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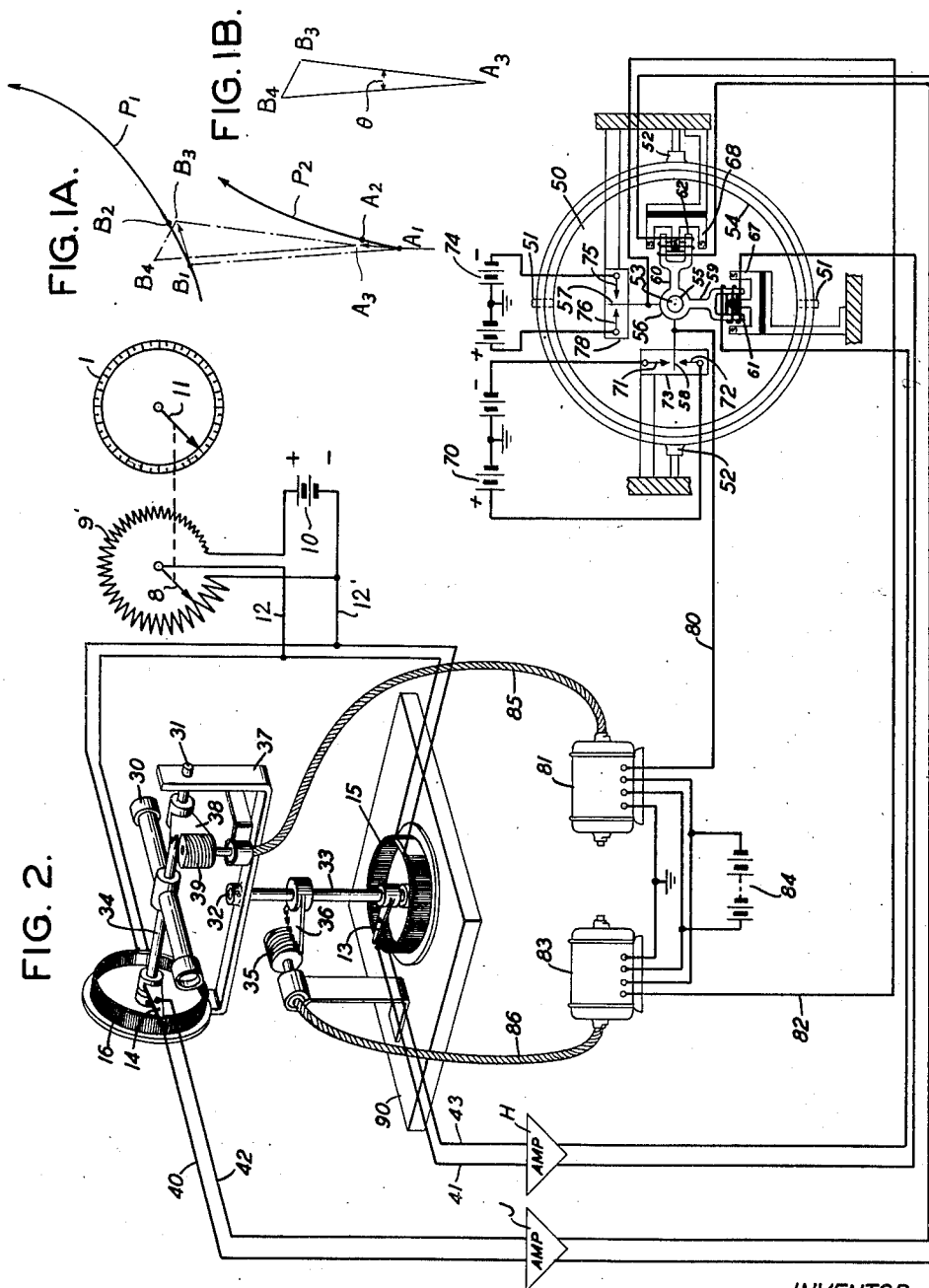
L. A. MEACHAM

