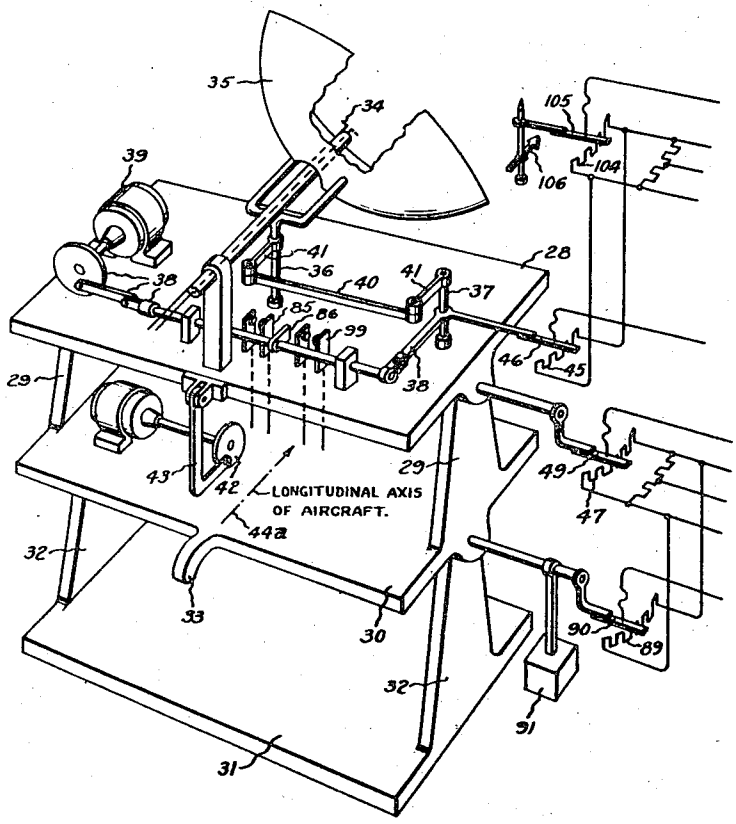
Oct. 19, 1948. E. F. W. ALEXANDERSON ET AL 2,451,793

RADIO LANDING APPARATUS

Filed May 22, 1943 4 Sheets-Sheet 1

Fig. 1.



