistance R1. The other side of resistance R1 is connected to a wire 19 leading down the column out through the brushes and to armature A1 of the azimuth motor 128. Also branching from wire 16 near the cams 442 is a wire 20 leading to a second double relay L4. Leading from relay L4 is a wire 21 which leads upwardly to a resistance R2 the other side of which is connected to a wire 22 leading to armature A2 of the elevation motor 146.

The fields of the elevation and azimuth motors are also connected to power wire 16. Branching upwardly from wire 16 near the center column is a wire 23 leading to a field reverse relay L5. Connected to one finger of relay L5 is a wire 24 leading to a field F2 of the elevation motor 146, the other side of which is connected to a wire 25 leading to a resistance R3. A wire 26 connects the other end of resistance R3 to the other finger of relay L5. Branching downwardly from wire 16 near the center column is a wire 27 leading down the column and out brush box to a field reverse relay L6 for reversing the azimuth motor 128. Leading from one finger of relay L6 is a wire 28 which connects to a field F1 of the azimuth motor 128. The other end of field F1 is connected to a resistance R4 and a wire 30 connects the other end of resistance R4 to the other finger of relay L6.

Referring to the control box in Figure 19 it will be noted that when the breaker arms 444 close on contact 450 that a current through the armature relays L3 and L4 is grounded operating the relays. The ground currents consist of four branches from wire 16, wires 31 and 32 passing through relay L3 and connected to the azimuth breaker arms 444 and wires 33 and 34 passing through relay L4 and connected to the elevation breaker arms 444. Since each cam 442 of a pair is rotated 180° with respect to the other, the general tendency is for the two contact members of relays L3 and L4 to be alternating in breaking contact. Depending upon the position of the contacts 450 with relation to the breaker arms 444, the contact members of the relays may both be opened or closed at any one instant. By varying the position of contact 450 the value of current may be varied from zero to the full value, thus controlling the motor over a very wide range of speeds.

In addition to the speed change by varying the duration of the interruptions of current to the azimuth and elevation motors, there is a stage speed control after the shots have been made so long in duration that the current is as continuous as possible. This second stage of high speed operation is effected automatically as the gunner moves the handle 402 to an extreme position in either direction of both azimuth and elevation movement. This high speed is obtained by increasing the armature current and decreasing the field in the azimuth and elevation motors. This is done by shunting around the armature resistances R1 and R2, and by opening normally closed shunts around field resistances R3 and R4.

Branching from wire 18 near resistance R1 is a wire 35 leading to one contact of a relay L7. The other contact of relay L7 is connected to a wire 36 connected to wire 19. Thus when relay L7 is energized a shunt circuit around resistance R1 is formed by wires 35 and 36. It will be noted that when relay L7 closes its movement opens a normally closed switch S6 one end of which is connected to a wire 37 passing down the column and out the brushes to connect to wire 30 near resistance R4. The other terminal of switch S6 is connected to a wire 38 which likewise leads down the column and connects to wire 29 near resistance R4. It is thus apparent that when relay L7 is energized, not only is a shunt formed around armature resistance R1, but a normally closed shunt around field resistance R4 is opened, decreasing the field current.

In the elevation motor wiring, branching from wire 21 near resistance R2 is a wire 39 leading to one contact of a relay L8, the other contact of which is connected to a wire 40 leading to armature wire 22. When relay L8 is closed a shunt is formed around resistance R2 through wires 39 and 40. The movement of closing relay L8 opens a normally closed switch S7 one terminal of which is connected to a wire 41 leading to a wire 26 near resistance R3. The other terminal of switch S7 is connected to a wire 42 leading to wire 25 near resistance R3. Energizing relay L8 therefore closes a shunt around resistance R2 and opens a normally closed shunt around resistance R3, decreasing the field current.

