

March 1, 1949.

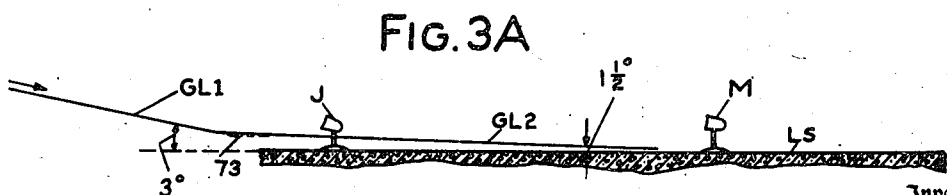
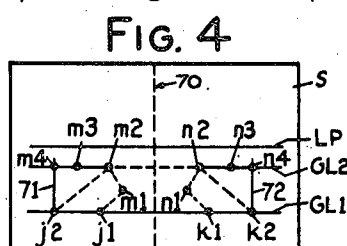
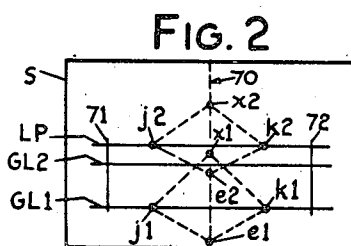
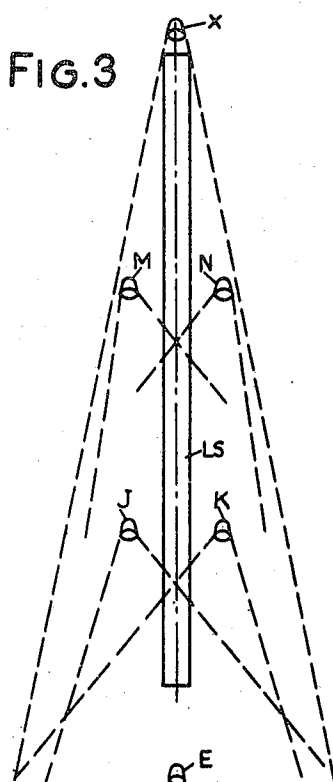
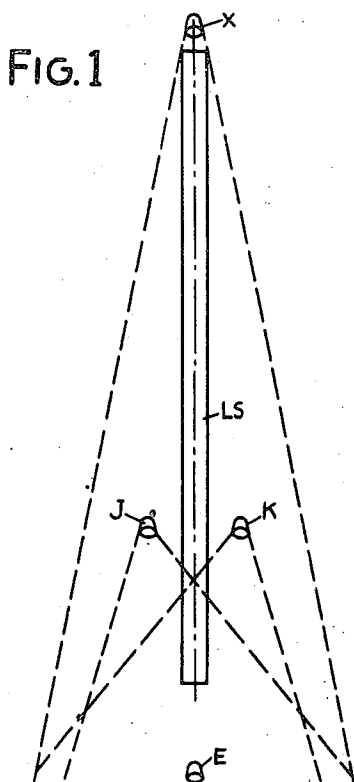
S. N. WIGHT ET AL

2,463,095

AIRWAY TRAFFIC CONTROL SYSTEM

Filed Aug. 9, 1944

3 Sheets-Sheet 1



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March 1, 1949.

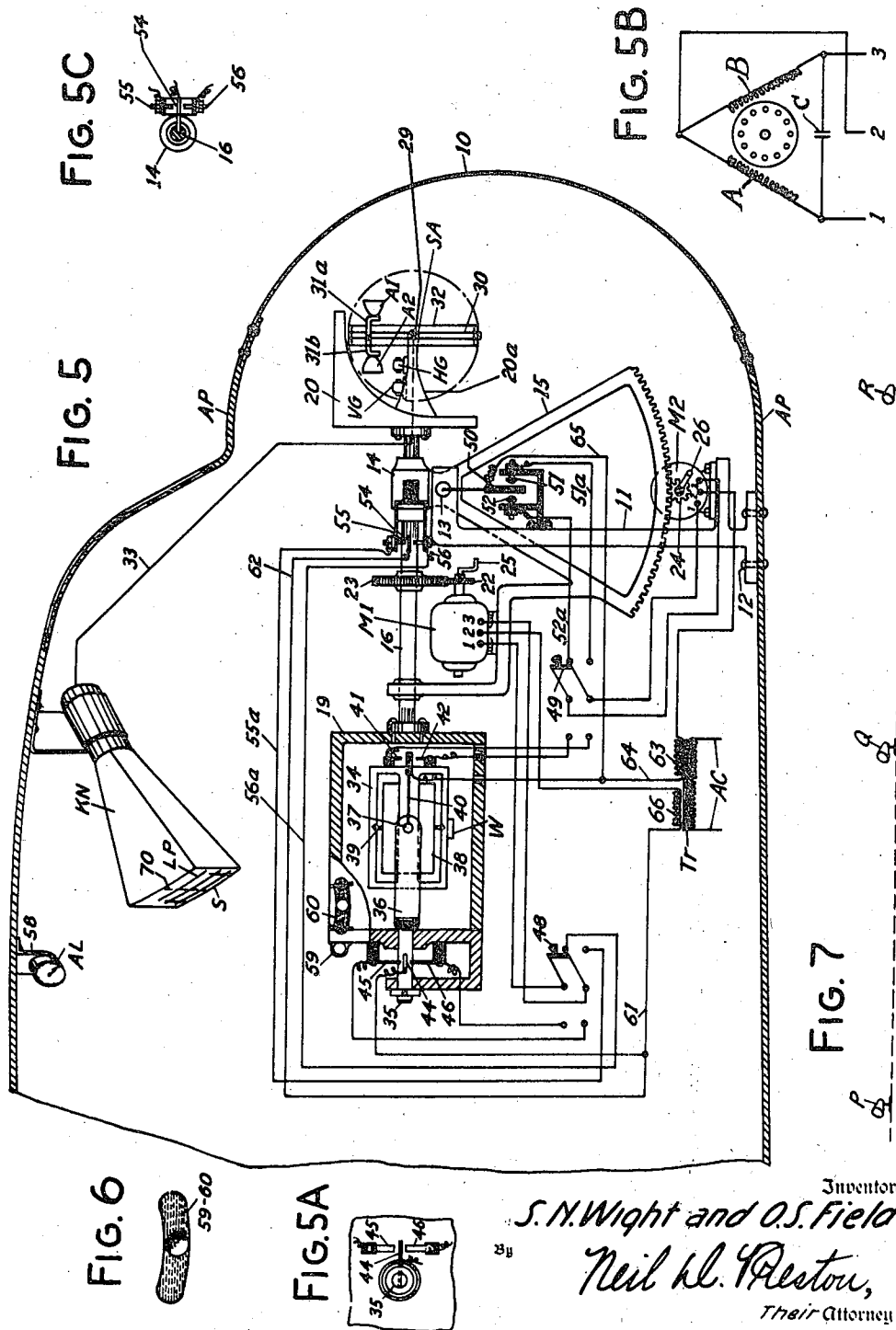
S. N. WIGHT ET AL

2,463,095

AIRWAY TRAFFIC CONTROL SYSTEM

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3 Sheets-Sheet 2



March 1, 1949.

