

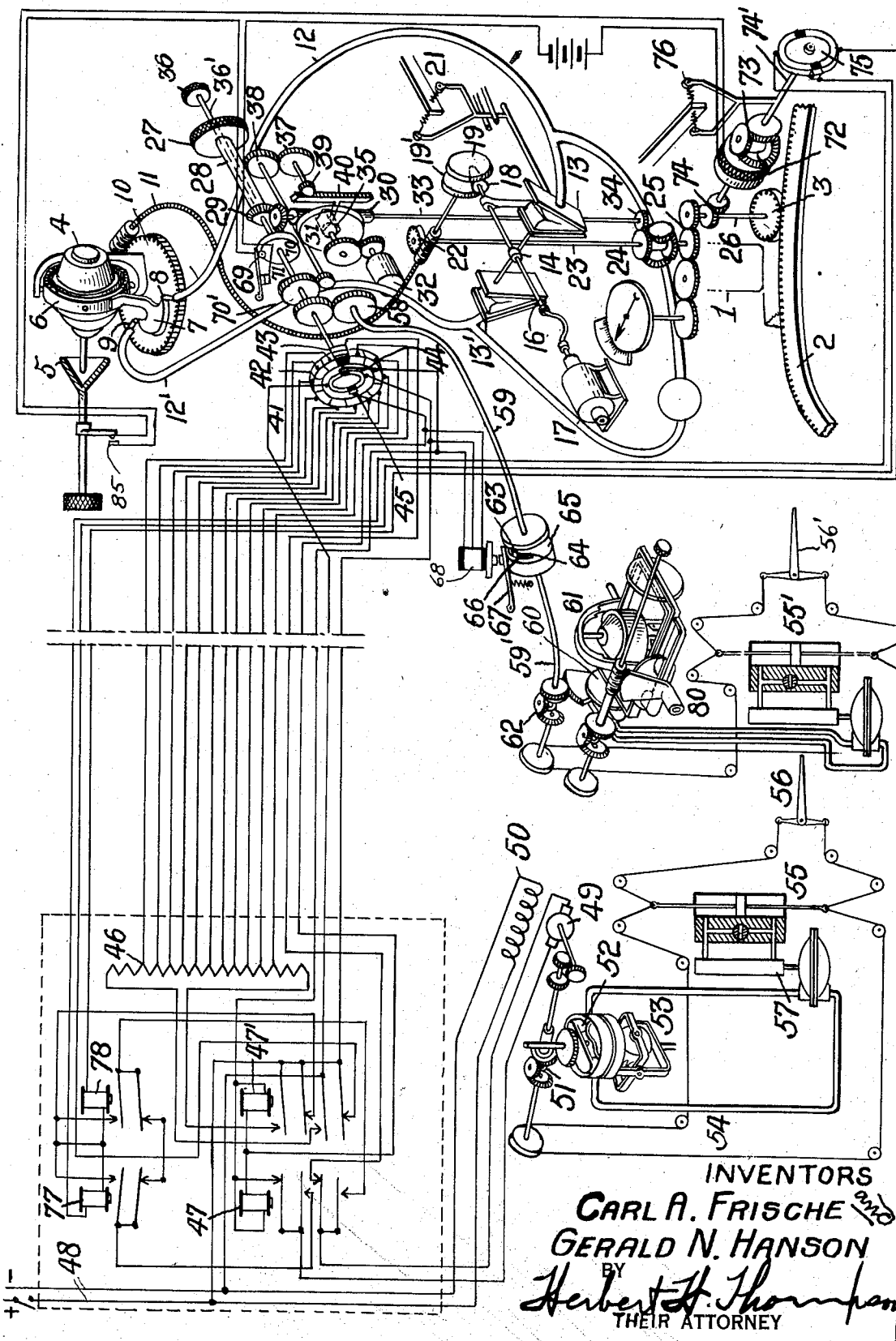
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AIRCRAFT AUTOMATIC PILOT WITH AUTOMATIC BANKING

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AIRCRAFT AUTOMATIC PILOT WITH
AUTOMATIC BANKING

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This invention relates to automatic pilots for aircraft, and more particularly, to an automatic pilot designed for use with or operation from a bomb sight. Many features of our invention, however, have application to automatic pilots in general, and the invention is therefore not limited to bomb sights.