Azimuth speed change relay L7 is operated by the extreme movement of azimuth control cam 464 and elevation speed change relay L8 is operated by the extreme movement of elevation cam 472. It will be noted that both cams 464 and 472 have projections designating the extreme position of movement. When rotated to either extreme position the projections on azimuth cam 464 cause it to close a switch S8 one terminal of which is connected by a wire 43 to power wire 16

and the other terminal of which is connected to a wire 44 leading down the column to relay L7. Thus when either projection on cam 464, corresponding to the extreme position of the cam, come into register at the top it will close switch S8 causing the speed control relay L7 to function. Although cam 464 is shown schematically in Figure 19 as a rotary cam, actually it moves axially to effect its control function. However, the switch unit actually used (but not shown) in place of the schematic showing of Figure 19 is a switch having a movable member axially arranged and having two high points thereon to be contacted by the cam at either extreme of axial movement to close the switch S8.

Elevation cam 472 operates in a manner similar to azimuth cam 464 to close a switch S9. One terminal is connected to a wire 45 branching from power wire 16. The other terminal of the switch is connected to a wire 46 leading to relay L8. Thus whenever the projections on cam 472 register, switch S9 is closed and the elevation speed change is thus effected. Cam 472 is shown accurately in Figure 18 because it is actually a rotary cam. The exact construction however was not shown previously to keep mechanical features of the control box separate from the electrical features.

The field reverse relays L5 and L6 are operated also by the elevation control cam 472 and the azimuth control cam 464 respectively. It will be noted that each cam in Figure 19 has a relieved portion on the bottom. This portion represents the travel of the cam in traversing the speed range from zero to one extreme. When the cams 464 and 472 are moved from zero to the other extreme they actuate switches S10 and S11 respectively. Switch 10 takes current from power line 16 and passes it to a wire 47 leading down the column and out the brushes to field reverse relay L6. Energizing relay L6 causes it to reverse the direction of current through azimuth field F1 from that shown reversing the motor 128. When elevation cam 472 passes the zero or neutral position the direction away from its relieved portion it causes a switch S11 to open which takes current from wire 16 and passes it to a wire 48 leading to field reverse relay L5. Actuating relay L5 causes current to pass through field F2 in a direction opposite from that shown, thus reversing the elevation motor 146.

The operation of the simplified circuit shown in Figure 19 is as follows. Current flows from battery B1 to relay L2. When the gunner grasps control handle 402 he closes switch S1 actuating relay L2 and passes current to power wire 16 leading to azimuth relay L3 and elevation relay L4 and to control box motor 430. Motor 430 causes cams 442 to rotate rocking breaker arms 444 so that they intermittently are grounded at contact 450 causing the connected part of the relays L3 or L4 to break contact for the duration of the ground at contact 450. The position of the contacts 450 are varied by manual control of elevation cam 472 and azimuth cam 464. By changing the duration of the ground at contact 450 the duration of the current interruption at relays L3 and L4 is varied, thus giving a speed control for the azimuth and elevation motors. Current passes through wire 18 connected to relay L3 leading down the column to resistance R1, to wire 19 and out the brushes to the azimuth motor, armature A1. Current passes through wire 21 leading up from relay L4 to resistance R2 and to wire 22 and to the elevation motor armature A1.

If a greater speed is desired than is obtainable at the position of the control cams when current is flowing uninterruptedly to the motor armatures, the control handle is moved to the extreme position for both azimuth and elevation in either direction. This movement causes the projections on azimuth cam 464 to close switch S8 which passes current to wire 44 energizing relay L7. Relay L7 then closes shunting current around resistance R1 and thereby increasing the armature current. The movement of relay L7 opens normally closed switch S6 thereby breaking a shunt around the field resistance R4, and decreasing the field current. This decrease of field current together with an increase in armature current causes azimuth motor to operate at an extremely high speed.

Likewise movement of elevation cam 472 to either extreme position causes its projection to close switch S9, passing current to wire 46 energizing relay L8 which then closes to shunt out armature resistance R2 increasing armature current. The movement of relay L8 causes normally closed switch S7 to open, breaking a shunt around field resistance R3, decreasing field current. Increasing the armature current and decreasing the field current causes elevation motor 146 to rotate at a very high speed to effect rapid movement of the elevation motor 146.