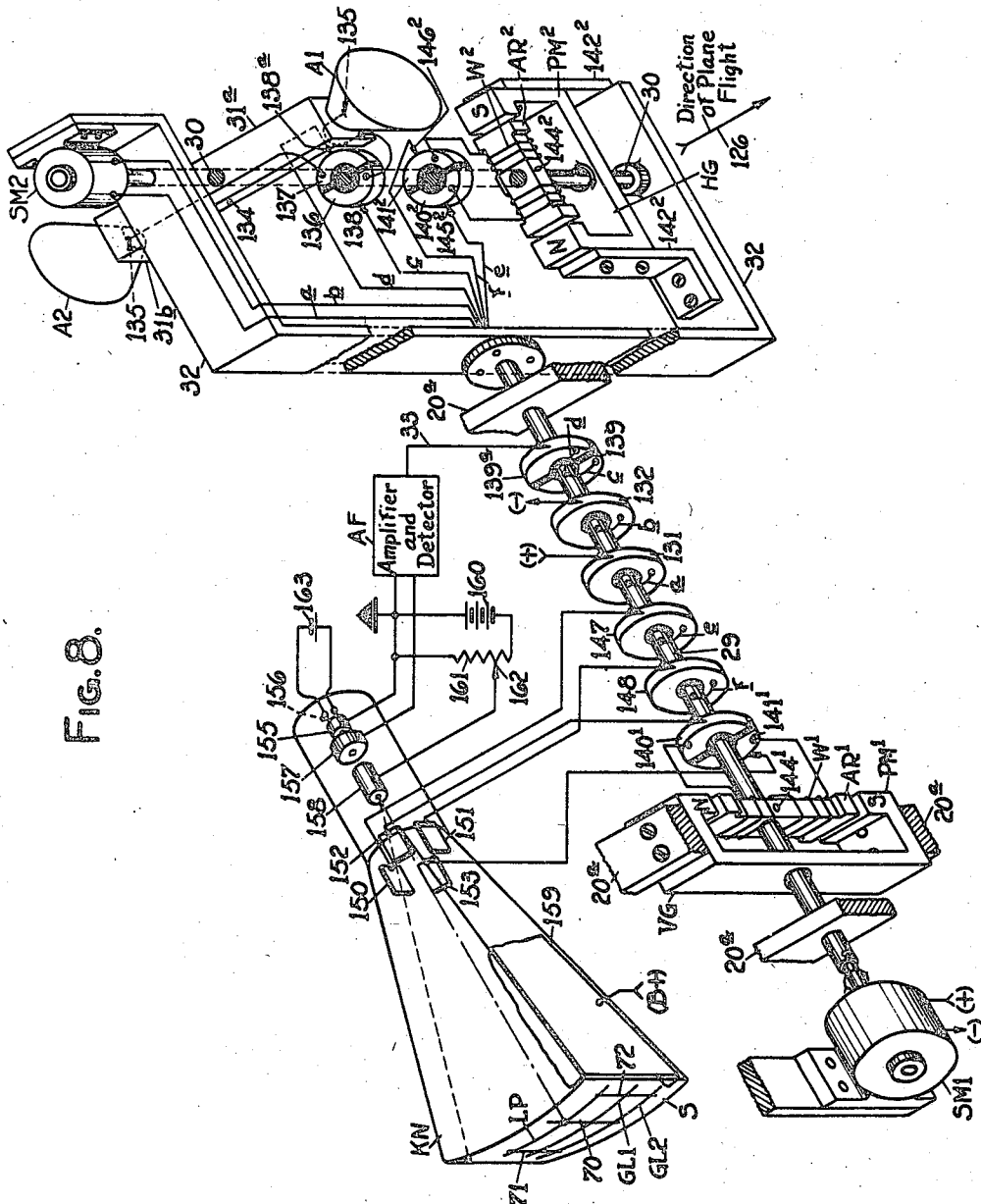
S. N. WIGHT ET AL

2,463,095

AIRWAY TRAFFIC CONTROL SYSTEM

Filed Aug. 9, 1944

3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,463,095

AIRWAY TRAFFIC CONTROL SYSTEM

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Application August 9, 1944, Serial No. 548,660

10 Claims. (Cl. 343—108)

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The present invention relates to combined blind flying course indicating means and blind landing apparatus and contemplates employing radio or other wave energy responsive scanning apparatus for scanning radio radiators in the field of view in advance of an airplane to produce a visible replica on a screen reproducing pictorially such field of view in advance of the airplane. The present invention contemplates employment of apparatus such as disclosed in the prior application of Field, Wight and Saint, Ser. No. 517,814, filed January 11, 1944, and in the application of Dicke, Ser. No. 532,181, filed April 25, 1944, now Patent No. 2,439,846, dated April 20, 1948.

Although under most weather conditions it is unnecessary to invoke the use of special apparatus enabling a pilot to operate his airplane wholly by indications within the cab, such apparatus should be available in view of the sudden change in weather conditions that may take place, or in view of the fact that high speed airplanes may fly from fair weather into cloudy and fog prevailing localities. One of the short-comings of blind flying apparatus such as is now employed is due to the inaccuracy of the information available from such blind flying instrumentalities and one of the objects of the present invention is to make available more accurate information to the pilot as to the approach of his airplane to the landing strip irrespective of visibility and weather conditions.

Another object of the present invention resides in the provision of apparatus which will lend itself to both blind course flying and blind landing operation even though not all of the apparatus involved is necessarily used to perform each of these functions separately.

Another object of the present invention resides in the provision of suitable radio radiators or other wave energy emitting radiators for outlining either the course of travel or glide paths, of angles of declination, which the pilot may follow, in cruising and to make his landing, very precisely.

Another object of the present invention resides in the provision of both vertical and horizontal lines on the screen of a cathode ray tube or kinescope with respect to which the replicas of the various wave or radio radiators may be aligned or arranged to obtain very precise information of the airplane's location either during level flight or during deviations from such flight as may be required in the maneuvering of the airplane when making a landing.

In accordance with another object of the present invention it is proposed in at least one form of the invention to employ suitable stabilizing means so that the replica on the screen of the cathode ray tube defines the location of the airplane with respect to ground located radiators rather than its particular oriented position in space.

In another form of the invention the use of such stabilizing apparatus may be dispensed with and in this case the accuracy of flight along definite lines, as determined by the relationship of the replicas of certain ground located wave or radio radiators with respect to lines on the screen, will be lessened because the direction of heading of the airplane rather than the direction of its flight is available by interpretation of the replicas on the screen with respect to the lines thereon.

Another object of the present invention resides in employment of motive power means to determine the position assumed by suitable scanning apparatus with respect to the airplane or with respect to suitable gyroscopically controlled control means and in accordance with this object of the invention it is proposed to provide manual control whereby the pilot may determine whether the motive power means shall position the scanning apparatus so as to have a definite relationship with the airplane itself or a definite relationship with the axis of rotation of the gyroscope.

Other objects, purposes and characteristic features of the present invention will in part be pointed out in the specification hereinafter and will in part be obvious from the accompanying drawings, in which:

Fig. 1 shows radio radiators arranged with respect to a landing strip in an airfield which is suitable when the invention is practiced by either the employment of the stabilizing apparatus or by its omission under conditions of descending on a glide path having only one angle of declination;

Fig. 2 illustrates the screen of the cathode ray tube employed with replicas of the radio radiators illustrated in Figs. 1 or 3 in relationship to lines appearing on the screen to give the pilot precise information as to his landing operation insofar as the horizontal lines are concerned and to indicate the course insofar as one of the vertical lines is concerned.