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GUN SIGHT CONTROL

Filed Dec. 1, 1943

2 Sheets-Sheet 1



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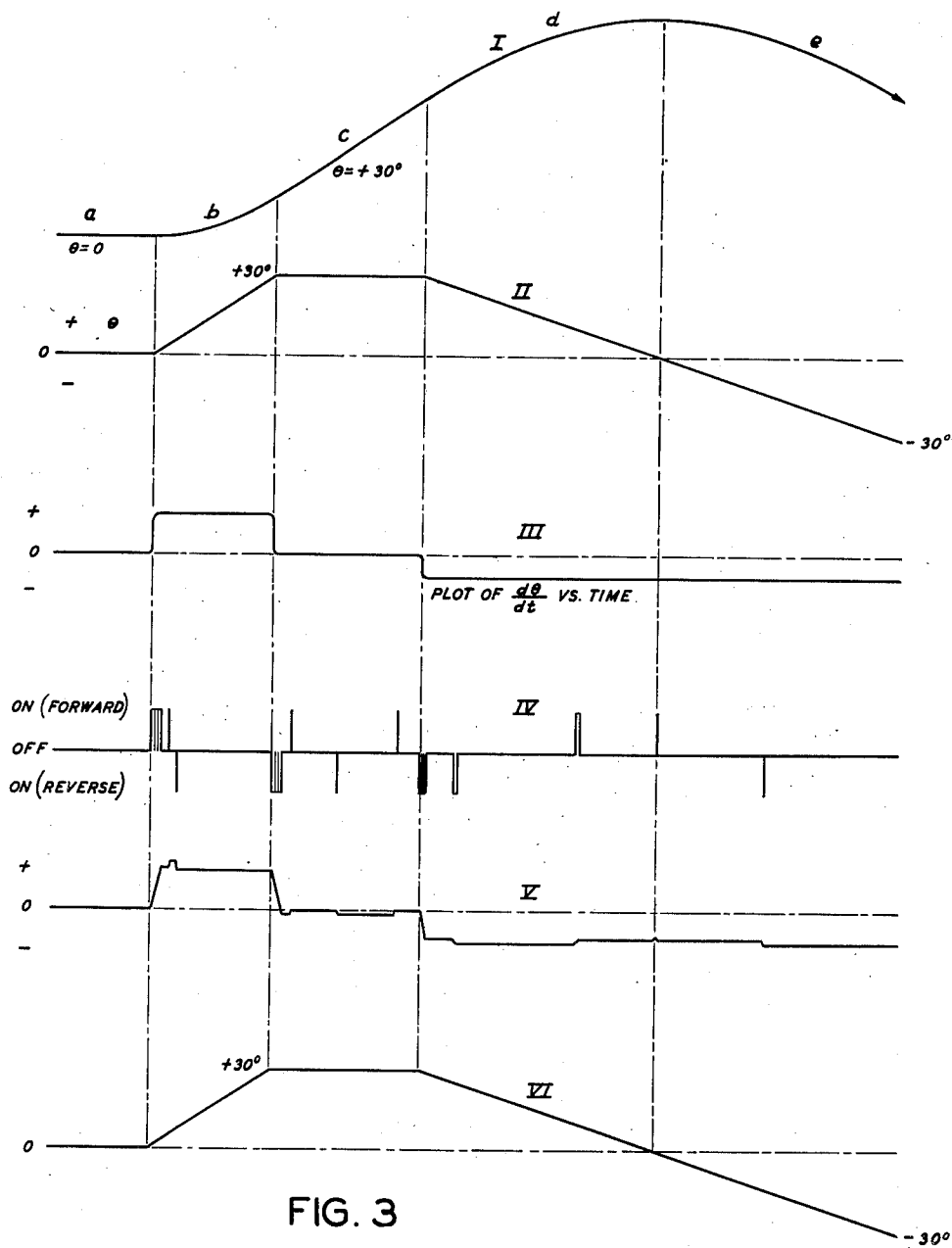
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2,471,278

GUN SIGHT CONTROL

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3 Claims. (Cl. 33—49)

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This invention relates to an improvement in means for controlling the direction of gunfire with particular reference to the case of an airplane with fixed guns pursuing a target plane the motion of which has a component transverse to the line of sight.