One object of the invention is to provide a simple means for banking the craft at the correct angle when turning through the automatic pilot, so as to prevent side slip at that time. This we accomplish by proportioning the banking angle to the rate of turn by a direct setting and without the use of an auxiliary pendulum and the like.

We have illustrated the invention as applied to the type of bomb sight disclosed in the prior application of E. W. Chafee and H. C. VanAuken, now Patent No. 2,371,606, dated March 20, 1945.

In the single figure of the drawing, a portion of the mechanism of the sight is shown diagrammatically, together with a diagrammatic showing of the automatic pilot and wiring diagram of the electrical connections for controlling the rate of turn and banking angle, the parts on the right hand side of the sheet representing a portion of the bomb sight, and the left hand side the automatic pilot and the relays controlled from the rate of turn setting on the sight.

The bomb sight proper, represented at 1, is mounted for turning in azimuth around a fixed annular gear 2 with which pinion 3 on the sight meshes. The sight is normally maintained stabilized in azimuth from a directional gyroscope 4. Said gyroscope is shown as of the usual three degree of freedom type which may be caged and uncaged by a locking device 5 on the gyro casing.

The vertical ring 6 is shown as carrying some form of controller for maintaining the optical system fixed in azimuth. As shown, this comprises a cut-off plate 7 carried by the vertical ring, cooperating with a pair of ports or air nozzles 8 and 9 which are preferably supported on a rotatable platform 10 rotated from a follow-up shaft 11. The pressure drop due to said nozzles in supply pipes 12 and 12' differentially controls a pair of bellows 13 and 13', or other air pressure responsive device, which are oppositely connected to a sleeve 14 within which is journaled a jointed shaft 15 continuously rotated from a constant speed motor 17. At the end of said shaft 15 is shown a friction cone 18 which engages, on lateral displacement of the shaft, one or the other of conical friction discs 19 or 19' by means of which shaft 11 is driven in one direction or the other. The cone is normally maintained in its

central position by means of spring centralizing mechanism 21. Shaft 11 is shown as rotating the pinion 3, and hence the entire sight, through a worm and worm wheel 22, shaft 23, differential 24, gears 25 and shaft 26, on which pinion 3 is mounted.

For initially setting the line of sight on the target, there is shown azimuth setting knob 27 mounted on a sleeve 28 which directly turns, through bevel gears 29, the cylinder 30 of variable speed drive 31, the disc of which is constantly driven from motor 32. The shaft 33 of said cylinder carries a pinion 34 which drives a second arm of the differential 24. Thus, knob 27 directly rotates the line of sight in azimuth without affecting the position of the roller carriage 35 of the variable speed drive 31.

For turning the line of sight after it is directed on the target, we employ a separate rate setting knob 36 on shaft 36' which rotates a gear 37 through idling gear shaft 38. On the shaft of said gear 37 is a pinion 39 which meshes with rack teeth on the bar 40, which bar carries the roller carriage 35. By this means the roller 36 and the shaft 33 are driven in a direction and at a speed proportional to the setting of knob 36, so as to slowly turn the line of sight at the desired rate to keep it on the target.

We also mount on the shaft 36' of knob 36 a controller 41 for setting up a rate of turn of the craft itself through the automatic pilot, which rate is greater than and bears a fixed relation to the rate of turn of the line of sight in azimuth. From this it follows that the line of sight (with respect to the craft and not with respect to gyro 4) is actually turned oppositely to the turn of the craft. As shown, this controller comprises a commutator arrangement having a plurality of commutator bars 42 cooperating with a fixed brush 43, and also a reversing sector 44 cooperating with fixed brushes 45. While we have shown this controller as of the electrical form, it is obvious that a mechanical or pneumatic mechanical device, such as employed in the sight, might be employed if desired.