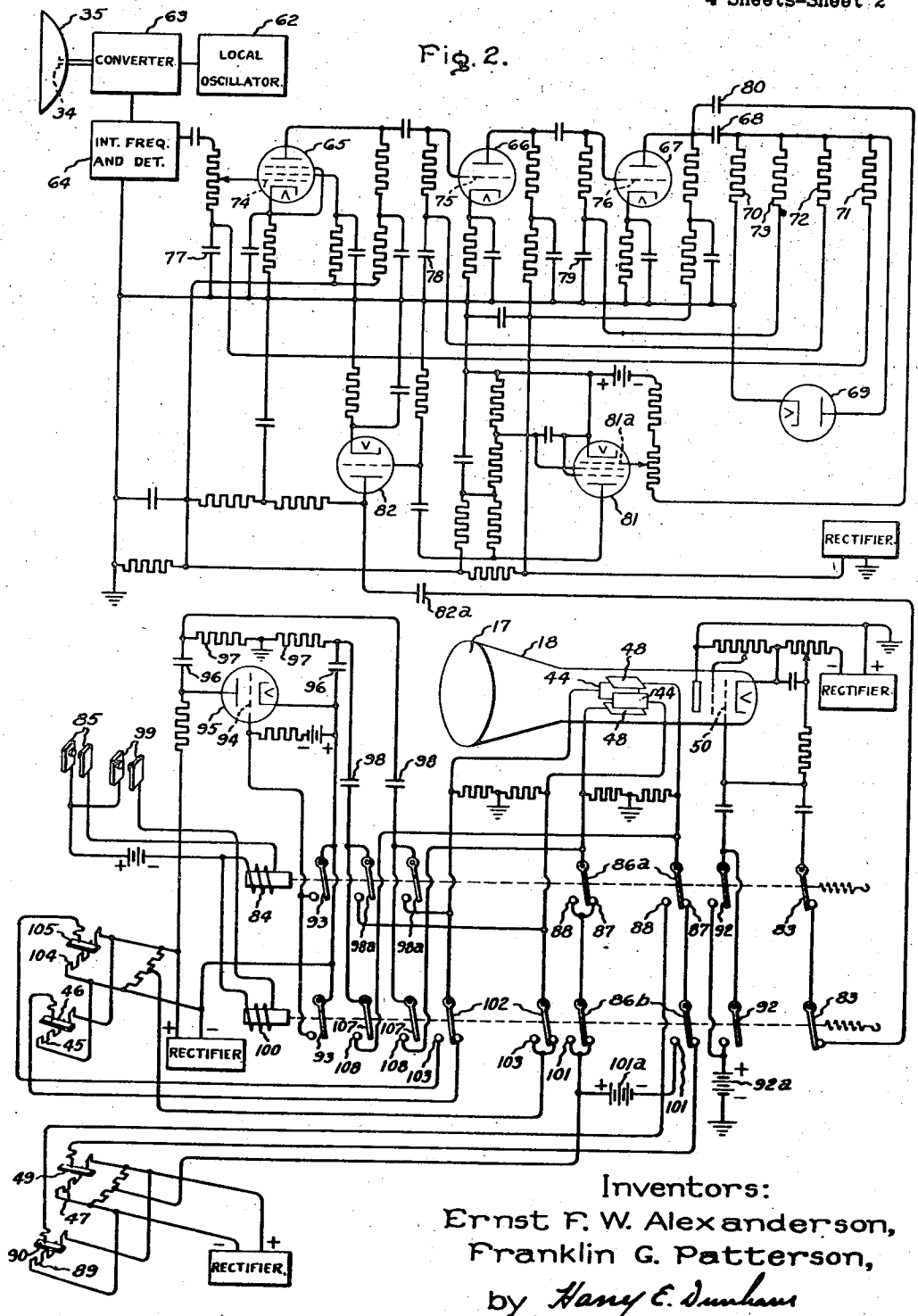
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Ernst F. W. Alexanderson,
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RADIO LANDING APPARATUS

Filed May 22, 1943 4 Sheets-Sheet 2

Fig. 2.



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RADIO LANDING APPARATUS

Filed May 22, 1943 4 Sheets-Sheet 3

Fig. 3.

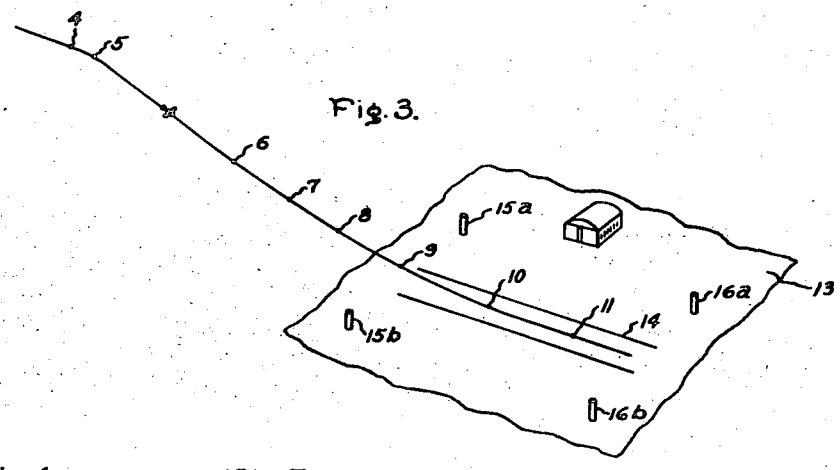


Fig. 4.