When the target pursued is moving in a straight line coincident with the line of sight, the pursuit plane may properly fire in that direction, but when the pursuit plane has changed heading to follow a target moving transversely of the sighting line, the pursuing pilot must select a heading in advance of the target and fire at such an angle ahead of the target that the projectile shall meet the target in the position predicted therefor at a time later than the instant of fire by an interval equal to the time of projectile flight over the distance separating pursuer and pursued. The invention provides means for automatically finding the proper angle of lead, if any lead is required.

It is, therefore, an object of the invention to provide means for controlling the direction of gunfire from an airplane pursuing a moving target.

The required heading may lead the direct line of sight by a constant or by a varying angle and the apparatus of the invention permits the angle between the line of sight and the heading of the pursuit plane to be continuously changed as the transverse component of the target's velocity changes. It is, accordingly, another object of the invention to provide means for continuously finding the heading which a pursuit plane must take in firing on a moving target, the velocity of which has a varying component transverse to the line of sight.

The pursuit plane is assumed to be equipped with means for pointing on the target and finding the range thereof and the required heading is determined by the cooperation of the aforesaid means with the apparatus of the invention. Therefore, another object of the invention is to provide a system of apparatus whereby a pursuit plane may be guided in firing on a transversely moving target.

A structure is described which enables the pilot of the pursuit plane to head continuously toward the changing predicted future position of the target while continuing to follow the target with a sighting device. It is thus also an object of the invention to provide an improved means for aiming the guns of a pursuit plane at a predicted future position of a moving target.

The invention will be understood from the fol-

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lowing description, read with reference to the accompanying drawings, in which:

Fig. 1A represents a horizontal projection of the paths of the target plane and of the pursuit plane;

Fig. 1B in part redrawn from Fig. 1A represents the relative motion of target and pursuit plane during the time of projectile flight over the initial distance;

Fig. 2 is a schematic diagram of a preferred form of the invention; and

Fig. 3 exhibits a series of curves illustrative of the functioning of the apparatus of Fig. 2.

Referring to Fig. 1A, P_1 is the horizontal projection of the path of the target plane, P_2 that of the pursuit plane. The discussion which follows, of course, applies also to the vertical projection of the two paths. The positions of the planes at times T_1 and T_2 will be A_1 and A_2 , respectively, for the pursuit plane; B_1 and B_2 , respectively, for the target. Let the target move in the interval T_2-T_1 over the path element B_1B_2 and let this interval be the time of bullet flight over the range A_1B_1 , that is, A_1B_1 divided by S , where S is the velocity of the bullets fired by the guns of the pursuit plane, these guns being assumed in fixed position with respect to the fore and aft axis of the pursuit plane. In the same interval, let the pursuit plane travel from A_1 to A_2 . Let the vectors A_1A_2 and B_1B_2 represent the velocities of the two planes at time T_1 . Points A_2 and A_3 are nearly coincident as are points B_2 and B_3 . On drawing A_3B_4 equal and parallel to A_1B_1 , it is seen that the relative motion of the target with respect to the pursuit plane during the time interval T_2-T_1 is from B_4 to B_2 which may be represented closely enough by the line B_4B_3 .

Referring now to Fig. 1B, the lines A_3B_4 , A_3B_3 and B_4B_3 are redrawn. The distance B_4B_3 through which the target moves in the time a bullet would take to travel from A_3 to B_4 is, of course, exaggerated and the distance A_3B_3 is approximately equal to the initial range A_1B_1 . The bullet fired from position A_1 partakes of the velocity of the pursuit plane and should be launched in the direction A_3B_3 to strike the target when the latter reaches B_2 (or B_3 approximately). The heading of the pursuit plane must lead the initial line of sight by the angle θ . The rate of change in this heading, $d\theta/dt$, is substantially constant for the short time interval involved and the angle θ is equal to $d\theta/dt$ times T_1 , where T_1 equals the initial range divided by the bullet velocity.