Fig. 3 is similar to Fig. 1 but illustrates a modified form of airfield employing two additional radio radiators which enable a pilot to descend

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at a steep angle of declination followed by descent at a shallow angle of declination, or he may descend at either one of these angles of declination;

Fig. 3A illustrates a side view of the airfield shown in Fig. 3 with a compound glide path starting out at one angle of declination and finishing at another and smaller angle of declination;

Fig. 4 illustrates the screen together with replicas of radio radiators thereon as a result of making a two slope landing when using the gyroscopic stabilizer;

Figs. 5, 5A and 5C illustrate the airplane carried apparatus of the present invention certain portions of which may be omitted in practicing the invention in different manners;

Fig. 5B illustrates conventionally the windings and rotor of motors M1 and M2 of Fig. 5;

Fig. 6 illustrates a ball inclinometer on an enlarged scale two such inclinometers also being illustrated in Fig. 5; and

Fig. 7 illustrates conventionally an air route equipped to cooperate with the airplane carried apparatus shown in Fig. 5; and

Fig. 8 illustrates the scanning antennas and the cathode ray tube shown in Fig. 5 more in detail.

STRUCTURE

Ground located structure.—Two forms of ground located structures have been shown in Figs. 1 and 3 insofar as blind landing is concerned and the ground located structure for an air route consists of a plurality of radio or wave energy radiators located along an air route as more clearly disclosed in the prior application of Field et al., Ser. No. 517,814, above referred to and as conventionally illustrated in Fig. 7 of the drawings which shows the three radiators, P, Q, and R of an eastbound route.

Referring to Fig. 1 wherein there has been illustrated a landing strip LS to the rear of the entrance end of which is located an entrance radiator E and at the exit end of which is located an exit radiator X for radiating suitable wave energy to be detected by the apparatus on the airplane. These radiators aid the pilot in aligning his aircraft to the landing strip LS. A pair of landing radiators J and K is provided, one radiator being located on each side of the landing strip LS and a short distance beyond the entrance end of this landing strip. These radio radiators E, X, J and K are preferably constructed directional so as to emit their radiating energy in a spreading beam substantially as illustrated by dotted lines in Fig. 1.

The airfield landing strip illustrated in Figs. 3 and 3A of the drawings is substantially identical to the one illustrated in Fig. 1 and differs therefrom by having an additional pair of radio radiators M and N similarly located on opposite sides of the landing strip LS but at a point slightly farther from the entrance end than are radiators J and K but still far enough from the exit end to allow an airplane to be brought to a full stop before reaching the end of the landing strip.

Fig. 3A illustrates in side elevation a compound glide path the first portion of which is at a steep descending slope conveniently designated GL1 and which may have a 3° slope whereas the second portion of the glide path is at a much shallower slope of say 1½° and conveniently designated GL2. Under the heading of "Operation" it will be pointed out how the pilot is informed as to his progress of his airplane down this com-

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pound glide path illustrated in Fig. 3A of the drawings.

Airplane carried structure.—In Fig. 5 of the drawings has been illustrated conventionally the airplane carried apparatus of one embodiment of the invention which may be used in practicing the invention in several ways.

Referring to Fig. 5 a portion of an airplane AP has been illustrated the lower portion of the nose of which is closed by a suitable preferably transparent cover 10 which allows the free passage of radio or other wave energy which is to be detected by the scanning device SA which will for convenience be called a scanning antenna. To the body of the airplane AP is secured a bracket 11, as by rivets 12, in which is pivotally supported as by a shaft 13 pinned or otherwise secured to a unitary bearing block 14 and gear sector 15. This bearing block 14 has a bearing opening provided therein substantially at right angles to the shaft 13, in which opening is pivotally supported a second shaft 16 which shaft has fastened thereto, at the forward end thereof, the scanning antenna support 20 and at the rear end thereof a gyroscope housing 19. In other words, the gyroscope housing 19 and the scanning antenna support 20 are rigidly supported by the same normally stationary shaft 16 as a result of which if the shaft 16 is adjusted to a different position in bearing block 14 both the antenna supporting bracket 20 and the gyroscope housing 19 will be rotated together and if this shaft 16 is swung about the axis of shaft 13 both of these elements 19 and 20 will be swung about the axis of shaft 13 in the same manner.

In order to operate these two structures 19 and 20 into any particular oriented position the shaft 16 may be rotated through the medium of the motor M1, pinion 22 and gear 23, whereas this shaft 16 may be swung about the axis of pin 13 through the medium of gear sector 15 operated by the motor M2 through the medium of its pinion 24. These motors M1 and M2 are preferably alternating current motors of the split phase condenser type and illustrated conventionally in Fig. 5B of the drawings. From Fig. 5B of the drawings it is readily seen that when alternating current is connected across terminals 1 and 2 of the motor, the winding A will carry lagging current by reason of the induction of the winding A, whereas the winding B will be supplied with leading current due to the capacitance of condenser C, and similarly if alternating current energy is connected across terminals 2 and 3 the relationships of leading and lagging currents will be reversed and the motor will operate in the opposite direction. The pinion 22 is provided with a crank 25 and the pinion 24 is provided with a crank 26. These cranks 25 and 26 are employed when the invention is practiced by the omission of the gyroscope hereinafter described, in which event these pinions 22 and 24 may be rotated by hand if desired.

The supporting bracket 20 supports a scanning antenna such as disclosed in either of the two applications referred to above and as more fully shown in Fig. 8 of the drawings. The conventional scanning antenna SA shown supported by the support 20 of the type disclosed in the prior application of Field et al., Ser. No. 517,814, but the invention is not limited to the use of this specific form of scanning antenna. As illustrated this scanning antenna SA includes outwardly extending arms 31a and 31b extending from a shaft 30 pivoted in a fork 32 terminating in a shaft 29

pivoted in the extending hub 20a. These arms 31a and 31b at their ends support parabolic directional antennas A1 and A2, respectively. In practice the shaft 30 rotates at a speed many times the speed of rotation of the shaft 29. Also supported on the hub 20a of bracket 20 is a vertical scanning sweep late voltage generator VG and a horizontal scanning sweep plate voltage generator HG. These generators VG and HG are respectively driven in synchronism with the shafts 29 and 30. These generators VG and HG supply voltages to the sweep plates of the cathode ray tube KN.

In the particular embodiment of the invention illustrated in Fig. 8, although other forms of scanning apparatus may, of course, be used, the scanning apparatus includes a main shaft 29 which is positioned horizontally with respect to the airplane and at right angles to the direction of movement of such airplane. In other words, the scanning apparatus illustrated is so oriented with respect to the direction of airplane flight as indicated by its oriented relation to the arrow 126 (see Fig. 8) that high speed horizontal and low speed vertical scanning is accomplished.

The shaft 29 is supported by fixed bearings 20a. One end of this shaft 29 is driven by a motor SM1 and the other end of this shaft is bifurcated to form a fork 32 which fork constitutes rotating bearings for a second shaft 30 having its axis substantially at right angles to the shaft 29 and supporting two directional radio receiving antennas A1 and A2. This shaft 30 is driven by another motor SM2 which receives its energy through wires a and b and slip rings 131 and 132 on shaft 29. To the shaft 30 is pinned a U-shaped member 31a—31b as by a pin 134 which supports the directional radio antennas A1 and A2 in such a manner that the axis of these radio antennas A1 and A2 are substantially at right angles to the shaft 30 and displaced about the shaft at an angle of 180 degrees. These antennas A1 and A2 comprise parabolic metallic reflectors which have an antenna element 135 located in the focus thereof. These antenna elements 135 are connected to two segments 136 and 137 of a commutator. This commutator is engaged by brushes 138 or 138a in such manner that only the forwardly directed antenna A1 or A2 will be electrically connected to the proper contact brush 138 or 138a. These contact brushes 138 and 138a are in turn connected to the input side of the amplifier-detector unit AF through the medium of wires c and d and commutator 139—139a. It should be observed that if we assume the shaft 30 to be stationary in the fork 32 that the connections to the antennas A1 and A2 must be commutated with respect to rotation of shaft 29 and it is for this reason that commutator 139—139a is provided.