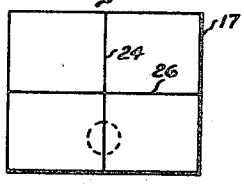


Fig. 5.

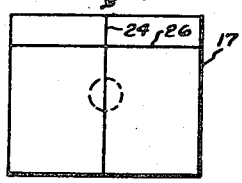


Fig. 6.

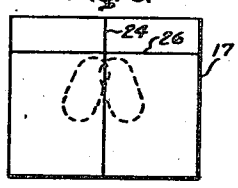


Fig. 7.

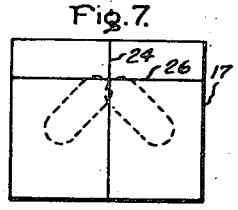


Fig. 8.

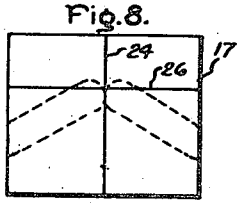


Fig. 9.

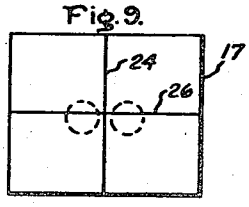


Fig. 10.

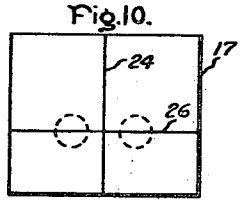


Fig. 11.

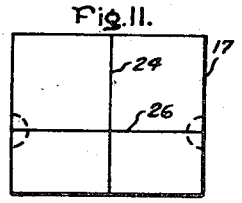


Fig. 12.

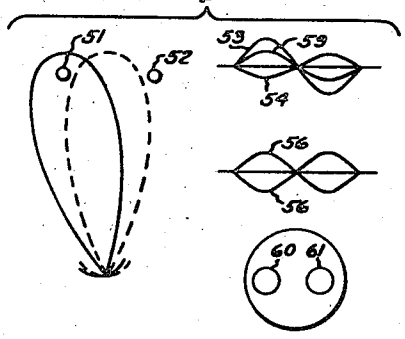
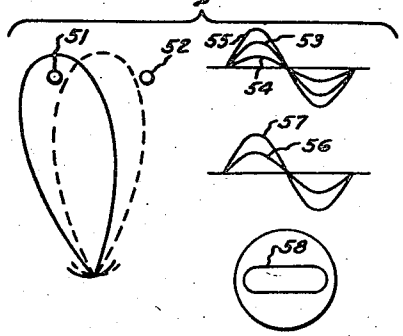


Fig. 13.



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Oct. 19, 1948. E. F. W. ALEXANDERSON ET AL 2,451,793

RADIO LANDING APPARATUS

Filed May 22, 1943 4 Sheets-Sheet 4

Fig. 14.

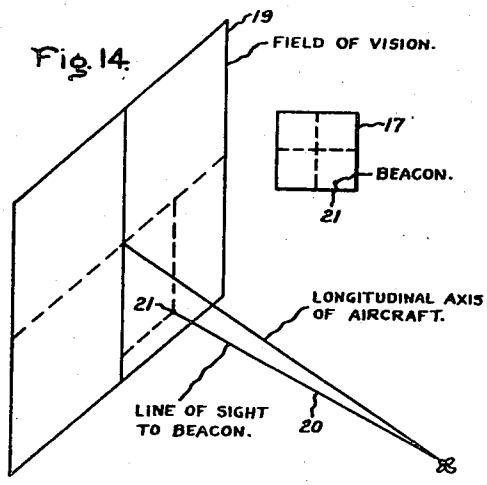


Fig. 15.