To give the pursuit plane this angle of lead, there must be established the angle θ between the

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line of sight A_3B_4 and the required heading A_3B_3 . A target moving from left to right must appear to be dead ahead when it is actually to the left of that direction.

Referring now to Fig. 2, the pursuit plane is assumed to be provided with optical ranging and sighting means of any well-known type. Range index 11 on range dial 1 controls in any convenient way the position of wiper 8 on potentiometer 9'. It is desired to impress between conductors 12 and 12' a fraction of the voltage of battery 10 inversely proportional to the range from pursuit plane to target. The reason therefor will later appear. The optical axis of telescope 30, which is initially adjusted parallel to the fore and aft axis of the airplane and thereafter is controlled by the apparatus to be described, defines the line of sight which must point on the target.

Battery 10 is connected across the entire resistance element of potentiometer 9', and conductors 12 and 12' are connected respectively to wiper 8 and to one end of potentiometer 9'. Potentiometers 15 and 16 are connected in parallel between conductors 12 and 12', forming a constant resistance load across potentiometer 9', which has a tapered resistance element, the taper being proportioned, with due regard to the aforesaid load, so that the voltage appearing between conductors 12 and 12' is by the connection to range index 11 made inversely proportional to the range of the target.

In the present case, it is preferred to deflect the pointing means itself to look down as the pursuit plane rises to follow the target or to the left if the target is traveling from left to right across the line of sight. Again the angle between the axis of telescope 30 and the heading of the pursuit plane must equal the time of projectile flight over the range at the time of firing set on dial 1 multiplied by the time rate of change of heading. Telescope 30 is rotatable about horizontal axis 31 and vertical axis 32. Stand 33, of which the axis coincides with axis 32, may be rotated about axis 32 by the operation of worm 35 engaging a toothed sector 36. Suitably mounted on stand 33 is yoke 37 supporting member 34 which carries toothed sector 38 with the teeth of which meshes worm 39, the operation of worm 39 rotating telescope 30 about horizontal axis 31. Telescope 30 and the mounting just described are supported on any convenient base 90, fixed in the plane.

Conductors 12 and 12' supply voltage across the potentiometers 15 and 16 which now are mounted concentrically with axes 32 and 31, respectively. Wiper 13 turns with the rotation of telescope 30 about axis 32 and traverses potentiometer 15. Wiper 14 turns with the rotation of the telescope about axis 31 and traverses potentiometer 16. In Fig. 2, wipers 13 and 14 are shown in contact with the mid-points of potentiometers 15 and 16, respectively, corresponding to the dead ahead orientation of the pointing telescope. Conductor 40 is connected to the mid-point of potentiometer 16 and conductor 41 to that of potentiometer 15. Wiper 14 is joined to conductor 42 and in the position shown in Fig. 2, none of the voltage between conductors 12 and 12' appears between conductors 40 and 42. Wiper 13 joined to conductor 43 is likewise shown in the figure in a position where no voltage appears between conductors 41 and 43. Accompanying the rotation of telescope 30 about either axis 31 or 32, a voltage appears between conductors 40 and 42

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proportional to the reciprocal of the initial range multiplied by the angle of rotation about axis 31 or between conductors 41 and 43 proportional to the reciprocal of the range multiplied by the angle of rotation about axis 32. The polarity of these voltages, of course, is dependent upon the direction in which wipers 14 and 13 have rotated from the mid-points of their respective potentiometers.

It is required to make these rotations, namely, about axis 31 and about axis 32, proportional to the range multiplied by the rate of change of heading which is constant only when the path of the pursuit plane is a straight line or a circle. The orientation of telescope 30 must, in the general case, continuously readjust itself as the transverse motion of the target varies. This is accomplished by the operation of the apparatus next described.