The commutator bars are tapped into a resistance or rheostat 46 of the potentiometer type, and the reversing brushes 45 are connected to reversing relays 47 and 47', by which the direction of flow of current from the main leads 48 to the potentiometer or rheostat 46 is reversed when the knob 36 is turned through its zero position. The output of the brushes 45 and slider 43 controls the polarity and magnitude of the D. C. voltage which is applied across the armature 49 of a motor

having a constantly excited field 50, said motor being connected through suitable gearing to one side of a differential 51 connected to the controller or pick-off device 52 at the azimuth gyroscope 53 or other direction maintaining device of the automatic pilot, the other side of the differential being actuated from the follow-up cables 54 from the main servo motor 55 operating the rudder 56. The type of automatic pilot shown is more completely disclosed in the prior patent to Carlson, Bates and Sperry, #1,992,970, dated March 5, 1935, in which differential air flow ports are employed, operating the pneumatic-hydraulic relay 57 to operate the hydraulic servo motor 55.

In order to bank the plane automatically during turns, we have shown the shaft 36' of the knob 36 as connected through gearing 58 and flexible shafts 59 and 59' to the aileron controller 60, on the artificial horizon 61 or other attitude maintaining device of the automatic pilot. This control may likewise be brought in through the follow-up system from the servo motor 55' through a differential 62 and will therefore set in the angle of bank in proportion to the rate of turn and without the employment of any auxiliary mechanism.

Preferably, however, means are employed to delay the movement of the ailerons until after the rudder has had time enough to start a turn of the craft, as otherwise the turning of the ailerons might cause a temporary turning of the plane in the opposite direction from that desired. To this end, we have shown a delayed action device connecting the two parts of shaft 59, 59', consisting of a crank pin 63 on shaft 59 which enters an annular slot 64 in a drum 65 on shaft 59' and is normally centralized therein by opposed springs 66. A spring pressed brake shoe 67 normally engages disc or drum 65 to prevent it from turning, said brake shoe being released by a delayed action electromagnet 68 or other delayed action device in circuit with the leads to reversing switch 44. Therefore the disc 65 will follow the pin 63 after a predetermined interval has elapsed after the starting of motor 49, dependent on the time lag of the delayed action device.

Stated from a different viewpoint, the single control member 36 for the turn and bank mechanism first causes a rudder displacement to initiate a turn in the proper direction, shortly followed by displacement of the ailerons to establish a bank. As the rate of turn builds up due to both causes, the rudder is returned toward its central or trailing position as the position or heading of the craft in azimuth catches up with that being set up by the variable speed motor 49, so that as the proper rate of turn is approached, the rudder usually trails. If the amount of turn at any instant exceeds or falls below that corresponding to the instantaneous angle of turn established by the variable speed drive (due to the rate of turn being too great or too slow), the rudder is displaced to subtract from or add to the rate until a match is again obtained. As a result, the desired rate of turn is maintained with great accuracy with approximately correct banking angle.

As the straight ground track is approached, the knob 36 is gradually turned back to turn the controller 42 to its zero position, thus stopping the motor 49. In this position, a spring pressed roller 69 will drop into a notch on a disc 70 on shaft 36' and close a contact 71 to excite an electromagnetic clutch 72 which locks, when excited,

the center arm of the differential 73, to then cause the shaft 26 to turn, through bevel gears 74 and shaft 74', a reversing contactor 75 which is normally spring centralized by spring arm 76. Said contactor 75 controls the motor 49 on the azimuth gyro on the straight ground track target approach, at which time the controller 42 is centralized and therefore inoperative. The automatic pilot therefore is then under direct control of the bomb sight, any movement of the sight off the target being followed by the operator turning knob 27 to bring it back on the target, thereby also turning the controller 75 to turn the ship back on the correct course. The controller 75 is shown as operating the motor 49 through separate relays 77 and 78, which are shown as operating the motor independently of the potentiometer 46 and without automatic banking, although obviously such may be provided if desired.

In order to excite the magnetic clutch 72, not only must the roller 69 be in notch 70, but also the gyro 4 must be uncaged, or in other words, in fully operative condition. To this end, switch 85 on the gyro cage 5 and switch 71 are in series with magnet 72. During the initial target approach the gyro 4 is caged and therefore the clutch 72 is open, and turning of the sight through knob 27 has no effect on the steering of the craft. In the next stage, the magnetic clutch 72 remains inoperative as long as the craft is turning due to the rotation of the knob 36, but when the straight ground track is reached, the clutch 72 closes and the control of the automatic pilot is transferred from the controller 42 to the controller 75.