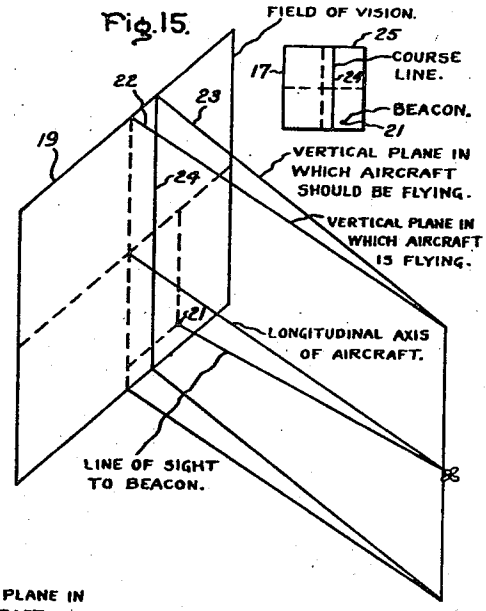
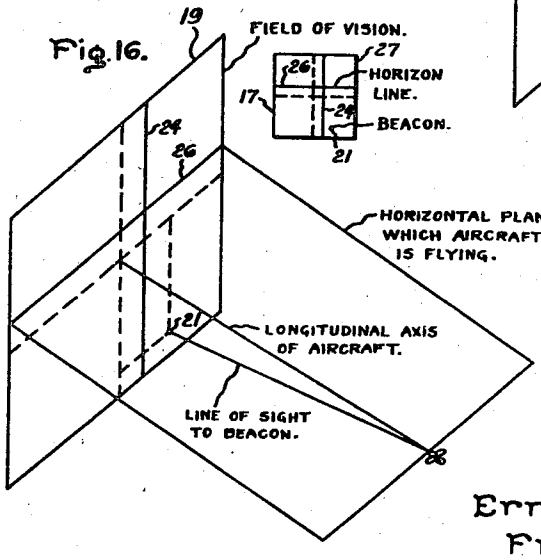


Fig. 16.



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UNITED STATES PATENT OFFICE

2,451,793

RADIO LANDING APPARATUS

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Application May 22, 1943, Serial No. 488,012

14 Claims. (Cl. 343—107)

1

The present invention relates to apparatus utilizing radio waves to reproduce a visual image of a significant area, for example the runway of an airport. Such apparatus, which may be called "radio vision apparatus," is useful for such purposes as landing aircraft in darkness or fog when normal vision is inadequate.

A complete visual image such as the pilot obtains by looking through a window in the aircraft when coupled with his trained sense of perspective furnishes all of the necessary information as to the relative position of the aircraft. If such an image were reproduced on a picture screen, the pilot could land the aircraft by looking at the artificial image on the picture screen just as well as by looking through the window.

The complete visual image, although desirable, is not necessary and the apparatus for artificially producing the complete visual image is complicated. It is sufficient to provide an image which contains only the significant details of the complete visual image necessary to define to an experienced pilot the runway and the three-dimensional position of the aircraft relative to the runway.

The object of our invention is to provide simplified radio vision apparatus for reproducing a visual image of a significant area.

The novel features which we believe to be characteristic of our invention are set forth with particularity in the appended claims. Our invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings in which Fig. 1 represents a directional antenna system for use in radio vision apparatus embodying our invention; Fig. 2 is a circuit diagram; Fig. 3 represents a runway and the successive positions assumed by an aircraft during landing; Figs. 4 to 11 inclusive show the images produced by the apparatus at the positions indicated by corresponding reference numerals in Fig. 3; Figs. 12 and 13 are diagrams illustrating the operation of the amplifier in sharpening the indications of the positions of adjacent radio beacons; Fig. 14 represents the perspective relation between the image produced by the apparatus and one of the beacons; Fig. 15 represents the perspective relation between the image produced by the apparatus and the course line; and Fig. 16 represents the perspective relation between the image produced by the apparatus and the horizon line.

