

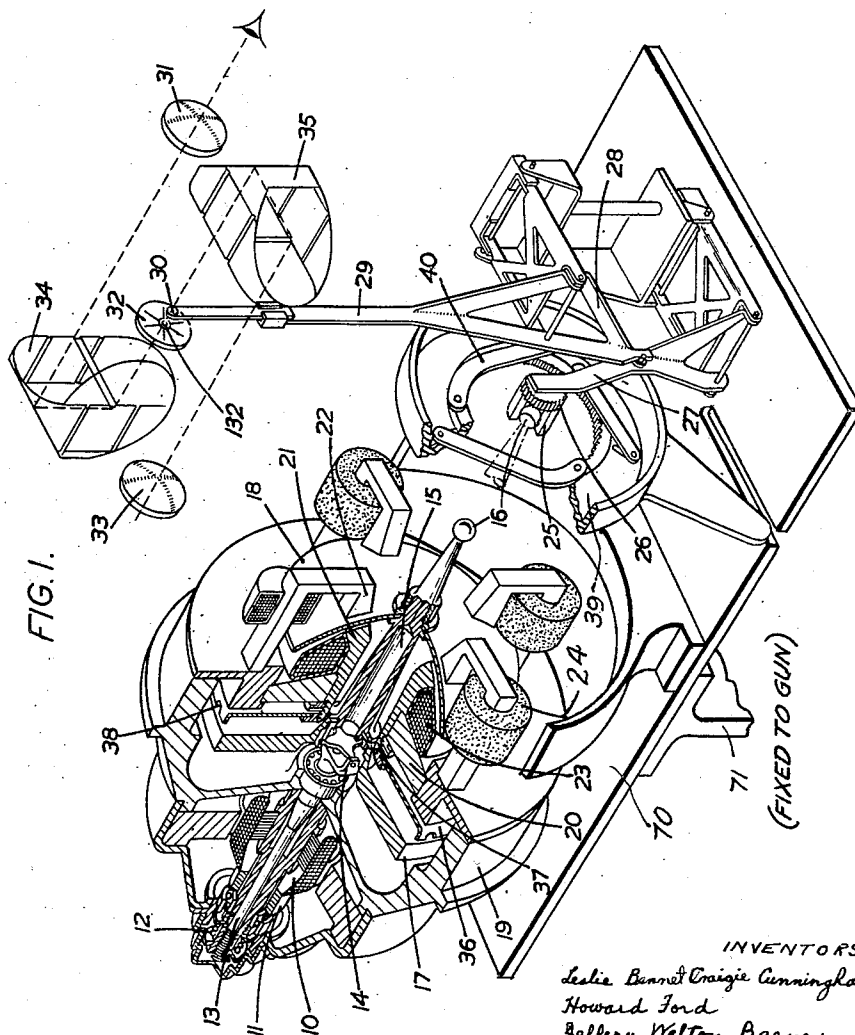
Oct. 24, 1950

L. B. C. CUNNINGHAM ET AL
GYROSCOPICALLY CONTROLLED GUNSIGHT

2,527,245

Filed March 17, 1944

5 Sheets-Sheet 1



INVENTORS

Leslie Bennet Craigie Cunningham
Howard Ford
Jeffery Walton Barnes
Ben Dykes
Maurice Hancock
Bernard Wheeler Robinson

By
Lloyd Hall Sutton
Attorney

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FIG. 7.

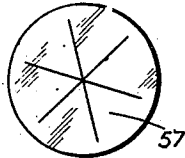
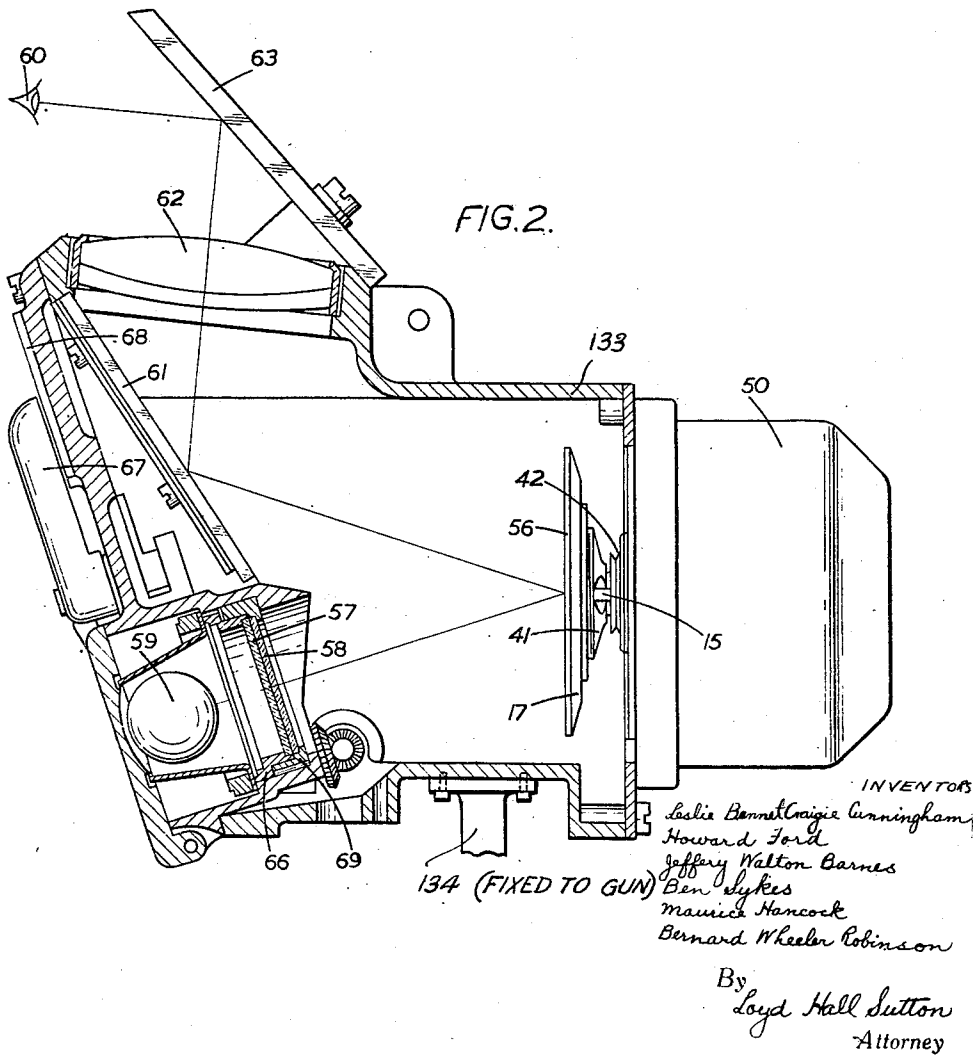
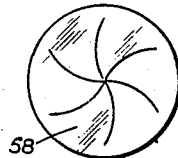