From this construction it is readily seen that only the focused antenna disposed to the front of the airplane will be electrically connected to the amplifier-detector, and it is further readily seen that upon high speed rotation of the shaft 30 the focal lines of the focused antennas A1 and A2 will describe substantially horizontal lines one above another the spacing between these lines depending upon the ratio of speeds of rotation of the shafts 29 and 30. In other words, if the shaft 30 rotates 16 times while the shaft 29 rotates a half-revolution, 32 horizontal lines will be scanned over the field for each frame of observation or each half-revolution of the shaft 29. It will also readily be seen that when the shaft 29 has been rotated 90° from the position shown,

namely, has rotated to a position where the shaft 30 is horizontal the directional antenna A1 will come out of view of the field of vision ahead of the airplane and the directional antenna A2 will enter such a field so that another 32 lines may be scanned by the antenna A2. This makes a total of 64 lines of scanning per revolution of the shaft 29. Also, as the antenna A1 passes out of the field of vision the brushes 138 and 138a pole change on segments 136 and 137. In this connection it should be understood that if it is desired to scan only below the horizon and if it is desired to only scan a horizontal distance of 45° to the right of the course of the plane and 45° to the left of the course of the plane, namely, if it is desired to scan an area 90° by 90° two more directional antennas placed at right angles to the two illustrated would be employed in which event four pole generators instead of two pole generators, to described hereinafter, would be required to be employed. In this case the commutator 136—137 would be required to be a four segment commutator.

The shaft 29 is provided with a two-pole generator VG and the shaft 30 is provided with a two-pole generator HG. Since these generators are identical, like parts will be designated by like reference characters having distinctive exponents and only one of these generators will be described in detail. Referring to the generator HG associated with the high speed shaft 30 this generator comprises a permanent magnet field magnet PM² supported on one leg of the fork 32 by brackets 142², between the north pole N and the south pole S of which is supported a soft iron laminated armature AR² secured to the shaft 30 as by a pin 144². On this armature AR² is provided a winding W² which has one end electrically connected to the commutator segment 140² and has its other end electrically connected to the commutator segment 141². Stationary brushes 145² and 146² displaced 180° about the shaft 30 engage the commutator 140²—141². These brushes are so oriented with respect to the field magnet PM² that commutation from one segment to another, or pole changing of the wires e and f leading from the armature winding W² and connected to slip rings 147 and 148 takes place when there is substantially zero flux in the armature AR². In other words, these generators HG and VG do not deliver direct current as is usually the case of generators of similar construction because they commutate the current at the maximum voltage value rather than at zero voltage value as is customarily done. The voltage delivered at the brushes is therefore substantially of saw-tooth form.

Since the commutator 136—137 and the commutator 140²—141² perform their commutating function at the same time it will be seen that the voltage delivered by the generator HG is of maximum plus value when a new focused antenna enters the field and that this voltage is of maximum minus value when such focused antenna leaves the field which is being scanned. The voltages delivered by these generators HG and VG are used to deflect the electron beam of the cathode-ray tube KN all in a manner as hereinafter more fully described.

The cathode-ray tube KN, commercially known as a kinescope and illustrated in the upper left part of Fig. 5 and in Fig. 8 of the drawings is of well known construction and is employed to visually indicate on a fluorescent screen the pictorial location of one or more of the ground

located radio transmitting antennas. Cathode-ray tubes of this construction are well known in the art for which reason the kinescope KN has been illustrated rather conventionally. This kinescope comprises a fluorescent screen S, also shown in Figs. 2 and 4, over which an electron beam is adapted to sweep in a manner to be described hereinafter. This electron beam has been shown at two different positions by a dotted line and by a dot and dash line. The electron beam is located in the position as shown by the dotted line when the sweep voltage delivered by the generator HG is of maximum plus value and the sweep voltage delivered by the generator VG is also of maximum plus value. Under the condition of zero sweep voltages the electron beam of Fig. 8 will assume a neutral position as shown by the dot and dash line. This swing of the electron beam is accomplished by horizontally located sweep plates 150 and 151 connected to the high speed generator HG and by the vertically located sweep plates 152 and 153 connected to the brushes of the low speed generator VG. As is well known by those skilled in the art the electrons are emitted by the heater or cathode 155 which is heated by a filament 156 as through the medium of a battery 163. The electrons emitted by the cathode 155 may be controlled by a grid or controlling element 157 and may be brought to a sharp focus by the focusing or anode structure 158. A second anode 159 is provided on the inner surface of the tapered portion of the cathode-ray tube to accelerate the electrons after the grid or control element 157 has once allowed these electrons to be emitted. As illustrated the focusing structure or first anode 158 has a potential applied thereto through the medium of the battery 160 and a potentiometer 161, so that by adjusting the slide contact 162 of this potentiometer the electron beam may be focused so as to concentrate the electrons into as narrow a beam as desired. It should be understood that the cathode 155, the grid 157 and the anode 159 constitute the so-called electron gun whereas the cathode 158 is the optical system for focusing the electron beam into a narrow stream. The screen S may also be called the target.

When a focused receiver A1 or A2 receives a momentary radio or other wave energy signal, this reception being momentary on account of the high speed rotation of these antennae A1 and A2 in two different planes, current flows over the wire 33 and through amplifier and detector AF to the grid of the cathode-ray tube KN.

Within the gyroscope housing 19 is pivotally supported a shaft 35 which terminates into a U-shaped fork 36, only one leg of which is visible in Fig. 5 of the drawings. This fork 36 is provided with bearing pins 37 extending inwardly from the two legs of the fork and comprise pivots for pivotally supporting the gyroscope frame 34. Within this gyroscope frame 34 is pivotally supported as by a shaft 39 a fly wheel or gyro 38 of a gyro artificial horizon indicator such as, for instance, disclosed on pages 73 and 85 of Civil Pilot Training Manual, furnished by the U. S. Department of Commerce, and dated September, 1941, or as disclosed in the A. I. E. E. Technical Paper 44-70, dated December, 1943, disclosing an electrically operated gyro horizon indicator.

This fly wheel or gyro 38 may be either pneumatically driven as are the gyros disclosed in the above referred to Pilot Training Manual or it may be electrically driven by a suitable high fre-

quency alternating current motor as is true of the apparatus described in the above referred to A. I. E. E. Technical Paper, and whether it is pneumatically or electrically driven the supply of power thereto may be manually cut on or off as desired, this manual control having for convenience been omitted from the drawings.