The pitch control of the airplane is operated from the controller 80 on the gyro vertical 61, but is not shown herein.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

Having described our invention, what we claim and desire to secure by Letters Patent is:

1. In an automatic pilot for aircraft, adjustable means for causing through the automatic pilot a continuous turn of the craft at a rate dependent on the adjustment, and means operable from the adjustment of said first means for banking the craft through the automatic pilot at an angle proportional to the rate of turn.

2. An automatic pilot for aircraft as claimed in claim 1, in which delayed action means are interposed between said other two means to retard the banking means until after the turn has started.

3. In an automatic pilot for aircraft, having direction maintaining and attitude maintaining devices and pick-offs at each for governing the rudder and ailerons of the craft, a variable speed device for rotating the direction device pick-off to cause turning of the craft at a rate proportional to the device's speed, adjustable means for governing the speed and direction of said variable speed device, and a connection from said last named means to said attitude device pick-off to bank the craft at an angle proportional to the direction and rate of turn.

4. An automatic pilot for aircraft as claimed in claim 3, having delayed action means in the

aforesaid connection to retard the aileron deflection until the rudder has been deflected.

5. In an automatic pilot director for bomb sights, the combination with a bomb sight having means for setting up any desired rate of turn of the sight with respect to a direction maintaining means to keep it on the target, a variable speed device for causing turning of the craft through the automatic pilot at a rate governed by the speed of said device, and a connection between said means and device to cause simultaneous operation of each at different but proportionate rates.

6. In an automatic pilot director for bomb sights, the combination with a bomb sight having means for setting up any desired rate of turn of the sight with respect to a direction maintaining means to keep it on the target, a variable speed device for causing turning of the craft through the automatic pilot at a rate governed by the speed of said device, a connection between said means and device to cause simultaneous operation of each at different but proportionate rates, means for varying the angle of bank through the automatic pilot, and a connection between said first named means, said device and said last named means for banking the craft automatically at an angle proportional to the rate of turn.

7. In a bomb sight for aircraft, the combination with an optical system rotatable in azimuth and an automatic pilot director, a common means for rotating said system to maintain the sight on the target and for simultaneous operation of said automatic pilot to cause turning of the craft until the straight ground track is reached, a directional gyroscope for normally stabilizing said optical system in azimuth, and means for transferring the control of said automatic pilot to said gyroscope upon the straight ground track being reached.

8. In an automatic pilot director for bomb sights as claimed in claim 5, automatic means for banking the craft through the automatic pilot at an angle proportional to the rate of turn of the craft set up.

9. In an automatic pilot for aircraft, manually adjustable means, variable speed motive means controlled thereby for causing the automatic pilot to effect the turning of the craft at a desired rate that is variable at will dependent upon the setting of said manual means, and means also actuated by said manual means for causing the automatic pilot to effect the banking of the craft during the turn at a banking angle proportionate to the setting of said manual means.

10. In an automatic pilot director for bombers, the combination with an automatic pilot and a bomb sight rotatable in azimuth on the bomber, a variable speed device for rotating said sight to maintain the same on the target, manual means for adjusting said device, and a second variable speed device for causing turning of the craft through said automatic pilot, said second device being also controlled from said manual means to cause turning of the craft at a speed proportional to but greater than turning of the sight.

11. In a bomb sight for aircraft, the combination with an optical system rotatable in azimuth and an automatic pilot, directional gyroscopic means for normally stabilizing said optical system in azimuth, a variable speed device having a null position, manually settable means

for adjusting said device at a speed proportional to the setting of said means, a servo means for causing turning of the craft, a controller turned by said manual means for causing said servo means to turn the craft at a rate proportional to but greater than the rate of turn of said optical means, alternative manual means for directly turning the sight in azimuth, an alternative controller operated from said last-mentioned means for controlling said servo means to steer the craft, and means operative upon adjustment of said variable speed device to a null position to transfer the control of said servo motor from said first controller to said alternative controller.