FIG. 8.



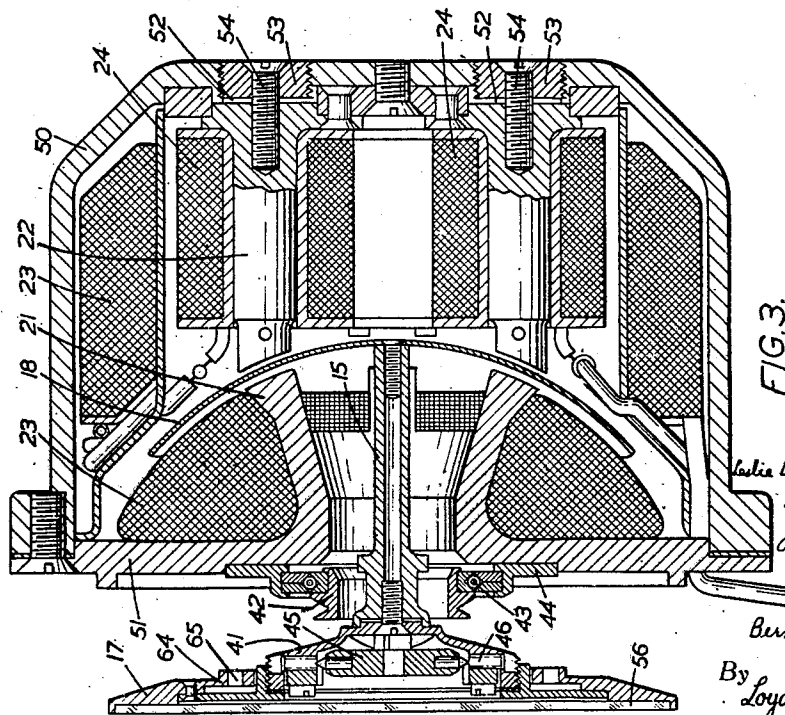
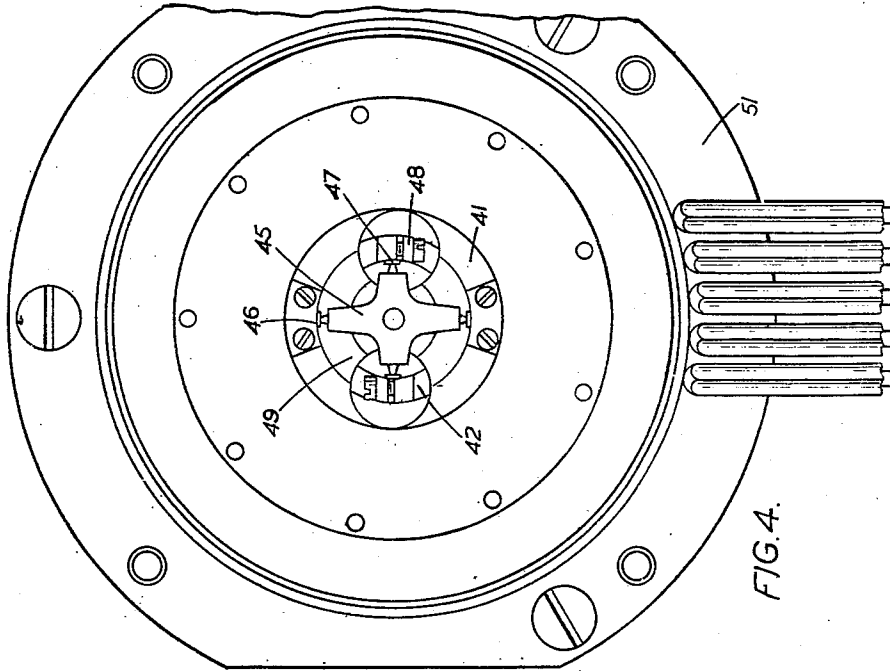
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INVENTORS
Lester Bennett Cunningham
Howard Ford
Jeffrey Walton Barnes
Ben Lykes
Maurice Hancock
Bernard Wheeler Robinson
By Lloyd Hall Sutton
Attorney