Referring to the drawings, at 13 in Fig. 3 is represented part of an airport having a runway 14 marked by pairs of beacons 15a, 15b and 16a, 16b, respectively, at the near and far ends from the point of view of aircraft approaching from the

2

desired landing direction. In a typical installation, the beacons of each pair might be spaced 1000 feet apart and the pairs of beacons might be 5000 feet apart. The beacons may consist of radio transmitters radiating uniformly in all directions or at least over beams wide enough to encompass approach paths along which aircraft are expected. Alternatively, the beacons may consist of reflectors for, or echo beacons energized by, radio waves from a transmitter either carried by the approaching aircraft or located so the waves from the beacons will encompass the expected approach paths. Since the physical size of the apparatus decreases with increasing frequency, it is expected that the radio waves will be of ultra high frequency (e. g. 10 cm.) when the apparatus is to be used over the relatively short ranges required for landing aircraft.

Irrespective of the type of beacon, the radio waves travel from the beacons in straight lines and some of the radio waves travel on lines of sight connecting the approaching aircraft with the respective beacons. The intersections of the respective lines of sight with a field of vision from the aircraft including the beacons furnishes a true perspective image of the beacons as viewed from the aircraft and accordingly defines the boundaries of the runway, the points of greatest significance to the pilot. In the present apparatus the image of the beacons appears on the screen 17 of a cathode ray tube 18 as shown in Figs. 4–11 inclusive for the corresponding positions of the aircraft. If the image of the beacons on the field of vision is correlated with the direction in which the aircraft is traveling (the course) and the angle between the horizontal and the direction of travel of the aircraft (the glide angle during landing), the pilot is provided with the significant information to enable blind landing of the aircraft.

To provide a scale for the images so the pilot can estimate the relative position of the aircraft, the images are formed on a screen representing a field of vision centered on the longitudinal axis of the aircraft. In other words, the trace of the longitudinal axis of the aircraft passes through (the aircraft is flying toward) the center of the field of vision.

The traces of the lines of sight to the beacons appear on the screen displaced from the center of the screen in accordance with the divergence of the respective lines of sight from the longitudinal axis of the aircraft. The perspective relations are shown in Fig. 14 where 19 represents the field of vision centered on the longitudinal axis of the aircraft, 20 represents a line of sight from the aircraft to one of the beacons, and 21 represents the image of the beacon as it appears on the screen 17 of the cathode ray tube.

The image of the beacons alone does not fur-

nish complete information. The pilot should also know whether the aircraft is on the proper course and the angle of flight of the aircraft with respect to the horizontal.

In the present construction, the course appears on the screen of the cathode ray tube as a vertical line representing the intersection with the field of vision centered on the longitudinal axis of the aircraft of the vertical plane in which the aircraft should be traveling if it is on the proper course. The aircraft is traveling in a vertical plane including its longitudinal axis. The course line accordingly is displaced from the center of the screen in accordance with the divergence of the vertical planes in a manner shown in Fig. 15 where 22 represents the vertical plane in which the aircraft is flying, 23 represents the vertical plane in which the aircraft should be flying if it were on its proper course, 24 represents the intersection with the field of vision 19 of the vertical plane 23, and 25 represents the resultant image on the screen of the cathode ray tube. If the aircraft is on the proper course, the line 24 (the course line) bisects the center of the screen. The pilot will instinctively steer the aircraft so as to bring the course line in the center of the screen. In Figs. 4–11 inclusive, the course line 24 bisects the image of the beacons because the aircraft, as it should, is traveling toward the beacons in a vertical plane bisecting the length of the runway so as to land on the center line of the runway. The course line 24 is obtained in a manner hereinafter described from apparatus associated with the aircraft compass.