To one leg of the fork 36 is secured, but insulated therefrom, a movable spring contact finger 40 which is arranged between two relatively stationary contacts 41 and 42 supported on the gyroscope frame 34. It is thus seen that if the fork 36 moves from its neutral position in one direction or the other about the pivot 37, the gyro frame 34 being at times held stubbornly in its oriented position by the gyro 38, the contact 40 will engage one or the other of contact 41 or contact 42 and if the fork 36 is moved in the opposite direction about the pivot 37 the opposite contact 41 or 42 is engaged by contact 40. Similarly, a spring contact arm 44 is supported by the shaft 35 and extends radially therefrom and between relatively fixed contacts 45 and 46 supported by, but insulated from, housing 19. Therefore, spring contact 44 may engage one or the other of contacts 45 or 46 depending on the temporary rotation of gyro housing 19 about shaft 35. From this structure it is readily seen that if the shaft 35 is turned in one direction from its neutral position in housing 19 it will engage the contact 45 and if it is turned in another direction from such neutral position it will engage the contact 46. These contacts 40, 41, 42, 44, 45 and 46 are used to control the motors M1 and M2 when the antenna supporting bracket 20 is to be positioned to conform with the position then assumed by the axis of rotation of the gyro 38.

Two additional sets of contacts 50, 51, 52, 54, 55 and 56 are provided to similarly control these motors M1 and M2 when the antenna supporting block 20 is to be positioned and oriented with respect to the body of the airplane itself. In other words, the contacts 50, 51 and 52 perform functions corresponding to the functions performed by contacts 40, 41 and 42 and the contacts 54, 55 and 56 perform functions comparable with the functions performed by the contacts 44, 45 and 46. These functions will be more specifically pointed out in the operation of the system hereinafter.

An end view of the contacts 44, 45 and 46 and the shaft 35 on which the contact 44 is supported has been illustrated in Fig. 5A of the drawings. Similarly, the contacts 54, 55 and 56 and the manner in which contact 54 is secured to shaft 16 is indicated in Fig. 5C of the drawings. As readily seen from the drawings, the motor M1 is controlled by either the contacts 44, 45 and 46 or the contacts 54, 55 and 56 depending upon the position assumed by the two pole double-throw switch 48, whereas the motor M2 is controlled by either the contacts 40, 41, 42 or by the contacts 50, 51, 52 depending upon the active position assumed by the double-pole double-throw switch 49.

The alternating current required for operating these motors M1 and M2 is preferably derived from a suitable airplane carried alternating current generator which generates the alternating current AC supplied to the primary winding of the transformer Tr and this alternating current may also be used for spinning directional antennae A1 and A2 about two axes at right angles to each other at comparatively high speeds and

which may also be used for propelling the gyro 38 at very high speed.

Modern airplanes are provided with suitable indispensable instruments which are needed to aid the pilot in maneuvering his airplane. Only those instruments that are essential in practicing the present invention have been illustrated conventionally in the drawings and they include an altimeter AL for convenience shown supported from the airplane AP through the medium of a bracket 58 and two ball-type inclinometers 59 and 60 preferably supported in a manner to move relatively to the airplane in exactly the same way as the antenna supporting block 20 is positioned relative to the airplane. As shown the inclinometer 59 is supported on the rear face of the gyroscope casing 19 to indicate the rocked position of support 20 whereas the inclinometer 60 is supported on a side wall of this casing 19 to indicate the extent of nosing of this support. These inclinometers 59 and 60 each comprise a slightly bent round tube of glass the ends of which are sealed and in which there is contained a metal ball preferably of a diameter slightly smaller than the inside diameter of the glass tube, this tube then being filled with a suitable transparent liquid such as clear oil. These inclinometers are merely dampened levels and indicate to what extent the support therefor has been moved from a perfectly level position in that if one end of this tube is higher than the other the ball will roll toward the lower end to an extent depending on the tilted position assumed by the tube, the oil being employed to dampen the movement of the ball so that it will not move about unnecessarily. It is thus seen that the inclinometer 59 will indicate the extent of banking of the scanning antenna bracket 20 whereas the inclinometer 60 will indicate the extent of nosing up or down of this scanning antenna supporting bracket 20 and the scanning antenna mounted thereon.

OPERATION

The operation of the system is preferably divided into two phases the first phase of which may be limited to the manner in which the gyroscopic stabilizing apparatus is cut into service and how it functions after it has been cut into service and the second phase of which may be limited to the manner in which a pilot employs the apparatus of the present invention either with or without the employment of the gyro-stabilizer in flying over a traffic route and also in making a blind landing.

Operation gyro-stabilizer

During flying over a route defined by successive ground located radio radiators irrespective of whether there is good or poor visibility and irrespective of whether radio energy or some other fog penetrating wave energy is used the apparatus of the present invention will be useful in more accurately flying over such route. This is especially true because the route over which the pilot proposes to fly may not have sufficient markers thereon visible to the eye to adequately aid the pilot during clear weather flying.

In any event, and in accordance with the present invention, when the pilot flies over a traffic route it will be necessary for him to hold his scanning antenna so as to assume a predetermined fixed relationship with his airplane. And this relationship is preferably such that the scanning antenna supporting bracket 20 points level

and directly ahead over the route when the airplane is flying level. In order to establish such relationship between the antenna supporting bracket 20 and the airplane AP the two selecting switches 48 and 49 are operated to their right-hand position. The closure of the switch 48 to its right-hand position will cause current to flow from the left-hand terminal of the secondary winding 66 of the transformer Tr over wires 61 and 62 to contact 54 supported by but insulated from the shaft 16. If this shaft 16 is now in any other than its neutral position with respect to the bearing block 14 current will flow from contact 54 to either contact 55 or 56 and their respective wires 55a or 56a to in turn cause operation of the motor M1 in a direction to cause the contact 54 to be returned to its neutral position, in which position the antenna supporting bracket 20 assumes an erect position with respect to the airplane. In the same manner, if the double-throw switch 49 is closed in its right-hand position current may flow from the left-hand terminal of the secondary winding 63 of the transformer Tr over wires 64 and 65 to contact 59 which moves with segment 15. If this contact 59 does not assume its middle position current will be applied to one or the other terminal 1 or 2 of the motor M2 through contact 51 and wire 51a or through contact 52 and wire 52a, to thereby cause this motor M2 to operate the gear sector 15 until the contact 59 again assumes its middle open position. With the contact 59 assuming its middle position the bearing block 14 and the shaft 16 pivoted therein will assume a position parallel to the plane of flight of the airplane, and with the contact 59 also assuming its middle position the shaft 16 assumes a non-banking position during level flying.

Let us now assume that the pilot has completed his trip over the air route in a manner as clearly described in the Field, Wight and Saint application and is about to make a blind landing. In practicing that form of the invention where the gyroscopic stabilizer is used for making blind landings the pilot will cut his gyroscopic stabilizing apparatus into operation. To do so the operator will first operate suitable manual means such as an air valve or a switch (not shown) for supplying energy to the gyro 38 to cause it to accelerate until it reaches its full speed of about 20,000 R. P. M. While the gyro 38 is being accelerated, which may take several minutes, the pilot will make a real effort to fly at constant altitude by observing the indication from his altimeter AL, and with a minimum of nosing either up or down or banking. This even flying at constant altitude is not necessarily accompanied by the airplane body assuming a level position due to the extent and distribution of airplane loading. The gyroscope frame 34 is preferably weighted as by a weight W so that the axis of rotation of the gyro 38 will be perfectly perpendicular when this gyro 38 comes up to its full operating speed. The operator will have in the meantime operated both of his selecting switches 48 and 49 to the left-hand position so that if one or the other of the contacts 40 or 44 or both, controlled by the gyro frame 34 and shaft 35, respectively, will have engaged one or another of their relatively stationary contacts due to the pendulum action of weight W the motors M2 and M1 respectively will have been operated to again open such contacts. In other words, when the gyro 38 has come up to full speed the scanning antenna supporting bracket 20 will assume a perfectly level position both insofar as its rocked position as deter-

mined by shaft 16 is concerned and insofar as its nosing position about the axis of shaft 13 is concerned. This level position of the scanning antenna supporting bracket 20 will be maintained throughout the entire landing operation irrespective of irregular movements of the airplane in making a carefully controlled landing.