Oct. 24, 1950

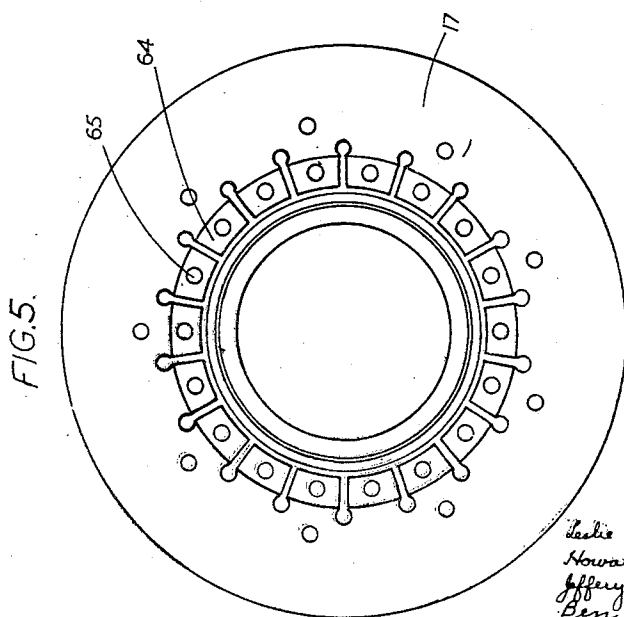
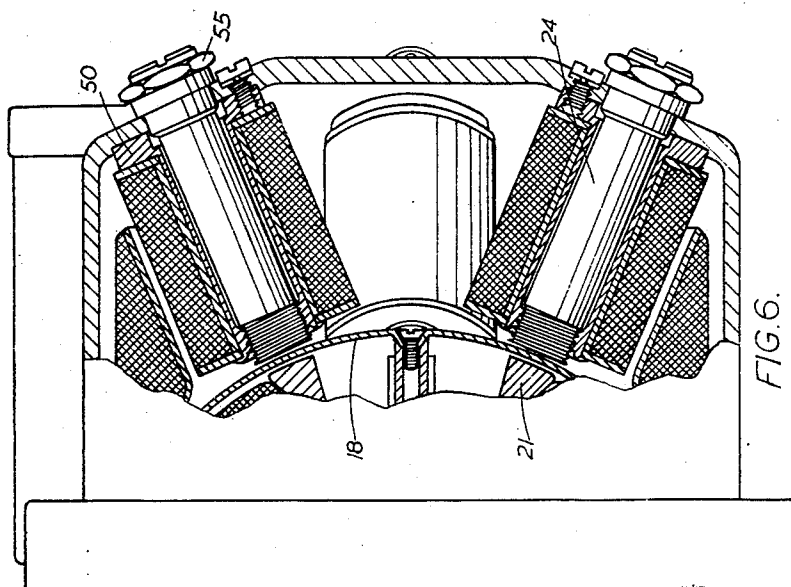
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GYROSCOPICALLY CONTROLLED GUNSIGHT

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INVENTORS

Leslie Benoit Craig Cunningham
Howard Ford
Jeffrey Walton Barnes
Ben Lykes
Maurice Hancock
Bernard Meeker Robinson