The reversal of the azimuth and elevation motors is also effected by manual operation of the control cams 464 and 472. Each cam is recessed on the bottom for a space corresponding to full movement of the cam from zero to one extreme. When the cams are rotated in the other direction from the zero point they close switches controlling the field reverse relays L5 and L6. Moving azimuth cam 464 past the center point and away from the recessed portion closes switch S10 passing current to wire 47 which actuates relay L6, reversing the field current from the direction shown. Likewise, movement of cam 472 past the center point closes switch S11 passing current to wire 48 which actuates relay L5 reversing the field of elevation motor 146.

The complete electrical power system is shown in Figure 20. The complete system differs from the simplified system of Figure 19 by the addition of a dynamic brake and controls to make the lower limit of elevation of the guns dependent upon the position of the guns in azimuth. The provision of a dynamic brake causes the stopping of the motors by causing them to act as generators. This dynamic braking is effective in both elevation and azimuth motors when a given limit of movement is reached, and for a short interval after the gunner releases his grasp on the control handle. The varying lower limits of the guns in elevation are provided to roughly conform the lower limit to the shape of the airplane structure in which the gun is mounted.

The parts of the circuit identified in Figure 19 are readily recognizable in Figure 20. In the wire 19 to the azimuth armature A1 however a relay L9 is inserted to cause the azimuth motor to act as a dynamic brake. The wire 19 therefore leads to dynamic brake relay L9 and a wire 49 leads therefrom to armature A1. In normal position relay L9 connects wire 19 to wire 49 allowing normal operation of armature A1. When relay L9 is energized, however, it grounds wire 49 allowing a large current to flow through wire 49 to ground thus imposing the greatest possible load on the azimuth motor 128 when acting as a

dynamic brake. The circuit for actuating dynamic brake relay L9 will later be described.

It will be noted that the movement of relay L9 actuates a switch S10 which closes during dynamic braking to shunt out resistance R4 from the azimuth field circuit. Switch S10 is connected to wire 38 which is one part of the speed change shunt and the other terminal of switch S10 is connected to a wire 50 connected to wire 37 the other part of the speed change shunt. Thus a shunt circuit is formed around field resistance R4 through wires 38, switch S10 and wire 50 and wire 37 which is operative during dynamic braking to produce the greatest possible field in motor 128.

A dynamic braking relay L10 is provided for the elevation armature circuit also. Relay L10 is connected to armature wire 22 and a wire 51 leads therefrom to elevation armature A2. Relay L10 also operates a field shunt switch S11. One terminal of switch S11 is connected to wire 42 and the other terminal is connected to a wire 65 which connects to wire 41. Thus when elevation brake relay L10 is actuated, the armature A2 is grounded and the resistance R3 in the field circuit is shunted. This produces the maximum load on the armature A2 and the greater strength in field F2. Each cam is recessed on the bottom for a space corresponding to full movement of the cam from zero to one extreme.

Several additions to the electrical circuit to accommodate the dynamic brakes are also shown in Figure 20. It will be noted that the operation of power relay L2 operates three switches S12, S13 and S14. When power relay L2 is energized it closes normally open switch S12 and opens normally closed switches S13 and S14. Switch S12 is connected to a wire 64 leading to a time delay relay L11 which has the characteristic of maintaining its energization for a short time after the energizing current has been cut off. Relay L11 is connected on one side to a branch from main power wire 1 and on the other side is connected to a wire 52 which is connected at the central column to the elevation field wire 23 and to the azimuth field wire 27. Thus energizing the power relay L2 closes switch S12 which energizes time delay relay L11 causing current to flow to the azimuth and elevation motor fields. After power relay L2 is deenergized, delay relay L11 continues to pass current to the motor field for dynamic braking because of its time delay characteristic.