It may be pointed out here that the screen S of the kinescope KN is provided with a level plane line LP and with a vertical center line 70 (Figs. 2, 4 and 5), and with the scanning antenna supporting bracket 20 maintained in its level plane position any horizontally emitted radio beam which strikes the scanning antenna A1 or A2 will cause a spot of light to appear on the level plane line LP and if this beam is radiated from directly ahead the spot will also fall on this vertical line 70.

To return the apparatus to route flying operation all that is necessary is that the double-throw switches 48 and 49 be returned to their right-hand position and the power supply for rotating the gyro 38 be cut off.

If the invention is practiced by omitting the gyroscopic stabilizer it may at times, due to unusual loading of the airplane, be necessary to position the scanning antenna supporting bracket 20 differently with respect to the airplane than the plane-axial relationship above mentioned. In this form of the invention the motors M1 and M2 may be omitted but their respective pinions 22 and 24 will be retained, these pinions in this case being turned by hand through the medium of cranks 25 and 26 respectively. These cranks 25 and 26 will in this case be turned until a radio beam approaching in plane-flight axial line will place its image at the point on the screen S where lines 70 and LP cross. Or these cranks may be adjusted until both of the ball inclinometers 59 and 60 assume their level position.

Operation system

Blind landing omitting stabilizer.—As already pointed out above the scanning antenna stabilizer apparatus may be omitted and in this case the invention is used in a slightly different manner than when this stabilizer is used. When the stabilizer is omitted it is assumed that the motors M1 and M2 are also omitted and that in this case the scanning antenna supporting bracket 20 is adjusted to a non-banked, non-nosing level position by the operation of the cranks 25 and 26. For instance, if the pilot uses the inclinometers 59 and 60 he will operate the crank 25 until the ball in the inclinometer 59 assumes the middle position and will then operate the crank 26 to a position where the ball in the inclinometer 60 assumes the middle position. These adjustments and particularly the adjustment of crank 26 is necessary to compensate for different conditions of loading of the airplane. If the airplane is heavily loaded it will be required to nose slightly higher and for this reason the crank 26 will have to be turned slightly to the left from its normal position. These cranks 25 and 26 may be frictionally or otherwise locked into their last operated position.

Proceeding now on the assumption that the scanning antenna supporting bracket 20 is properly adjusted and that the scanning antenna is operated and all the circuits (see Field et al. application) leading to the kinescope KN are closed, the operator will observe replicas of the various ground radio radiators ahead of the plane. If he is flying, without crabbing (pointing into a

side wind) on a course such as indicated in Fig. 7 of the drawings he will have these replicas lined up on the vertical line 70 on the kinescope screen S. If he is crabbing his airplane he will line up the replicas sidewise differently to an extent depending on the extent of crabbing.

Let us now assume that he is approaching an airfield such as shown in Fig. 1 and that he contemplates landing on the landing strip LS under severe fog conditions. As he approaches the air strip LS, flying in a direction to approach the entrance end E first, he will line up the two replicas of radiators E and X on the line 70 of the kinescope screen S (see Fig. 2) and will maintain level flight so far as possible. As he approaches closer and closer to the entrance of the landing strip LS the replicas *j*1 and *k*1 will finally register on the horizontal line GL1, which we may assume to constitute a declination line or glide path disposed at an angle of 3° with respect to the level flying field. This arrival of the replicas *j*1 and *k*1 on the line GL1 will inform the pilot that he is crossing a declination line, assumed to be a 3° line, which terminates near entrance end of landing strip LS. The pilot will now nose his airplane downward very quickly until the spots *j* and *k* have shifted to the positions *j*2 and *k*2 on the level flight line LP. This informs the operator that he is flying directly toward the radio radiators J and K on opposite sides of the landing strip LS. If the pilot continues to keep the replicas of radiators J and K on the line LP these replicas will gradually spread apart and when they have reached the vertical lines 71 and 72 respectively the wheels of his plane will touch the landing strip near the entrance end thereof.

Had the pilot desired to make his descent first at a large angle of say 3° with respect to the horizontal as just described, followed by a glide path of smaller declination angles, such as 1½° with respect to the horizontal flying field, the flying field would have to be provided with an additional set of radio radiators M and N as shown in Fig. 3 of the drawings. In this case the pilot would have returned his airplane to level flight, as shown by dotted line 73 (Fig. 3A) when the images *j* and *k* have separated a predetermined distance from the center line 70 and he would then have maintained this level flight (line 73) until the replicas or images of radiators M and N appear on the glide path line GL2 (assumed to be a 1½° declination line) on his kinescope screen. When this is observed the pilot will know that he is then crossing the more shallow glide path line of slope GL2 (see Fig. 3). He will then again nose his airplane downward slightly until the images *m* and *n* appear on the level line LP after which he will continue his flight down this glide path of smaller slope until the images *m* and *n* have separated to an extent to have reached the vertical lines 71 and 72 at which point in his flight his airplane wheels will just touch the landing strip LS.

It has thus been pointed out that without the employment of the gyroscopic stabilizer shown in Fig. 5 and assuming that weather conditions are not too rough, the pilot is able to make a landing by apparatus which informs him when in horizontal flight that he is crossing a glide path of predetermined declination. He may then nose his airplane downward, in a manner comparable to aiming at the radio radiators such as J and K on opposite sides of the landing strip. This will cause him to fly over a substantially

straight declining path toward such radio radiators. It has also been pointed out that after he has glided down a glide path of rather steep declination he may shift to a glide path of more shallow declination by temporarily flying level (see dotted line 73, Fig. 3) and that he will eventually make a landing on the landing strip instantaneously with certain visual information displayed on his kinescope screen. Under stormy weather conditions the accuracy of blind landing of an airplane is naturally diminished and for this reason the employment of the gyroscopic stabilizer disclosed in Fig. 5 is believed a desirable adjunct.

Blind landing using stabilizer.—From the operation just considered it is obvious that the replicas on the screen reflect not only the location of the airplane in space with respect to the radio radiators of which these replicas are images but also reflect the oriented position of the airplane at this point in space. It is readily seen that if a gyroscopic stabilizer is used to stabilize the scanning antenna supporting bracket 20 that under this condition most orientation changes of the airplane have been eliminated and the images on the screen S will reflect or manifest solely the position assumed by the airplane in space irrespective of its oriented position except for orientation about a vertical axis about which the scanning antenna is not stabilized. From this consideration it is of course apparent that the procedure of making a blind landing when using a gyroscopic stabilizer must of necessity be quite different from the procedure when using the same apparatus when no gyroscopic stabilizer is employed.