By *Lloyd Hall Sutton*
Attorney

Oct. 24, 1950

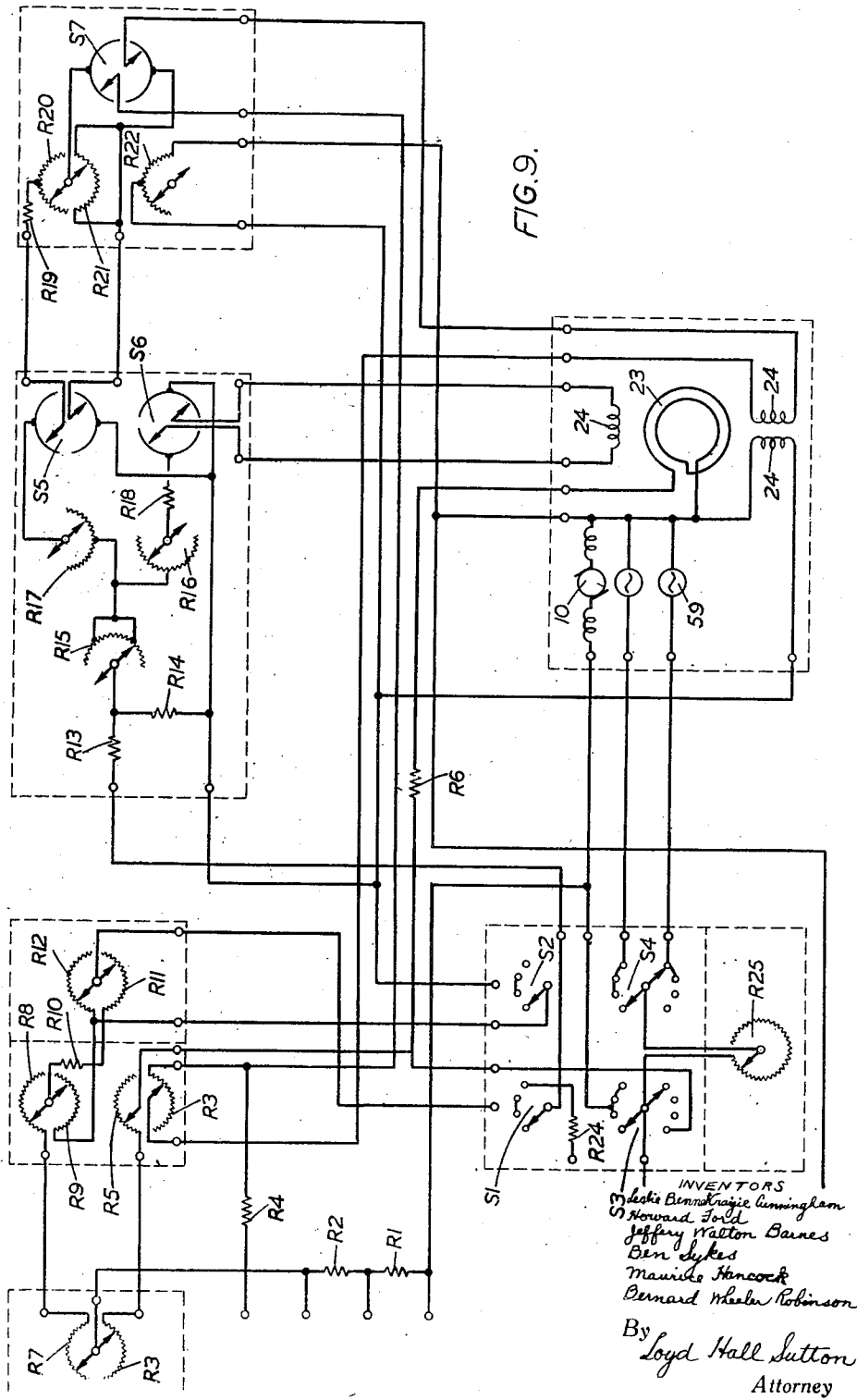
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UNITED STATES PATENT OFFICE

2,527,245

GYROSCOPICALLY CONTROLLED
GUNSIGHT

Leslie Bennet Craigie Cunningham, Stanmore, and Howard Ford, Jeffery Walton Barnes, Ben Sykes, Maurice Hancock, and Bernard Wheeler Robinson, Farnborough, England; Barclays Bank Limited, London, England, administrators of said Cunningham, deceased, assignors, by mesne assignments, to Ferranti Limited, Hollinwood, England, a company of the United Kingdom of Great Britain and Northern Ireland

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8 Claims. (Cl. 88—1)

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The invention relates to an improved gunsight. Whenever relative motion takes place between a gun and its target, or, when relative motion takes place between the gun and the surrounding air having a component in a direction at right angles to the gun barrel, giving rise to "bullet trail," or when the gun barrel is not parallel to the direction of the earth's gravitational field, giving rise to "bullet drop," it is necessary to point the gun in a direction different from that of the straight line joining it to the target in order to hit the target. When these various conditions exist simultaneously, the required angle between the gun barrel and the straight line joining the gun to the target is the vector sum of the angles necessitated by the said separate factors. This resultant angle between the gun barrel (the line of aim) and the line joining the gun to the target (the sighting line) is termed the deflection angle.

In conventional practice, when using non-automatic gunsights, the gunner estimates the required deflection angle approximately by the application of simple standardised rules and aims accordingly. The exact evaluation of the required deflection angle involves consideration of the following factors:

- (a) the velocity of the target relative to the gun,
- (b) the range of the target,
- (c) the velocity of the air relative to the gun,
- (d) the density of the air along the trajectory of the projectile,
- (e) the direction of the earth's gravitational field relative to the gun,
- (f) the ballistic characteristics of the gun and the projectiles.

It is therefore a matter of considerable complexity. The approximate estimate of the required deflection angle obtained by the application of said standard rules is therefore frequently in considerable error, and is known to be responsible for much ineffective shooting.

The invention has the object of enabling such aiming allowance to be made automatically by interposing a variable deflection angle between the sighting line and the line of aim by automatic adjustment of the gunsight, which may be termed a predictor gunsight, since it enables the required deflection angle to be automatically computed and maintained.

In accordance with the present invention, an automatic predictor gunsight comprises means for indicating a sighting line, a mechanism for continuously evaluating the required deflection

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angle to a desired degree of precision while said sighting line is pointed continuously towards the target, and means for interposing said deflection angle between the sighting line and the line of aim by causing said indicated sighting line to move relative to the body of the sight.