Switch S13 is connected to field supply wire 52 on one side and on the other side is connected to a wire 53 leading down the control column and out the brush box to energize dynamic brake relay L9. Switch S14 is likewise connected on one side to wire 52 and the other side is connected to a wire 54 leading up the column to energize elevation dynamic brake relay L10. Thus when power relay L2 is energized no current passes to the dynamic brake relays because switches S12 and S14 are open, but for a short time after deenergization of the power relay L2 (at which time switches S13 and S14 are closed) current passes to the dynamic brake relays because time delay relay L11 continues to pass current to wire 52.

The purpose of the dynamic brake circuits just described is to provide a "dead man" control for dynamic braking. If the gunner were moving the guns rapidly at the instant he was shot, there might be a possibility that the guns would travel through their normal limit control and damage the turret or the airplane. Thus the instant the gunner relaxes his grip because of injury, and the main power is cut off at power relay L2, the dynamic brakes are applied to stop the movement of the guns. The dynamic braking is possible only by maintaining a field in the elevation and azimuth motors and this purpose is served by time delay relay L11. The actual application of the dynamic brakes is by means of relays L9 and L10 operated by switches S13 and S14 respectively.

The circuits for operating the dynamic brake relays L9 and L10 at the limits will now be explained. It will be remembered that the only limit for moving the guns in azimuth is when the guns are near 90° elevation and pointing toward the rear. If it is then desired to swing the guns clockwise or counterclockwise in azimuth the guns would strike the fuselage of the airplane in which the turret is mounted. These two positions are represented in azimuth movement by cam 404 which has a notch corresponding to the counterclockwise limit and cam 406 which has a notch corresponding to the clockwise limit. These two limit cams operate in combination with elevation cam 414 corresponding with the elevation position of the gun. The three cams operate switches in a circuit which will now be described and only when the elevation cam and an azimuth cam act together is there an application of the dynamic brakes.

Branching from wire 30 near the azimuth field resistance R4 is a wire 55 leading around to a switch S15 actuated by counterclockwise limit cam 404. Wire 30 is at a high potential only when the relay L6 is in the position shown in Figure 20, operating the turret in a counterclockwise direction. When the turret reaches its counterclockwise limit, cam 404 closes switch S15 passing current to a wire 56 leading around to the column and up the column to elevation switch cam 414. When the guns are at a substantially horizontal position the switch cam 414 will make contact passing current to a wire 57 which leads part way down the column until it connects with wire 53. It will be remembered that wire 53 controls the azimuth dynamic brake relay L9.

Branching from wire 47 near azimuth field relay L6 is a wire 58 leading around to a switch S16 actuated by clockwise limit cam 406. Wire 47 is the wire energizing field reverse relay L6 and when energized, the turret rotates clockwise. When the turret rotates to its clockwise limit switch S16 will close also passing current to wire 56. If switch cam 414 is in the proper position current will flow to wire 57, thence to wire 53 and actuate the azimuth dynamic brake.

The limits of movement of the turret in azimuth have now been described, and the remaining limits are limits on the elevation movements of the turret. When the guns are pointing aft or toward the rear, the fuselage of the airplane will permit them to be depressed to a horizontal position. When the guns are pointing toward the front or fore position and the sides, the shape of the airplane stops them short of the horizontal position upon depression. The upper limit of elevation is the same for all positions of the turret in azimuth and is the zenith or straight upward position.

The upper elevation limit is regulated by azimuth cam 412. Current is supplied by tapping elevation field reverse relay wire 48, which is energized only when the field is in a position to cause elevation of the guns, the tap being wire

59 leading to a switch S17 actuated by the limit cam 412. When the guns are elevated to the zenith position the cam 412 permits switch S17 to close passing current to a wire 60 connected to the elevation dynamic brake wire 54. Thus whenever the guns approach the zenith the elevation dynamic brake is applied.