The information as to the angle of flight (the glide angle during landing) is obtained as shown in Fig. 16 from an artificial horizon line 26 representing the intersection with the field of vision centered on the longitudinal axis of the aircraft of the horizontal plane in which the aircraft is instantaneously located. The resultant image is represented at 27 which also shows the relative positions of the beacon and the course line. The position of the image of the beacons relative to the horizon line is a measure of the angle between the horizontal and the lines of sight connecting the aircraft and the respective beacons. During level flight, the horizon line is at the center of the screen. As the aircraft is coming down, the image of the beacons is at the center of the screen and the horizon line is above the center of the screen an amount proportional to the glide angle as shown in Figs. 5–8 inclusive. As the aircraft levels off for landing, the image of the beacons approaches the center of the screen and the horizon line (Fig. 9). If the nose of the aircraft is raised to decrease the landing speed, the image of the beacons and the horizon line will drop below the center of the screen (Figs. 10–11). This is in accord with the conscious and subconscious observations of the pilot during visual landing. In the present apparatus the horizon line is obtained, as hereinafter described, from a stable vertical associated with the cathode ray tube.

Because the course and horizon lines and the image of the beacons are coordinated on the cathode ray tube screen in accordance with the normal visual observations of the pilot, the pilot can, under conditions in which normal vision is inadequate, make a landing by observing the screen which is equivalent to a visual landing.

The apparatus responsive to the radio waves on lines of sight connecting the aircraft and the respective beacons (Fig. 1) is carried on a platform 28 journaled on standards 29 for tilting about a horizontal axis transverse to the longitudinal axis of the aircraft. The standards 29 are carried by a base 30 which in practice would be fixed to the aircraft so as to tilt with the longitudinal axis of the aircraft. In other words, the longitudinal axis 44a of the base 30 would be coincident with the longitudinal axis of the aircraft. A tilting of the base 30 equivalent to the tilting of the longitudinal axis of the aircraft is obtained by journaling the base on standards 32 on a fixed support 31 for tilting about an axis transverse to the longitudinal axis of the aircraft. By tilting the base 30 the same effect is produced as that obtained by fixing the base to an aircraft and changing its angle of flight with reference to the horizontal. The arrangement for supporting the base on a fixed support, since it duplicates the essential flying conditions, is convenient for testing purposes during which the base may be tilted in any suitable manner, for example by raising and lowering the handle 33 to simulate the angle of flight of aircraft.

Fixed on the platform 28 is an antenna 34 associated with a parabolic reflector 35 fixed to a vertical shaft 36 journaled in the platform 28. Parallel to the shaft 36 is a shaft 37 oscillated by a crank and linkage 38 driven by a motor 39 mounted on the platform. The oscillating motion of the shaft 37 is transmitted to the reflector 35 through a connecting rod 40 connected to crank arms 41 on the shafts 36 and 37. As the reflector 35 is oscillated by the shaft 36, the direction of maximum response of the antenna 34 remains substantially constant in a plane parallel to the platform 28 and varies in that plane along an axis displaced from the axis of the antenna by twice the angle between the axes of the antenna and reflector. By oscillating the reflector, the response of the antenna 34 is varied along a path parallel to the platform 28. The width of the path depends upon the wavelength of the radio waves to be received and the diameter of the reflector. For a wave length of 10 cm. and a reflector 18" in diameter the antenna responds to radio waves received in a beam 15 degrees wide, and the oscillation of the reflector accordingly results in scanning a path 15 degrees wide parallel to the platform 28. In the present apparatus, the scanning parallel to the platform 28 (horizontal scanning) is at a rate of 5 cycles/second and through an angle of 60 degrees (a 30 degree swing of the reflector).

In addition to the horizontal scanning obtained by oscillating the reflector 35, there is a slower vertical scanning (one cycle/second) obtained by oscillating the platform 28 by means of a motor driven crank 42 on the base 30 and connected to the platform 28 by a connecting rod 43. Tilting the platform, which in the present apparatus is through an angle of 30 degrees, results in the scanning of a field of vision in a series of overlapping horizontal paths covering a field of vision 60 degrees wide by 30 degrees high. It is obviously unnecessary that the scanning of the field of vision be carried out in rectilinear paths or with the particular apparatus illustrated. The field of vision is centered on the longitudinal axis 44a of the base 30 which corresponds to the longitudinal axis of the aircraft. Radio waves along lines of sight in the field of vision will be picked up by the antenna 34 in accordance with the instantaneous position and the directional response characteristics of the antenna and its associated reflector.