In a convenient form, the gunsight may comprise a constrained gyroscope coupled mechanically or optically with an optical sight, said gyroscope and optical sight being associated with, and mounted in close proximity with a gun or group of guns in such a manner that the equilibrium direction of the spin axis of the gyroscope, the indicated sighting line, and the axis of the gun barrel or controidal axis of the group of gun barrels are parallel when the required deflection angle is zero. When the mounting of said gyroscope is rotated to follow a relatively moving target, the spin axis of said gyroscope will deviate from its no rotation equilibrium position relative to said mounting by an amount and in a direction governed jointly by the nature of said rotation and the characteristics of said constraint. In this form of gunsight said constraint may take the form of a precessing torque whose magnitude is very nearly proportional to the deviation of the gyroscope spin axis from its equilibrium position for no rotation, and whose direction is such as to cause said axis to move directly towards said equilibrium position. In consequence, it follows that when the mounting is rotated with uniform angular velocity, the spin axis will take up an equilibrium position which lags behind said no rotation equilibrium position by an amount which is proportional to said uniform angular velocity, and in a direction parallel to the plane of said rotation, or, when said angular velocity is not uniform, the magnitude and direction of said lag will vary from their equilibrium values appropriate to uniform rotation by amounts proportional to the rate of change of said rotation.

When relative motion takes place between the gun or guns and target, the component of the deflection angle required to allow for this factor is proportional to the product, angular velocity of sighting line required to follow target multiplied by time of flight of projectile from gun to target, and is in the plane of said rotation provided said angular velocity is uniform, or, is nearly proportional to said product and in said direction when said angular velocity does not change rapidly. Since conditions involving rapid change of angular velocity of sighting line are rarely encountered in practical gunnery, it follows that the lag of said constrained gyroscope from its no rota-

tion equilibrium position will, in all practical cases, be nearly proportional to that component of deflection angle required to allow for relative movement between guns and target so long as the mounting of said gyroscope is moved so as to par-

take of said relative movement.

When conditions are encountered which introduce into the required deflection angle corrections for bullet trail and bullet drop, said corrections being termed trail and gravity angles respectively, the no rotation equilibrium position of the gyroscope spin axis may be deflected from its initial position through an angle proportional to the vector sum of trail and gravity angles. Accordingly, when the gyroscope mounting is rotated to follow a relatively moving target in these circumstances, the total deviation of the gyroscope spin axis from its initial no rotation equilibrium position will be proportional to the vector sum of the separate components of deflection angle enumerated above, and will therefore be proportional to the required deflection angle.

In a preferred form in accordance with the invention the gyroscope rotor is mounted on, and driven through a Hooke's joint from an electric motor. A spindle is attached to the rotor and carries a dome of high electrical conductivity having the form of a spherical cap concentric with the kinematic centre of the Hooke's joint. The centre of gravity of the moving system comprising said gyroscope rotor and its coupling with the optical system is at the kinematic centre of the Hooke's joint. The gyroscope is constrained through the medium of a magnetic system which links the high conductivity dome and reacts on said dome through the medium of induced eddy currents when the rotor spins. The magnitude and direction of said eddy current reaction may be controlled by known means, either through the medium of adjustable magnetic shunts associated with the magnetic system, or through the control of electric currents in windings which may link the magnetic system. Said magnetic system may be energised either solely by electromagnetic means or jointly by a combination of electromagnetic windings and permanent magnets. In order to ensure dynamic stability of the moving system, the moment of inertia of the gyro rotor about its spin axis must exceed a certain limiting value which is defined jointly by the transverse inertia of said moving system and by the design of the magnet system. This condition is fulfilled by the use of a Hooke's joint gyro mounting which enables the amount of non-spinning mass embodied in the moving system to be reduced to the lowest practicable limit.

Various features of the invention will now be described with reference to the accompanying illustrations in which:

Fig. 1 is a perspective view, partly broken away showing one form of sight in accordance with the invention,

Fig. 2 is a side sectional elevation of an alternative form of sight,

Fig. 3 is an enlarged sectional elevation of the gyroscope unit embodied in the sight shown in Fig. 2,

Fig. 4 is a front view of the gyroscope rotor shown in Fig. 3 with the mirror removed,

Fig. 5 is a rear view of the gyroscope rotor unit shown in Fig. 3,

Fig. 6 is a section elevation of an alternative magnet system to that shown in Fig. 3,

Figs. 7 and 8 are detail views of the graticule patterns embodied in the sight shown in Fig. 2,

Fig. 9 is an electric circuit diagram of an installation of the sight shown in Fig. 2.

Referring to Fig. 1, an electric motor 10 drives a hollow shaft 11 connected at one end through a spring coupling 12 to a second shaft 13 which is located within and co-axial with the hollow shaft 11. The end of the shaft 13 remote from the spring coupling 12 is connected through a Hooke's joint 14 to a spindle 15 terminating at its free end in a ball 16, and carrying between its ends a gyroscope rotor 17 and a dome 18 of high electrical conductivity, preferably copper, in the form of a spherical cap concentric with the kinematic centre of the Hooke's joint 14.

Surrounding the gyroscope and motor is a housing 19 in which is mounted a magnet system having four independent flux paths formed by the pole pieces 21 and 22 and the intervening air gaps through which the copper dome passes. The magnet system is excited jointly by the radially magnetised annular permanent magnet 20, the electromagnetic windings 23 which links all the flux paths, and the electromagnetic windings 24 which link the flux paths individually. The ball 16 engages in a sleeve 25 carried by an arm 27 forming one member of a linkage indicated generally at 28. An extension of a second member 29 of this linkage carries a graticule 30 which is interposed in the optical system of the telescopic sight formed by the eye lens 31, the field lens 32, the object lens 33 and the prisms 34 and 35, through which the target is observed. The graticule 30 is situated near the common focal plane of the object and eye lenses of the sight in order to ensure sharpness and freedom from parallax in its image. In order to ensure that motions of the spindle 15 and the sighting line defined by the graticule 30 are always in the same or nearly the same directions relative to the housing, the linkage 28 is arranged to introduce a reversal of direction into relative motions of the ball 16 and the graticule 30 parallel to the refracting edge of the prism 34, but no such reversal into relative motions parallel to the refracting edge of the prism 35.