The lower elevation limits for the aft position are actuated by the combination of azimuth switch cam 410 and elevation switch cam 416. Branching from elevation field wire 24 is a wire 61 leading down the central column and around to azimuth switch cams 410 and 408. Field wire 24 is at a high potential only when the guns are being depressed. When the turret is pointing aft in azimuth the switch cam 410 closes and passes current to a wire 62 leading around to the column and up the column to switch cam 416. If the guns should now be depressed until they approach horizontal, the switch cam 416 will make contact and pass current to the wire 60, applying the elevation dynamic brake. It will be noted that switch cams 414 and 416 are identically positioned.

The lower elevation limits for side and fore are actuated by the combination of azimuth switch cam 408 and elevation switch cam 418. Again wire 61 supplies the current, and where the guns are in any position except aft, cam 408 makes contact to pass current to a wire 63. Wire 63 leads around to the column and up the column to cam 418. If the guns are depressed to a slightly upward angle, the cam 418 will make contact and pass current to the wire 60 actuating the elevation dynamic brake.

The operation of the limits of Figure 20 are as follows. Assuming that the guns are pointing aft and substantially horizontally, if the turret is moved clockwise, azimuth cam 404 would allow switch S15 to close passing current from wire 55 to wire 56 and thence upwardly to elevation cam 414. When the guns are in a horizontal position current will travel through cam 414 to wires 57 and 53 actuating the dynamic brake and stopping azimuth motion.

If it is desired to start the turret in operation again the azimuth direction must be reversed or the guns elevated. Azimuth movement is reversed by reversing handle 402 which causes switch S10 to close energizing wire 47 and field relay L6 reversing the azimuth field. This causes wire 55 to be at ground potential and the azimuth dynamic brake relay L9 can no longer be energized and the dynamic brake is released. The azimuth dynamic brake can also be released by elevating the guns which causes cam 414 to break contact and dynamic brake relay L6 is deenergized.

If the guns are moved too far counterclockwise, switch S16 is closed passing current from wire 58 to wire 56 and the azimuth dynamic brake is again applied. The brake can be released by elevating the guns or reversing the azimuth motor. Reversing the azimuth motor deenergizes wire 47 from which wire 58 derives its power and the dynamic brake is released.

There are only these aft limits in azimuth movement of the turret and then only when the guns are substantially horizontal. When the guns are above horizontal, the turret can rotate continuously in azimuth without interruption. The other limits are those of elevation of the gun.

The upper limit of elevation is at zenith and is controlled by elevation cam 412. When the zenith position is reached cam 412 will allow switch S17 to close. Wire 59 will be energized because wire 48 is energized in elevation and current is passed through switch S17 to wires 60 and 54 operating the elevation brake. This brake is released by reversing the elevation field which deenergizes wire 48 and the dynamic brake relay L10 is therefore deenergized.

The lower limits in elevation depend upon position in azimuth. For the fore and side azimuth positions the lower limit is above horizontal. The limit is controlled by azimuth cam 408 and elevation cam 418. High potential current obtains in wire 61 when the guns are being depressed and for fore and side positions the cam 408 makes contact passing current to wire 63. This wire leads up to elevation cam 418 and when the lower limit is reached contact is made passing current to wires 60 and 54 actuating the elevation dynamic brake, the brake is released by moving the turret in azimuth to the aft position. The turret is also released by reversing the field of the elevation motor. This action reduces wire 61 to ground potential and the brake relay L10 is deenergized.

For the aft position in azimuth the lower elevation limit is substantially horizontal. This limit is controlled by azimuth cam 410 and elevation cam 416. When the guns are depressing and pointing aft, cam 410 passes current from wire 61 to wire 62 and thence to cam 416. When the horizontal limit is reached, cam 416 makes contact passing current to wires 60 and 54 and actuating the elevation dynamic brake. This brake is released by reversing the elevation field motor which reduces wire 61 to ground potential.

The sight compensation circuit

As mentioned previously, the turret has a sighting device in connection with the periscope which corrects for the ballistics of a bullet fired from a moving airplane and which corrects for lead. This correction is made by moving the H hair 628 and the V hair 632 relative to the field of the periscope as described with relation to Figures 10 and 12. The electrical circuit for actuating the cross hairs is shown in Figure 21 as applied to an outline of the turret.