To coordinate the received signals with the

scanning position of the antenna system the horizontal plates 44 of the cathode ray tube 18 (Fig. 2) are connected to a potentiometer 45 having a contact arm 46 moved by the shaft 37 in such manner that the beam of the cathode ray tube is deflected horizontally from the center in accordance with the horizontal shifting of the axis of maximum response of the antenna due to the reflector 36. A similar potentiometer 47 is connected to the vertical plates 48 of the cathode ray tube and has a movable contact arm 49 moved by the tilting of the platform 28 in such a manner that the beam of the cathode ray tube is deflected vertically from the center in accordance with the vertical shifting of the axis of maximum response of the antenna due to the tilting of the platform 28. The beam of the cathode ray tube is accordingly deflected in accordance with the instantaneous scanning position of the antenna so as to scan the screen of the cathode ray tube coordinate with the scanning positions of the antenna system. The signal picked up by the antenna system is applied to the grid 50 of the cathode ray tube to contrast modulate the beam and produce contrast spots on the cathode ray tube screen positioned in accordance with the direction (the scanning position) from which the signal is received.

Because of the width of the beam of the antenna system, there is difficulty in distinguishing radiation from directions having an angular spacing of the order of or less than the width of the beam. For example, with an antenna system having a 15 degree beam, radiation from sources which are 15 (or even 30) degrees apart would produce indications on the cathode ray tube screen which merged into a single spot.

If the radio waves from the respective sources are in phase (or have in phase components to which the receiver responds), the additive effect of the radio waves tends to increase the angular separation required for discrete response to the respective sources. This latter effect is illustrated in Fig. 13 in which an antenna system is shown in the full line position directed toward a source of radio waves 51 and in the dotted line position directed intermediate the source 51 and a source of radio waves 52. The response curves for the antenna in the respective positions are indicated respectively in full and dotted lines. In the full line position, the received signal is primarily from the source 51 as represented by the curve 53, but there is a small additive signal from the source 52 as represented by the curve 54 which produces the total represented by the curve 55. In the dotted line position, the same signal (represented by curve 56) is received from the sources 51 and 52 which when added (as represented by the curve 57) produces a sum of substantially the same magnitude as the signal in the full line position. If the signal picked up by the antenna were applied to the grid of the cathode ray tube 18, the resultant indication on the screen 17 of the cathode ray tube would be an elongated spot 58 which would not sharply differentiate the directions of the sources 51 and 52.

The effect illustrated in Fig. 13 is overcome as represented in Fig. 12 by making the signals received from the sources 51 and 52 of opposite phase. This can be effected by radiating radio waves from the respective sources which arrive at the antenna system in opposite phase, but it is simpler to radiate radio waves modulated in opposite phase at audio frequency. It is sufficient that the components of the signals from the respective sources to which the receiver responds are of opposite phase. In the full line position, the net signal is represented by curve 59 which is equal to the algebraic sum of the signal 53 from source 51 and the subtractive signal 54 from the source 52. In the dotted line position, the signals 56 from the sources 51 and 52 are of equal magnitude but opposite phase and accordingly cancel. In the arrangement of Fig. 12, if the signal picked up by the antenna were applied to the grid of the cathode ray tube 18, the resultant indication on the screen of the cathode ray tube would be represented by the spots 60 and 61 which more clearly indicate the respective directions of the sources 51 and 52.