The housing 19, the base of the linkage 28, and the body of the telescopic sight are coupled rigidly together on a common mounting plate 70 carried on a bracket 71 which is fixed to and turns with the associated gun or guns.

In operation, when the motor 10 is running, eddy currents are set up in the dome 18 as a result of the relative motion between the dome and the magnetic flux which links it, and a mechanical drag is therefore imposed on the dome. In general, the distribution of drag throughout the dome is such as to provide a pure couple about the spindle 15, against which the motor 10 works, and a force which, acting on the spindle 15, provides a precessing torque which causes the gyroscope to move towards a unique position in relation to the magnet system in which the drag reduces to a pure couple only. The instantaneous rate of precession of the gyroscope is proportional within very close limits to its angular displacement from the position in which the drag reduces to a pure couple only, and is also dependent on the magnetic field strength in the air gaps of the magnet system. When the housing and magnet system are turned in relation to space axes, the precessing action described causes the spindle 15 to follow the angular motion of the housing with a lag which is determined jointly by the excitation of the magnet system and the characteristics of the angular motion of the housing. This lag, which

is transmitted to the optical system via the linkage 28 and the graticule 30 constitutes the aiming allowance indicated by the sight, and its characteristics in relation to the motion of the housing may be controlled within wide limits by variation of the electric currents supplied to the windings 23 and 24. Additional control over the relationship between aiming allowance and housing motion is also provided by an adjustable magnetic shunt consisting of the soft iron disc 36 mounted on the screwed bush 37 so that its distance from the rear face of the magnet system may be varied. This adjustment is used during manufacture only, to compensate for variations arising from manufacturing tolerances; when correctly set, the disc 36 is locked in position by means of the slots 38 in its edges and a locking screw not shown.

The deflection of the spindle 15 in relation to the housing is limited by a ring 39 which makes contact with the outside of the sleeve 25 when the maximum limit of the deflection is reached. The teeth 26 on the outside of the sleeve 25, and a set of similar teeth on the inside of the ring 39 form a locking arrangement which prevents sudden rotation of the direction of deflection through a right angle owing to the precessing effect of the reaction between the sleeve 25 and the ring 36 when the limit of free deflection has been reached. The ring 39 may be coupled to an iris diaphragm consisting of the leaves 40, and to an external member controlling the supply of current to the motor 10, thereby providing means for automatically centralising the spindle 15 and the graticule 30 when the gyroscope is not running.

A reference pattern fixed in relation to the sight body may be provided by the graticule pattern 132 on the surface of the field lens 32.

In the form shown in Figs. 2 to 5, the gyroscope rotor consisting of the wheel 17, the wheel hub 41, the spindle 15, and the aluminum dome 18 is belt driven from a motor (not shown in Figs. 2-5 but indicated at 10 in Fig. 9), the belt engaging with a hollow pulley 42 carried in the ball race 43 in the flanged ball race housing 44. The spindle 15 passes through the opening in the pulley 42. The drive is transmitted from the pulley 42 to the wheel 17 via a Hooke's joint consisting of the pivoted spider 45 which engages with pivot cups 46 carried in the wheel hub 41, and pivot cups 47 carried in lugs 48 projecting from the pulley 42, see Fig. 4. The spider 45 carries a light spring wire 49 which, by bearing against the hub 41 to varying extents when the Hooke's joint is bent partly corrects the performance of the gyroscope for secondary errors caused by the inertia of the pulley 42 and the spider 45.

The dome 18 passes through gaps between four pairs of pole pieces 21 and 22 associated with a magnet system consisting of the body 50 and cover 51, together with the magnetising windings 23 and 24. The entire magnetic system may conveniently be made from low hysteresis magnetic alloy such as "radiometal," but no permanent magnets are used in this arrangement. The flange of the ball race housing 44 is spigoted into a recess in the outer face of the magnet cover 51.

The magnet system in the arrangement has four subsidiary air gaps 52 in series with the main air gaps in which the dome spins. The gaps 52 may be adjusted during assembly by means of the magnetic adjusting screws 53 and

non-magnetic locking screws 54 to compensate for accidental variations in dimensions and magnetic properties of the components of the magnet system. In an alternative form of magnet system shown in Fig. 6, the outer pole pieces 24 are screwed directly into the magnet body 50, being directed radially towards the dome 18. With this arrangement magnetic adjustments required during assembly are made by screwing the poles bodily towards or away from the dome and locking them in the correct position by means of the lock nuts 55.

The front face of the wheel 17 carries a mirror 56 which forms part of a reflector optical system shown in Fig. 2, all the mirrors being "front silvered" to prevent the formation of double images. In this system, the graticule assembly 57, 58, illuminated by the lamp 59 acts as a source of light which is seen superposed on a direct view of the target by the observer's eye 60 via the gyro mirror 56, the mirror 61, collimating lens 62 and transmitting reflector 63, items 61, 62 and 63 being rigidly fixed to the body of the sight.