The trajectory of a bullet fired from a moving airplane deviates from the axis of the gun depending upon the combined effects of windage, magnus and gravity. Further, these variations differ for every point in the hemispherical field of fire of the turret. Corrections must therefore be applied which are dependent alone upon the position of the gun in its hemisphere of fire.

The deflection of a bullet from the axis of a gun may be broken into two components with respect to the airplane, lateral and vertical deflections. When thus broken down, these deflections may be accommodated by the V and H cross hairs. The lateral deflection may be taken on the vertical or V cross hair, and the vertical deflection may be taken on the horizontal or H hair.

In actual tests, it has been found that 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 21 indicating "lateral composite."

Vertical deflections vary greatly for a given position in azimuth depending upon position in elevation. Accordingly an electrical cam V90° is provided to produce a voltage wave correspond-

ing to a deflection curve for all azimuth positions at 90° elevation. An electrical cam V45° is provided to produce a voltage wave corresponding to a vertical deflection curve for all azimuth positions at 45° elevation. 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° elevation.

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 cam shaft 166.

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 B2 having the terminals connected to a double switch S18. The positive end of switch S18 is connected to a wire 70 leading to a resistance R5 of a manual potentiometer 640 and the negative end is connected to a wire 71 leading to a resistance R6 of the potentiometer 640. The potentiometer 640 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 72 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 73 for positive potential, and leading from resistance R6 is a wire 74 for negative potential. The three wires 72, 73 and 74 lead to the four azimuth cams V90°, V45°, V0° and LC supplying respectively zero, positive and negative potential where needed. The wire 72 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, 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 75 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 76 leading to a central point of cam VE, and a wire 77 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 78 connected thereto leading to a corner of bridge HB opposite to the connection of wire 72.

The wiper of azimuth cam LC is connected to a wire 79 which leads up the column to bridge VB where it is connected to a corner opposite to the connection of wire 72.

Lead in a vertical direction is furnished by a generator G1 built into the elevation motor 146. 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 146, the greater will be the lead current generated. Wires 80 and 81 are connected to the generator G1 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 G2 having wires 82 and 83 leading up to column to opposite corners of bridge VB.

The operation of the sight compensation system shown in Figure 21 is entirely dependent upon movement of the turret in elevation 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 G2 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 cams V90, V45 and V0° as modified by the elevation position of the guns on cam VB. The lead correction is furnished by generator G1 and the resultant movement of the H cross hair is dependent upon the algebraic sum of the two currents.

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 I claim is:

1. In an electrically power operated turret for use on an aircraft or the like, the combination of a rotatable column constructed and arranged to carry a gunner so that his torso is substantially parallel to the axis of rotation of the column and his legs are astraddle thereof to enable him to rotate with the column through its entire movement in azimuth, a base fixed to the column and constituted for driving engagement, electrically operated means for engaging said base for rotating said column, a frame secured to the top of the column for rotation therewith, guns mounted on said frame and fixed relative to the column for movement in azimuth and pivoted relative to the column for movement in elevation, electrically operated means mounted on said frame for rotating said guns in elevation, cams constructed and arranged to be synchronized with the movement of the guns in elevation and azimuth so as to restrict the firing area of the guns to well-defined boundaries, an electrical power system comprising a power circuit connected to said first and second named means, and a single manual control connected to the electrical power system for controlling said first and second named means.

2. In an electrically power operated turret for use on an aircraft or the like, the combination of a rotatable column constructed and arranged to carry a gunner so that his torso is substantially parallel to the axis of rotation of the column and his legs are astraddle thereof to enable him to rotate with the column through its entire movement in azimuth, a base fixed to the column and constituted for driving engagement, electrically operated means for engaging said base for rotating said column, a frame secured to the top of the column for rotation therewith, guns mounted on said frame and fixed relative to the column for movement in azimuth and pivoted relative to the column for movement in elevation, electrically operated means mounted on said frame for rotating said guns in elevation, an electrical power system comprising a power circuit connected to said first and second named means, a single manual control for controlling said first and sec-

ond means, and a control circuit connected to said power circuit and including cams constructed and arranged to be synchronized with the movement of the guns in elevation and azimuth so as to restrict the firing area of the guns to well-defined boundaries, whereby said guns will be arrested at predetermined positions of azimuth and elevation.