At a convenient location in the pursuit plane, gyroscope 50 is mounted in gimbal supports 51, 51 and 52, 52 and is initially set in rotation about axis 53, parallel to the fore and aft axis of the plane. It is to be understood that gyroscope 50 is of the directional type possessing three degrees of freedom, viz., rotation about axis 53 normally parallel to the lengthwise center line of the airplane, and rotations about two mutually perpendicular axes both perpendicular to this center line and defined by gimbals 51, 51 and 52, 52 to be respectively vertically and horizontally athwartship when the airplane's lengthwise axis is horizontal. It is further to be understood that by well-known means (not shown) gyroscope 50 is caged before each flight to set axis 53 in the above described normal direction and uncaged after that setting. Means for driving gyroscope 50, being only conventional, are not shown. Casing 54 in which is carried gyroscope 50 is provided at each end with a boss centered in which is one end of shaft 55 of gyroscope 50. The end of shaft 55 shown in Fig. 2, is centered in boss 56 which also carries contact leaves 57 and 58 angularly spaced 90 degrees from each other and insulated from boss 56. Also on boss 56 diametrically opposite leaves 57 and 58, respectively, are carried non-magnetic yokes 59 and 60 about which are wrapped coils 61 and 62, respectively. Coil 61 is connected in series with wiper 13 and the mid-point of potentiometer 15 by conductors 41 and 43, while coil 62 is by conductors 40 and 42 connected between wiper 14 and the mid-point of potentiometer 16. Amplifiers H and J are included in the supply circuits to coils 61 and 62, respectively. These are direct current amplifiers of conventional design. They are assumed to have high-impedance inputs, so that they do not draw appreciable current from potentiometers 15 and 16, and hence do not disturb the constancy of the load presented by these potentiometers across potentiometer 9. Yokes 59 and 60 when currents flow in coils 61 and 62 are urged toward or away from permanent magnets 67 and 68 fixed in any convenient way to the structure of the plane supporting the mounting of gyroscope 50. The forces thus arising when currents flow in coils 61 and 62 produce precession of axis 53, the use of which will now be explained. It is to be understood that to preserve the balance of gyroscope 50 the masses of contact leaves 57, 58 and of yokes 59, 60 are compensated by suitable masses (not shown) carried at the end of axis 53 opposite the end shown in the drawing.

Battery 70 of which the mid-point is grounded, has terminals 71 and 72 supported by insulating support 73. One or the other of terminals 71, 72

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makes contact with leaf 58 as the plane axis tilts up or down through a small angle with respect to axis 53. Similarly, battery 74 grounded at its mid-point has terminals 75 and 76 on insulating support 78, one or the other of which makes contacts with leaf 57 when the plane turns horizontally through a small angle with respect to axis 53.

The arrangement of leaves 57 and 58 on boss 56 and the associated contacts 75, 76 and 71, 72, respectively, may suitably be patterned after that described in U. S. Patent 1,232,619, July 10, 1917, to E. A. Sperry, referring particularly to auxiliary gyroscope K of that disclosure. Conductors 80 and 82 leading to leaves 58 and 57, respectively, as well as conductors 41, 43 and 40, 42 supplying coils 61 and 62, respectively, are suitably firmly supported on the framework of the airplane at points conveniently near to gyroscope 50 from which points these conductors are continued as light flexible connections to their respective leaves and coils. It may be desirable for the sake of symmetry to give leaves 57 and 58 the same configuration as yokes 59 and 60.

A vertical change of heading of the pursuit plane therefore causes leaf 58 to touch one or the other of terminals 71, 72 and thereby impress on conductor 80 a voltage to ground from battery 70, the polarity of which depends on which of terminals 71 or 72 is in contact with leaf 58. This voltage is by conductor 80 applied to the armature of motor 81. In the same way, for a horizontal change of heading of the pursuit plane, the voltage to ground from battery 74 over one of terminals 75 or 76 in contact with leaf 57 appears on conductor 82 and is applied to the armature of motor 83. Power supply for the fields of motors 81 and 83 is supplied from a source symbolically represented by battery 84. The operation of the apparatus of Fig. 2 is as follows:

As the pursuit plane rises to attack a moving target parallelism is lost between the plane's axis and axis 53 of gyroscope 50. Leaf 58 makes contact, say with terminal 72 and a voltage positive to ground is applied by conductor 80 to the armature of motor 81. This armature then rotates as long as contact is maintained between leaf 58 and terminal 72, turning worm 39 through flexible cable 85. It is readily arranged that this movement of worm 39 shall depress the optical axis of telescope 30, the result being that when telescope 30 is directly aimed at the target, the pursuit plane is actually headed in a direction above the target. The depression of telescope 30 is accompanied by clockwise rotation of wiper 14 so that a voltage negative with respect to the mid-point of potentiometer 16 is applied between conductors 40 and 42 and current flows in coil 62 on yoke 60. The connections of coil 62 are made such that in this case a precessional force is exerted on axis 53 producing motion of that axis upward to break contact at leaf 58 whereupon no further rotation of cable 85 takes place and axis 53 is again parallel to the plane's axis.

The precessing force which causes axis 53 to seek to recover parallelism with the plane's axis is proportional to the voltage derived by wiper 14. So long as $d\theta/dt$, the rate of change of direction of the plane's axis, is constant, a constant precessional force is required and telescope 30 must maintain a fixed position. It will be understood that the precessional force required is proportional to $d\theta/dt$, and it will be recalled that the angle of deflection of the line of sight from parallelism with the plane's axis is desired to be pro-

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portional to the range multiplied by $d\theta/dt$. As described above, the circuit to which is connected battery 10 provides between conductors 12 and 12' a voltage proportional to the reciprocal of the range, while this reciprocal voltage is fractionated by wiper 14 proportionally to the angle of deflection of telescope 30, namely, by a factor proportional to the range multiplied by $d\theta/dt$. Therefore, the voltage delivered by wiper 14 to coil 62 is proportional directly to $d\theta/dt$. Thus the current in coil 62, and so the precessional force on axis 53, is just that required to align the gyro axis with that of the plane when telescope 30 has been deflected through the angle of lead appropriate for firing on the target being pursued.

As the rate of change of direction of the axis of the plane changes, corresponding to a value other than zero for $d^2\theta/dt^2$, contact 58—72 is reestablished to increase the depression already produced by the operation of motor 81 or contact 58—71 is established to rotate the armature of motor 81 in the opposite direction thereby canceling part of the displacement of wiper 14 from the mid-point of potentiometer 16 and therewith reducing the depression of the line of sight of the telescope.

Supplementing the foregoing description of the operation of the circuit of Fig. 2, Fig. 3 shows curves illustrative of the operations described.

In Fig. 3, curve I represents in vertical projection the course of a pursuit plane which in following a target at first rises, then levels off and finally descends. In all the curves of Fig. 3 time increases from left to right. Curve II exhibits as the angle θ the variation with time of the inclination of the plane's axis to the horizontal. Curve III shows $d\theta/dt$ as a function of time. Curves IV and V exhibit, respectively, the steps of the motor operation and the position of wiper 14. The direction of the gyro axis maintained parallel to the plane's axis by the precessing forces derived from wiper 14 is represented by curve VI substantially identical with curve II.

Sections *a*, *b*, *c*, *d* and *e* of Fig. 3 may be distinguished in curve I. In section *a* the pursuit plane keeps a level course, $d\theta/dt$ is zero and the telescope is directed dead ahead. As the plane starts to rise over section *b*, θ increases to reach the value 30 degrees and $d\theta/dt$ increases from zero to a constant value. While $d\theta/dt$ is increasing, motor 81 operates driving worm 39 to depress the line of sight of the telescope and shift wiper 14. When $d\theta/dt$ reaches a constant value, motor 81 ceases to operate leaving wiper 14 in a definite position such that it derives a voltage capable of producing a current in coil 62 resulting in continuous precession at a constant rate of axis 53 to regain parallelism with the plane's axis. Over section *c* the inclination of the plane's axis is 30 degrees, θ is constant and $d\theta/dt$ is zero. As $d\theta/dt$ falls to zero, motor 81 operates to restore the line of sight to dead ahead. Sections *d* and *e* of curve I correspond to the pursuit of the descending target and for simplicity it is assumed that the rate of change of the pursuit plane's inclination is constant. The operation of motor 81 and the position of wiper 14 during this interval are readily understood. Irregularities in curves IV and V are included to illustrate the occurrence of accidental temporary departures from the desired smooth variation in the course of the pursuit plane. A corresponding plan projection of the course, omitted here, would be similarly described.