The gyroscope wheel 17 has a ring of overhanging tabs 64 (shown in plan view in Fig. 5) which project from its back face. By bending these tabs towards or away from the wheel as required during manufacture, the gyroscope rotor assembly can be so balanced that the image found by the mirror 56 remains steady in spite of the rotor spin. The holes 65 in the tabs are provided for the insertion of a bending tool to facilitate this operation.

The action of the gyroscope magnet system in relation to angular movement of the sight body is identical in this arrangement with that described for the sight shown in Fig. 1. Angular deflections of the gyroscope rotor assembly from its normal position of symmetry in relation to the magnet system cause the direction in which the image of the illuminated graticule assembly 57, 58 is seen by the observer to change in relation to the sight body, these changes in direction constituting the indicated aiming allowances. The sight body 133 is carried on a bracket 134 which upstands from and turns with the associated gun or guns, this bracket, shown broken away in Fig. 2, therefore constituting a part of the gun means.

The graticule assembly 57, 58 consists of a pair of opaque screens carrying transparent patterns as shown in Figs. 7 and 8 which may conveniently be formed by engraving or etching the opaque background. These patterns when superposed concentrically allow light to pass through a central spot and through a concentric ring of six equally spaced apertures at the points where the straight lines of the pattern 57, and the curves of the pattern 58 cross. By constructing the pattern of the graticule 57 in the form of radial lines, and that of the graticule 58 in the form of logarithmic spirals, the arrangement may be made to constitute a simple range-finder. As indicated in Fig. 2, the holder 66 carrying the graticule 57 may be coupled by gearing to the external control handle 67 moving over the scale 68 calibrated in target span, and the holder 69 carrying the graticule 58 may be coupled also by gearing to an external pulley (not shown). By setting the handle 67 to indicate target span, and turning the pulley coupled to the holder 69 until the ring of dots seen through the optical system just embraces the target, the position of this pulley can

be made to indicate target range. In practice the range indicating pulley may be coupled to remote operating mechanism (e. g. pedals), the coupling also engaging with variable resistances which control the electric currents supplied to the magnet windings. In order to avoid parallax effects in the graticule image, the graticules 57 and 58 are mounted in the closest possible proximity with the transparent patterns on the adjacent faces.

A reference graticule pattern whose image remains fixed in relation to the sight body may also be provided if required. When fitted, this graticule may be illuminated by a separate lamp (not shown) which can be controlled independently of the lamp 59 by means of an external switching system.

An arrangement by which the electric currents required to ensure correct operation of the sight shown in Fig. 2 may be generated and supplied to the sight is illustrated by Fig. 9 which shows a circuit diagram of the installation.

Referring to Fig. 9 the switches S_1 , S_2 , S_3 , S_4 , the fixed resistance R_{24} and variable resistance R_{25} form the essential elements of the selector and dimmer control. The variable resistances R_3 and R_7 are controlled by range setting. The variable resistances R_{23} , R_5 , R_8 and R_9 are controlled by height setting. The height control also contains the fixed resistance R_{10} . The variable resistances R_{11} and R_{12} are controlled by air-speed setting. The variable resistances R_{15} , R_{16} , R_{17} and the reversing switches S_5 and S_6 are controlled by gun azimuth angle. The azimuth control also contains the fixed resistances R_{13} , R_{14} , and R_{18} . The variable resistances R_{20} , R_{21} , R_{22} and the reversing switch S_7 are controlled by gun elevation angle. The elevation control also contains the fixed resistance R_{19} . The fixed resistances R_1 , R_2 , R_4 and R_6 are housed in the junction box.

Alternative arrangements to that shown in Fig. 9 may be used with the sight according to the conditions of operation and the performance accuracy required. Thus, if the sight is used with guns which fire only straight ahead as in fixed gun fighter aircraft and only moderate accuracy is required, the ballistic computing system may be designed to take account only of range or of range and height, whilst if the greatest possible accuracy is required in turret gun installations considerably more complex computing circuits than that shown in Fig. 9 may be employed, and additional independent variables such as ambient temperature, and aircraft pitch, yaw and bank angles may be fed into the system.

We claim:

1. In a predictor gunsight, adjustable means for defining a sighting line, a gyroscope having a spindle, means operatively connecting said spindle to said adjustable means for actuating the same, an electrically conducting member mounted on the spindle to spin with the gyroscope and offset along the spin axis of the same, a symmetrical group of magnetic pole pieces arranged in pairs at either side of said electrically conducting member to impose an eddy current drag on said conducting member and thereby on the rotation of the gyroscope, coils associated with at least one pair of said magnetic pole pieces, whereby the pole strengths of said pole pieces may be modified, gun means with which said group of pole pieces is fast whereby when the gyroscope is spinning and

the gun means is moved the eddy current drag applies a couple about an axis perpendicular to the gyroscope spin axis which is therefore constrained to follow the movement of the gun means with a lag dependent on the angular velocity of movement of the gun means, and an electrical computing network for supplying variable currents to said coils associated with said pole pieces to modify the orientation of the gyroscope spin axis in accordance with ballistic requirements.