3. In an electrically power operated turret for use on an aircraft or the like, the combination of a rotatable column constructed and arranged to carry a gunner so that his torso is substantially parallel to the axis of rotation of the column and his legs are astraddle thereof to enable him to rotate with the column through its entire movement in azimuth, a base fixed to the column and constituted for driving engagement, electrically operated means for engaging said base for rotating said column, a frame secured to the top of the column for rotation therewith, guns mounted on said frame and fixed relative to the column for movement in azimuth and pivoted relative to the column for movement in elevation, electrically operated means mounted on said frame for rotating said guns in elevation, an electrical power system comprising a power circuit connected to said first and second named means, a single manual control for controlling said first and second named means, and a control circuit connected to said power circuit and including cams constructed and arranged to be synchronized with the movement of the guns in elevation and azimuth so as to restrict the firing area of the guns to well-defined boundaries, whereby said guns will be arrested at predetermined positions of azimuth and elevation.

4. A turret for an aircraft or the like wherein a gunner revolves with the turret as it rotates in azimuth, in combination, a rotatable column supported at its base and having a frame for mounting guns, guns mounted on said frame and fixed relative to the column for azimuth movement and pivoted relative to the column for movement in elevation and depression, a first means to rotate said turret and guns in azimuth, a second means to rotate said guns in elevation and depression, an electrical power system connected to said first and second means for rotating said guns azimuthly and vertically and comprising a single manual control manipulated by the gunner for controlling said guns and turret, and cams having cut-out portions corresponding to positions in azimuth where the guns would strike the aircraft, said cams being connected to the power system and driven by said first means and synchronized in movement with the turret and guns in azimuth, whereby rotation of the turret and guns in azimuth is arrested when said cut-out portions have rotated to predetermined positions.

5. A turret for an aircraft or the like wherein a gunner revolves with the turret as it rotates in azimuth, in combination, a rotatable column supported at its base and having a frame for mounting guns, guns mounted on said frame and fixed relative to the column for azimuth movement and pivoted relative to the column for movement in elevation and depression, a first means to rotate said turret and guns in azimuth, a second means to rotate said guns in elevation and depression, an electrical power system connected to said first and second means for rotating said guns azimuthly and vertically and comprising a single manual control manipulated by the gunner for controlling said guns and turret, and cams having cut-out portions corresponding to predetermined maximum positions of elevation and depression of the guns, said cams constructed and arranged to be driven by said second means and connected to said power system and synchronized in movement with the guns in elevation and depression to cause said guns to be arrested when the cut-out portions have been moved to predetermined positions.

6. A turret for an aircraft or the like wherein a gunner revolves with the turret as it rotates in azimuth, in combination, a rotatable column supported at its base and having a frame for mounting guns, guns mounted on said frame and fixed relative to the column for azimuth movement and pivoted relative to the column for movement in elevation and depression, a first means to rotate said turret and guns in azimuth, a second means to rotate said guns in elevation and depression, an electrical power system connected to said first and second means for rotating said guns azimuthly and vertically and comprising a single manual control manipulated by the gunner for controlling said guns and turret, cams having cut-out portions corresponding to positions in azimuth where the guns would strike the aircraft, said cams being connected to the power system and driven by said first means and synchronized in movement with the turret and guns in azimuth, and cams having cut-out portions corresponding to predetermined maximum positions of elevation and depression of the guns, said last named cams constructed and arranged to be driven by said second means and connected to said power system and synchronized in movement with the guns in elevation and depression, whereby movement of the guns in azimuth and elevation will be arrested only when the cut-out portions of both the first and second named cams have been rotated to predetermined positions.

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