12. In a bomb sight for aircraft, the combination with an optical system rotatable in azimuth and an automatic pilot, a directional gyroscope for normally stabilizing said optical system in azimuth, a common manual means for causing rotation of said system for setting up a desired rate of turn of the sight to maintain the sight on the target and for simultaneously causing said automatic pilot to cause turning of the craft at a proportional rate until a straight ground track is reached, a separate manual means for turning said optical system through any desired angle, and means for transferring the control of said automatic pilot from said common means to said separate means upon the straight ground track being reached.

13. In a bomb sight for aircraft, the combination with an optical system rotatable in azimuth, a directional gyroscope for normally stabilizing said optical system in azimuth, a manually settable variable speed device having a null position for rotating said sight at a speed proportional to the setting of said device, servo-motive means for causing turning of the craft in azimuth, a controller for adjusting the speed of said servo means, said controller being positioned according to the setting of said variable speed device to cause turning of the craft at a rate proportional to but greater than the rate of turn of said optical means, an alternative manually adjustable means for directly turning the sight in azimuth, an alternative controller for controlling said servo means, and means operative upon adjustment of said variable speed device to a null position to transfer the control of said servo means from said first controller to said alternative controller.

14. In a bomb sight for aircraft, the combination with an optical system rotatable in azimuth, a directional gyroscope for maintaining a fixed azimuthal space reference, a first control shaft actuating said sight and under the control of said gyroscope for maintaining said sight fixed in space irrespective of turning of the craft, an additional control shaft free from the control of said gyroscope for rotating said sight with respect to said gyroscope, a variable speed device having a null position for causing rotation of said additional shaft at an adjustable rate, servo means for causing turning of said aircraft in azimuth at an adjustable rate, common manual means for adjusting the speed of said variable speed device and said servo means, alternative means for directly displacing said additional control shaft, and means operative upon adjustment of said common manual means to a null position for actuating said servo means in response to the position of said sight.

15. In an automatic pilot director for bombing aircraft, the combination with an automatic

pilot for the craft and a bomb sight rotatable in azimuth on the craft, a directional gyroscope, a variable speed device for rotating said sight through said directional gyroscope, a variable speed device for causing turning of the craft through said automatic pilot, and manual means for adjusting the speed of each of said devices.

16. In a bomb sight for aircraft, the combination with an optical system rotatable in azimuth and an automatic pilot, common means for rotating said system to maintain the sight on the target and for simultaneous operation of said automatic pilot to cause turning of the craft until the straight ground track is reached, separate means for adjusting said optical system in azimuth, and means for transferring the control of said automatic pilot from said common means to said separate means upon the straight ground track being reached.

17. In a bomb sight for aircraft, in combination with an optical system rotatable on said aircraft and an automatic pilot for controlling the turning of the aircraft, a displacement control member for turning the bomb sight through any desired angle, means operated by said displacement control member for controlling the automatic pilot to turn the aircraft through a corresponding angle, a rate control member displaceable from a neutral position, variable speed means operated by displacement of said rate member from its neutral position for turning the bomb sight at a rate dependent upon said displacement, means controlled by said rate member for operating the automatic pilot to turn the aircraft at a rate greater than the turning rate of the bomb sight, and means operated by

the displacement of said rate control member from its neutral position for rendering said first-named means inoperative.

18. Apparatus for directing a dirigible craft toward an object comprising an objective-aligning instrument on said craft, means for turning said instrument relative to a directional reference at a rate to maintain alignment with an object, and means responsive to operation of said first turning means for turning said craft relative to said reference direction at a proportional rate greater than the turning rate of said instrument.

19. An automatic pilot for aircraft as claimed in claim 3, wherein means are employed causing the rudder to be operated in advance of the ailerons, thereby initiating a turn in the desired direction.

20. In an automatic pilot for aircraft, a single positionable controller for securing properly banked turns, means actuated therefrom for first displacing the rudder to initiate a turn in the desired direction, including a variable speed device governed by the position of said controller for regulating the rate of turn, and other means operated from said controller for secondly displacing the ailerons through the automatic pilot until the craft is banked at the angle proportional to the position of the controller, thereby maintaining a banked turn, whereby the rudder displacement is reduced as the rate of turn approaches that set by the controller on the variable speed device.

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