2. In a predictor gunsight, adjustable means for defining a sighting line, gun means, a housing fast with said gun means, a gyroscope mounted in said housing through the intermediary of a Hooke's joint, means operatively connecting said gyroscope to said adjustable means to actuate the same, an electrically conducting member operatively connected to said gyroscope to spin with the same and offset along the spin axis of the gyroscope, and a symmetrical group of separate magnetic pole pieces arranged in a plurality of pairs at either side of said electrically conducting member and all fixedly mounted in said housing whereby said electrically conducting member is continuously subjected to eddy current drag, said electrically conducting member and group of pole pieces having their axes normally aligned, so that when the gun is moved to disalign the axes of the electrically conducting member and the group of magnetic pole pieces, a couple is set up about an axis perpendicular to said spin axis whereby said gyroscope is precessed to follow the movement of the housing and associated gun means with a lag dependent on the angular velocity of the movement of the gun means and which represents the required deflection angle.

3. In a predictor gunsight, a telescope, a graticule interposed in the optical field of the telescope, means mounting said graticule to move across said field to adjustably define a sighting line, a gyroscope having a spindle operatively connected with said graticule to locate the same in accordance with the orientation of the gyroscope spin axis, an electrically conducting member operatively connected to said spindle to spin with the gyroscope and offset along the axis of the same, gun means, and a magnetic member mounted to move with said gun means comprising a plurality of individual pole pieces symmetrically arranged about a common axis in pairs at either side of said electrically conducting member and normally aligned axially with said electrically conducting member whereby said electrically conducting member is continuously subject to eddy current drag and said gyroscope spindle is subject to a couple about an axis perpendicular to the gyroscope spin axis when the axes of the electrically conducting member and magnetic member become disaligned and said graticule is caused to move with said gyroscope spin axis to follow angular movement of the gun means with a lag which varies with the angular velocity of said movement.

4. In a predictor gunsight, a transparent mirror through which a relatively moving target may be viewed, an optical projection system including a graticule operatively related to said mirror so that an image of the graticule is projected on said mirror and appears to be superposed on the target, a gyroscope, an electrically conducting member operatively connected to said gyroscope to spin with the same and offset along the axis of the gyroscope, gun means, a magnetic member mounted to move with said gun means and nor-

mally aligned axially with said electrically conducting member whereby said electrically conducting member is continuously subject to eddy current drag and to a couple at right angles to the spin axis when the axes of the electrically conducting and magnetic members become disaligned, whereby on angular movement of said gun means the gyroscope is precessed to follow said movement with a lag which varies with the angular velocity of movement of said gun means, and a mirror associated with the gyroscope to spin therewith and to move with its spin axis, said mirror forming a part of said optical projection system.

5. In a predictor gunsight, an optical system for defining a sighting line, gun means, means mounting said system to move as a whole with said gun means said system having an adjustable element, a gyroscope mounted to have three degrees of freedom with respect to the gun means and optical system, a connection between said gyroscope and the adjustable element in the optical system, whereby the sighting line is defined in accordance with the orientation of the gyroscope spin axis, and means for constraining the gyroscope to follow angular movement of the gun means with a lag depending on the angular speed of such movement, said last-named means comprising a part-spherical electrically conducting member mounted to rotate symmetrically with the gyroscope spin axis and operatively connected to said gyroscope and a circular group of circumferentially spaced, continuously magnetised pole pieces symmetrically arranged in a plurality of pairs on either side of said part-spherical member and operatively connected to said gun means mounted to move as a whole therewith whereby, when the gyroscope is rotating, eddy currents are set up in the part-spherical member giving a continuous drag on the spinning of the gyroscope and setting up a precessing couple about an axis perpendicular to the gyroscope spin axis when said spin axis does not coincide with the axis of the group of magnetic pole pieces.

6. A predictor gunsight comprising a movable support adapted to move with the gun, means for defining a sighting line carried by said support, a gyroscope, means operatively connecting said gyroscope to said sighting means to move the latter and control the direction of the sighting line with respect to the spin axis of said gyroscope, and means whereby said gyroscope is actuated to constrain its spin axis to follow angular movement of said support with a lag which indi-

cates the required deflection angle, said last named means including an electrically conducting member offset along the spinning axis of the gyroscope and operatively connected with the gyroscope to spin therewith and a magnetic system movable with said support having a plurality of pole pieces located on opposite sides of said electrically conducting member and providing a plurality of independent flux paths therebetween, the pole pieces of said magnetic system being symmetrically arranged about an axis normally aligned with the axis of said electrically conducting member, said member and pole pieces cooperating to set up an eddy current drag in said member which exerts a precessing couple about an axis perpendicular to the gyroscope spin axis when the axes of said member and pole pieces become disaligned.

7. A predictor gunsight according to claim 6 including individual electromagnetic windings for said pole pieces and means for variably exciting said windings.

8. A predictor gunsight according to claim 6 wherein the electrically conducting member consists of a relatively thin dome-shaped element of high electrical conductivity adapted to spin in the space between the opposed pole pieces of said magnetic system.

LESLIE BENNET CRAIGIE CUNNINGHAM.

HOWARD FORD.

JEFFERY WALTON BARNES.

B. SYKES.

MAURICE HANCOCK.

BERNARD WHEELER ROBINSON.

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