In the foregoing description it is assumed that

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the effects of successive rolls or pitches are mutually canceling, giving rise to the irregularities exhibited in curves IV and V. The same assumption is to be understood in the case of alternative gyroscope placements later mentioned.

What is to be noted is that motor 81 operates to depress the pointing means while the course is changing upward and to elevate that means when the course is changing downward. In each case, the actual heading of the pursuit plane leads the line of sight by an angle which has been shown to be proportional to that subtended at the pursuit plane by the target's motion and the time of projectile flight over the range indicated on dial 1.

The line of sight from the pursuit plane is caused to deflect from dead ahead through an angle equal to that subtended by the target's motion in the time of projectile flight from pursuit plane to target and in the sense opposite to the change of course made by the pursuit plane in following the target. The pilot, without interfering with the orientation of the sighting device, so heads his plane that at all times the deflected line of sight bears directly on the target. Index 11 is continuously adjustable to follow variations in range, so that the fixed guns of the pursuit plane have at every instant the pointing required to hit the target in a predicted future position.

It is obvious that the ranging and sighting means may be optical or electrical, or a combination of both, and that other devices than those specifically described may be used to control the line of sight and to correspond to the rate of change of course, without departing from the spirit of the invention. It will be realized that the described arrangement of the gyroscope, while the most convenient, is not the only possible one. For example, two gyroscopes may be used, one rotating about an axis initially vertical, the other about an axis initially horizontal and at right angles to the fore and aft axis of the pursuit plane. Up and down tilting of the line of sight would result from the functioning of the first of these gyroscopes, while the second would operate to effect control of the left or right deflection of the sighting means.

Moreover, while most conveniently one arranges the axis of a single gyroscope to be parallel to the fore and aft axis of the plane and the axes about which the line of sight is rotated to be perpendicular to each other and initially perpendicular to this fore and aft axis, the gyroscope axis is not limited to this orientation but may lie in any arbitrarily chosen direction other than perpendicular to the plane's fore and aft axis, provided the axes of rotation of the sighting means are arranged mutually at right angles to each other and to the arbitrarily chosen direction of the gyroscope axis. It is obvious that as the gyroscope in this case precesses to regain its arbitrary initial orientation with respect to the plane, the line of sight will be deflected appropriately just as in the described arrangement.

What is claimed is:

1. Means for determining the required direction of gunfire from an airplane changing course in pursuit of a moving target of which the motion has a component transverse to said course comprising means for measuring the range of said target, means for sighting on said target, said sighting means being normally aligned parallel to said course, a gyroscope supported in gimbal mountings in said airplane and rotating initially about an axis of rotation parallel to the fore and aft axis of said airplane, a first source of voltage,

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a first motor means for deflecting said sighting means perpendicularly to the fore and aft of said axis of said airplane, a first contact means carried by said gyroscope and adapted to apply said first source of voltage to said first motor means when said fore and aft axis departs horizontally from parallelism with said axis of rotation, a second source of voltage, a second motor means for deflecting said sighting means perpendicularly to said fore and aft axis and to the deflection producible by said first motor means, a second contact means carried by said gyroscope and adapted to apply said second source of voltage to said second motor means when said fore and aft axis departs vertically from said parallelism, a third source of voltage, means controlled by said range measuring means for deriving from said third voltage a voltage inversely proportional to said range, potentiometric means connected to said sighting means for deriving from said inversely proportional voltage a first and a second fractional voltage, said fractional voltages becoming proportional respectively to the time rates of horizontal and of vertical change of said course when said sighting means is deflected oppositely to the sense of change of said course through an angle equal to said range multiplied by the time rate of change of said course, and means energized by said fractional voltages to effect precession of said axis of rotation to regain parallelism with said fore and aft axis, whereby said fore and aft axis lies in said required direction when said sighting means is aligned directly on said target.