Let us now assume that the pilot is about to make a landing on a landing strip such as shown in Fig. 3 of the drawing except that it is employing only a single pair of radio radiators J and K. During flight of the airplane equipped as illustrated in Fig. 5 over an air route as illustrated in Fig. 7 the double-throw switches 48 and 49 will assume their right-hand position in which position the scanning antenna supporting frame 20 is lined up level with the airplane itself all for reasons hereinbefore described. For reasons already pointed out the gyroscopic stabilizing apparatus must be cut into service when a blind landing is contemplated. To make this blind landing operation the pilot will first set his gyro 30 into operation in a manner as described under the heading "Operation gyro-stabilizer" and he will simultaneously therewith operate the double-throw switches 48 and 49 to their left-hand position.

As the airplane moving in an E to K direction approaches the entrance end E on the landing strip LS in Fig. 3 of the drawings, he will continue level flight until the image point $j1$ and $k1$ appear on the horizontal line GL1 (see Fig. 4) and if these images of radiators J and K are held on this line GL1 by the pilot properly maneuvering his airplane these images will gradually spread or separate. When these images have separated to an extent to reach the points $j2$ and $k2$ (Fig. 4), it being understood that the maneuvering of the airplane just mentioned resulted in the airplane following a steep glide path GL1, which we may assume to be a slope of say 3° declination, the airplane has reached the shallow glide path terminating at radiators M and N. That is, when the airplane in gliding down this steep glide path, as determined by the line GL1 on his kinescope screen S (see also Fig. 3A), has reached

a certain point on this glide path, as manifested by the image points $j2$ and $k2$ (Fig. 4) reaching the vertical lines 71 and 72 respectively, the images of the radio radiators M and N will have reached the line GL2 as manifested by the dots $m2$ and $n2$ in Fig. 4 of the drawings. In other words, the replica of the four radiators J, K, L and M will first appear on the kinescope screen S in the form of a frustum of a triangle defined by image points $j1$, $k1$, $m1$ and $n1$ but after the airplane approaches closer to the landing strip LS in Fig. 3 this frustum of a triangle will have been enlarged on the screen S as is manifested by the image points $j2$, $k2$, $m2$ and $n2$. When this point in the descent of the airplane toward the landing strip down the steep slope is reached the pilot will disregard the image points $j2$ and $k2$ and will direct his attention to the image points $m2$ and $n2$. In fact, the pilot will maintain the images m and n on the line GL2, which for obvious reasons will mean that the airplane is now descending on the shallow glide path which we may assume to have a declination of 1½° with respect to the horizontal airfield. As these images m and n move apart on the line GL2 (Fig. 4), the pilot of course trying to keep these image spots m and n equal distances from the vertical line 70, they will eventually reach points $m3$ and $n3$. When these images m and n by their separating movement have reached the points of intersection of line GL2 with vertical lines 71 and 72 as manifested by the image points $m4$ and $n4$ the wheels of the airplane will just touch the landing strip LS and this will occur at a predetermined distance from a line connecting the radio radiators M and N along this landing strip LS (Fig. 3).

Under the operation just considered the pilot and his airplane came down a steep glide path until this glide path crossed a more shallow glide path and then he followed the shallow glide path until his wheels touched the landing strip LS. It is of course obvious that he could have maintained his flight down the original and steeper glide path in which event he would have landed with respect to radiators J and K rather than with respect to radio radiators M and N and, on the other hand, if he desired to make the landing entirely by following a shallow glide path he could have disregarded the images of radio radiators J and K and could have merely followed the images of the radio radiators M and N and have lined them up on line GL2 on the screen instead of first lining up the images of radio radiators J and K on line GL1 of the screen as above described. In other words, the apparatus illustrated in Figs. 3, 4 and 5 enables the pilot to make an accurate landing irrespective of how much a battering wind causes the airplane to roll around in space either by descending a steep glide path all the way to the airfield, by descending along a shallow glide path all the way to the landing strip or by following the steep glide path until it crosses the shallow glide path after which he may follow the shallow glide path until his wheels touch the landing strip, and in each case the pilot will be definitely and precisely informed the instant just before his wheels touch the landing strip.

Having thus shown and described apparatus which lends itself to flying an airplane course defined by a plurality of radio or other wave energy radiators located along such course and which also lends itself to blind landing on an airfield equipped with suitably arranged radiators, the

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images of which may be definitely controlled to perscribe positions in a kinescope screen, so as to make an accurate and precise landing in spite of a heavy fog or extreme darkness without the use of any form of light signalling, it should be understood that the several forms of the invention have been illustrated as examples of apparatus that may be used to carry out the purpose of the invention and it should be understood that various changes, modifications and additions may be made to the invention as required under various conditions encountered in practicing the invention without departing from the spirit or scope of the invention except as demanded by the scope of the following claims.

What we claim is:

1. Combined blind course indicating and blind landing apparatus of the type described comprising; the combination with airplane carried radio radiator display apparatus including a scanning antenna and a cathode-ray tube including a screen upon which a plurality of ground located radio radiators may be simultaneously displayed in perspective in substantially the same relationship as viewed from the airplane; of gyroscopic stabilizing apparatus for stabilizing the scanning antenna but allowing free maneuverability of the airplane; said stabilizing apparatus including a gyroscope having its casing supported rigidly with respect to the support for said scanning antenna and having a first set of two control devices one device manifesting movement of the gyroscope supporting frame about one axis at right angle to the spinning axis of said gyroscope and the other device manifesting movement of said frame about another axis at right angle to both of said first mentioned axis; motive power means controlled by said control devices for holding said scanning antenna and said frame in its original position, a second set of control devices for controlling said motive power means about two different axis to cause said scanning antenna to assume a specific relationship with respect to said carrier airplane; two ground located radio radiators one on each side of a landing strip on an airfield; a horizontal line on the screen of said cathode-ray tube at a height such that if a spot characterizing a ground located radio radiator is held on said line by the pilot by maneuvering his airplane said airplane will descend at an angle of a predetermined number of degrees declination; whereby if two spots identifying said two ground located radio radiators are both held on said line until said spots have separated a predetermined distance on said line the carrier airplane will land on said landing strip at a point predetermined by said two ground located radio radiators; and selecting means for causing said second set of control devices to control said motive power means when the carrier airplane is flying over a course defined by radio radiators arranged in a line and for causing said first set of control devices to control said motive power means when the carrier airplane is about to make a blind landing.

2. Blind landing apparatus of the type described comprising; the combination with airplane carried radio radiator display apparatus including a scanning antenna, sweep-plate voltage generating means and a cathode-ray tube including a screen upon which a plurality of ground located radio radiators may be simultaneously displayed in perspective in substantially the same relation to each other as viewed from the airplane; of gyroscopic stabilizing appa-

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ratus for stabilizing the scanning antenna but allowing free maneuverability of the airplane; said stabilizing apparatus including a gyroscope having its casing supported rigidly with respect to the support for said scanning antenna and having a first set of two control devices one device manifesting movement of the gyroscope supporting frame about one axis at right angle to the spinning axis of said gyroscope and the other device manifesting movement of said frame about another axis at right angle to both of said first mentioned axes; motive power means controlled by said control devices for operating said frame back to its original condition; a second set of two control devices for controlling said motive power means about two different axes to cause said scanning antenna to assume a specific relationship with respect to said carrier airplane; two ground located radio radiators one on each side of a landing strip on an airfield; a horizontal line on the screen of said cathode-ray tube at a height such that if a spot characterizing a ground located radio radiator is held on said line by the pilot by maneuvering his airplane said airplane will descend at an angle of a predetermined number of degrees declination; whereby if two spots identifying said two ground located radio radiators are both held on said line until said spots have separated a predetermined distance on said line the carrier airplane will land on said landing strip a predetermined distance to the rear of said two ground located radio radiators; and selecting means for determining whether said first set or said second set of control devices shall control said motive power means.