2. Means for determining the required direction of gunfire from an airplane changing course in pursuit of a moving target of which the motion has a component transverse to said course comprising means for measuring the range of said target, means for sighting on said target, said sighting means being normally aligned parallel to said course, a gyroscope supported in gimbal mountings in said airplane and rotating initially about an axis of rotation arbitrarily oriented at an angle other than zero with respect to a plane perpendicular to the fore and aft axis of said airplane, a first source of voltage, a first motor means for deflecting said sighting means perpendicularly to said arbitrarily oriented axis, a first contact means carried by said gyroscope and adapted to apply said first source of voltage to said first motor means when said fore and aft axis departs in one direction from its initial orientation with respect to said axis of rotation, a second source of voltage, a second motor means for deflecting said sighting means perpendicularly to said arbitrarily oriented axis and to the deflection producible by said first motor means, a second contact means carried by said gyroscope and adapted to apply said second source of voltage to said second motor means when said fore and aft axis departs from its initial orientation with respect to said arbitrarily oriented axis in a second direction at right angles to said one direction, a third source of voltage, means controlled by said range measuring means for deriving from said third voltage a voltage inversely proportional to said range, potentiometric means connected to said sighting means for deriving from said inversely proportional voltage a first and a second fractional voltage, said fractional voltages becoming proportional respectively to the time rates of change of said course in said one and in said second directions when said sighting means is deflected oppositely to the sense of change of said course through an angle equal to

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said range multiplied by the time rate of change of said course, and means energized by said fractional voltages to effect precession of said axis of rotation to regain its initial orientation with respect to said fore and aft axis, whereby said fore and aft axis lies in said required direction when said sighting means is aligned directly on said target.

3. Means for determining the required direction of gunfire from an airplane changing course in pursuit of a moving target of which the motion has a component transverse to said course comprising means for measuring the range of said target, means for sighting on said target, said sighting means being normally aligned parallel to said course, a gyroscope supported in gimbal mountings in said airplane and rotating initially about an axis of rotation parallel to the fore and aft axis of said airplane, a first and a second magnet supported in said airplane independently of said gyroscope and in a plane perpendicular to said fore and aft axis and angularly spaced 90 degrees with respect to said axis of rotation, a first and a second member supported on and in fixed relation to said gyroscope and facing respectively said first and second magnets, said members carrying each a coil adapted to be traversed by an electrical current whereby precession of said axis of rotation is effected as a result of the coaction of the magnetic field of said current and the magnetic field of the corresponding one of said magnets, a first source of voltage, a first motor means for deflecting said sighting means perpendicularly to the fore and aft axis of said airplane, a first contact means carried by said gyroscope and adapted to apply said first source of voltage to said first motor means when said fore and aft axis departs horizontally from parallelism with said axis of rotation, a second source of voltage, a second motor means for deflecting said sighting means perpendicularly to said fore and aft axis and to the deflection producible by said first motor means, a second contact means carried by said gyroscope and adapted to apply

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said second source of voltage to said second motor means when said fore and aft axis departs vertically from said parallelism, a third source of voltage, means controlled by said range measuring means for deriving from said third voltage inversely proportional to said range, potentiometric means connected to said sighting means for deriving from said inversely proportional voltage a first and a second fractional voltage, said fraction voltages becoming proportional respectively to the time rates of horizontal and of vertical change of said course when said sighting means is deflected oppositely to the sense of change of said course through an angle equal to said range multiplied by the time rate of change of said course, and means for applying said fractional voltages individually to said coils to effect precession of said axis of rotation to regain parallelism with said fore and aft axis, whereby said fore and aft axis lies in said required direction when said sighting means is aligned directly on said target.

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