3. Blind landing apparatus of the type described comprising; an airplane carried cathode-ray tube including a screen; apparatus on the airplane including a scanning antenna, means for swinging the electron beam in the cathode-ray tube and firing the same, to cause a replica of ground located radio radiators in the field to appear on the screen in substantially the same relationship to each other as they appear in the field ahead of the airplane; two horizontal lines on said screen, the first line of which is so located that if said scanning antenna is positioned for level flight a radio beam inclined at a predetermined angle will manifest itself on said line and the second line so located on said screen that a radio beam inclined at a predetermined but smaller angle will manifest itself on such second line; gyroscopic stabilizing apparatus for stabilizing said scanning antenna to level flight but allowing free maneuverability of the carrier airplane; two pairs of radio radiators one radiator of each pair being located at equal distances on opposite sides of a landing strip on an air field with the first pair located near the entrance end of said landing strip and the second pair located a predetermined distance in advance thereof; whereby if the two spots constituting the replica of said first pair of radio radiators is held on said first horizontal line by the pilot's maneuvering of said carrier airplane until two spots constituting the replica of the second pair of radio radiators fall on said second horizontal line and the airplane is then maneuvered to hold these second two spots on said second line until they have separated a predetermined distance such airplane will first descend on a glide path having predetermined declination, will then descend on a glide path having a smaller angle declination and will then land on said landing strip a predetermined distance to the rear of said other

pair of radio radiators; and means for rendering said stabilizing apparatus ineffective and for locking said scanning antenna on said airplane for level flight with said airplane flying level.

4. In combination, an airplane carried support, a gyroscope, a first control means controlled in accordance with the oriented relationship of said support with respect to the axis of said gyroscope, a second control means controlled in accordance with the oriented relationship of said support with respect to said airplane, motive power means for determining the oriented position of said support with respect to said airplane, and manually operable means to select whether said motive power means is to be controlled by said first control means or said second control means.

5. In combination, an airplane carried support, a gyroscope, a first control means including two contacts each movable between two other contacts and controlled in accordance with the oriented relationship of said support with respect to the axis of said gyroscope, a second control means including two contacts each movable between two other contacts and controlled in accordance with the oriented relationship of said support with respect to said airplane, two electric motors for determining the oriented position of said support with respect to said airplane, and manually operable means for determining whether said electric motors are to be controlled by said first control means or said second control means.

6. In a blind landing system having two radiators transversely spaced with reference to a landing strip, glide path defining apparatus on an aircraft comprising, a directional antenna, azimuth and elevation scanning means causing said antenna to scan the area ahead of the aircraft, means including a gyroscope for stabilizing said antenna with respect to orientation of said aircraft about transverse and longitudinal axes, a radio receiver having its input governed by said antenna, a cathode-ray tube having its grid governed by the output of said receiver, and sweep circuit means synchronized with said scanning means cooperating with the grid control of said cathode-ray tube to indicate the location of said radiators substantially as viewed in perspective from the aircraft along a particular horizontal line on the screen of said tube whenever said aircraft is on a glide path at a particular predetermined elevational angle from said landing strip, whereby said radiators are indicated above or below said horizontal line in accordance with said aircraft being respectively below or above said glide path, and whereby the indications of the locations of said radiators are unaffected by orientation of said aircraft about transverse or longitudinal axes.

7. In a blind landing system having two radiators for marking a landing strip, said radiators being spaced from each other along a line transverse to said landing strip, glide path defining apparatus on an aircraft comprising, a directional antenna scanning mechanism on said aircraft, a support for said antenna mechanism by which said mechanism can be operated to a limited extent about longitudinal and transverse axes with respect to said aircraft, a gyroscope pivotally disposed on said support to maintain a true vertical spin axis irrespective of relative operation of said support about said transverse and longitudinal axes, electrically operable control means responsive to a small out-of-corre-

spondence condition between said gyroscope and a predetermined transverse and longitudinal rotated position of said support to rotate said support about its respective transverse and longitudinal axes as required to correct for said out-of-correspondence conditions, a cathode-ray tube, and means including said tube and said antenna scanning mechanism for indicating the relative location of said radiators on the screen of said tube in positions with respect to a predetermined reference line on said screen above or below said reference line in accordance with whether said aircraft is respectively below or above a glide path at a predetermined elevational angle extending from said landing strip, irrespective of the orientation of the aircraft about respective transverse and longitudinal axes.

8. In a blind landing system having two pairs of transversely spaced radiators marking a landing strip, the respective pairs being longitudinally spaced with respect to the landing strip, glide path defining apparatus on an aircraft comprising, a directional antenna, azimuth and elevation scanning means causing said antenna to scan the area in advance of the aircraft, means including a gyroscope for stabilizing said antenna with respect to orientation of said aircraft about transverse or longitudinal axes, a radio receiver having its input governed by said antenna, a cathode-ray tube, and means including the output of said receiver and said cathode-ray tube for indicating the relative locations of said radiators substantially as viewed in perspective from said aircraft on the screen of said tube, whereby when one of said pair of radiators is indicated along a particular horizontal line on said screen said aircraft is on a first glide path extending from said landing strip at a particular elevational angle, and whereby while flying said first glide path, the intersection of a second glide path at a lesser angle is indicated by the presence of the indications for the location of the other pair of radiators along another predetermined horizontal line on said screen.

9. Blind landing apparatus of the character described comprising, the combination with aircraft carried radiator location indication apparatus including a receiver and a cathode-ray tube having a screen upon which indications of the locations of radiators marking the opposite sides of a landing strip may be displayed in perspective as viewed from the front of the aircraft, said screen having a horizontal reference line vertically disposed thereon to correspond to a particular predetermined elevational glide angle as viewed from the front of the aircraft when in level flight, of means including a direction scanning antenna and synchronized sweep circuits for control of said tube for indicating the location of said radiators respectively on said screen, and gyroscopic stabilizing apparatus in which a gyroscope has a truly vertical spin axis effective to stabilize said antenna with respect to a true vertical axis irrespective of the maneuvering of said aircraft, whereby the replica of the location of said radiators on said screen along said horizontal line is a true indication of the intersection of a glide path extending to the landing strip at said predetermined angle, irrespective of the orientation of the aircraft about transverse or longitudinal axes, and whereby the maintaining of the replica of the respective radiators on said horizontal line defines the following of a true glide path to direct the aircraft to the landing strip at said predetermined angle, the distance from the radiators at the landing strip

being indicated by the spacing between the replica of the respective radiators.

10. In a blind landing system of the character described, the combination with radiators spaced on opposite sides of a landing strip and an aircraft having a receiver responsive to said radiators, of directional antenna means on said aircraft, means including a gyroscope for stabilizing said directional antenna means with respect to orientation of said aircraft about transverse or longitudinal axes, a cathode-ray tube, and means including said directional antenna means and said cathode-ray tube for indicating the relative locations of said radiators on a screen of said tube in positions with respect to a predetermined reference line on said screen above or below said reference line in accordance with whether said aircraft is respectively below or above a glide path at a predetermined elevational angle extending from said landing strip, said means being effective irrespective of the orientation of said aircraft about longitudinal or transverse axes.

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