In the present apparatus, the beacons 15*a* and 16*a* are modulated in phase at 2000 cycles and the beacons 15*b* and 16*b* are modulated at 2000 cycles in a phase opposite to that of the beacons 15*a* and 15*b*. The indication from the beacons 15*a* and 16*a* and from the beacons 15*b* and 16*b* tend to merge in elongated spots defining the sides of the landing area as shown in Figs. 6, 7, and 8. The indications from beacons 15*a* and 15*b* and from beacons 16*a* and 16*b* are separated.

The sharpness of the directional response of the antenna system 34, 35 is further increased by the characteristics of the receiver (Fig. 2), the radio frequency stages of which are the conventional superheterodyne elements consisting of a local oscillator 62, a converted 63, and an I. F. amplifier and detector 64. The detector output, which contains only the audio frequency components, is fed to a three stage resistance coupled audio amplifier having electron discharge devices 65, 66 and 67. The amplifier output is fed through a condenser 68 to an automatic volume control having a diode 69 in shunt with a resistance 70. An increase in the amplifier output increases the negative voltage across the resistance 70 which is applied through resistance 71, 72, and 73 to the grids 74, 75, and 76 of devices 65, 66, and 67 to decrease the amplification. The resistances 71, 72, and 73 are in series with condensers 77, 78, and 79 proportioned so the time constant of the automatic volume control is relatively slow (of the order of 1 second) so the overall sensitivity of the receiver as measured by the amplifier output is adjusted in accordance with the average signal received during the scanning of the antenna system. Because of the large variation in the intensity of the signal picked up by the antenna during landing, the automatic volume control is proportioned to maintain a constant average output over a variation in average signal strength of 10,000:1.

The amplifier output is also fed through a condenser 80 to a clipper stage consisting of an electron discharge device 81 having its grid 81*a* negatively biased so it responds only to that part of the amplifier output which exceeds the bias (the positive peaks of the amplifier output). The output of the clipper consists of narrow negative pulses having an amplitude limited by the saturation current of the device 81. The sharpness of the output of the clipper stage is increased by operating the device 81 as a square law amplifier.

The output of the clipper stage is fed through a resistance coupled amplifier 82, which inverts the pulses, and through a condenser 82*a* to to switches 83 connected to the grid 50 of the cathode ray tube. The positive pulses applied to the grid 50 increase the intensity of the cathode

ray tube beam and cause bright spots on the screen.

The purpose of the automatic volume control and clipper stages differs somewhat from the automatic volume control in broadcast receivers. In broadcast receivers, the automatic volume control acts to provide a constant carrier level independent of variations in the intensity of the signals picked up by the antenna system. Such an automatic volume control would tend to smooth the peaks of the signals picked up by the directional antenna systems and accordingly would tend to produce broader rather than sharper indications of the directions of the beacons. The present automatic volume control, which maintains a constant average (as distinguished from instantaneous) response to the signals picked up by the antenna system tends to distort the response to the signals so as to increase the difference between the peak and average signal. The response is still further sharpened in the clipper stage which is biased to respond only to the peaks of the signals from the amplifier output. The result is a sharper response to the peaks of the signals picked up by the antenna system and accordingly a sharper response to the directions from which the signals are received. In the present construction, the directional response is increased from a beam 15 degrees wide to a beam 5 degrees wide.

The horizon line is placed on the screen of the cathode ray tube 16 by apparatus associated with a relay 84 energized at the left end of the horizontal scanning path of the antenna system by a switch 85 closed by an arm 86 on the linkage 38. At this time the horizontal plates 44 of the cathode ray tube are connected to the horizontal potentiometer 45 so the beam is initially deflected to the left side of the cathode ray tube screen corresponding to the scanning position of the antenna system. The relay 84 opens switches 86a normally connected to contacts 87 leading to the vertical potentiometer 47 and closes the switches 86a on contacts 88 leading to the horizon potentiometer 89 mounted on the base 30 and having a movable contact arm 90 positioned in accordance with a stable vertical illustrated as the pendulum 91 suspended from the base. In practice a gyroscopic stable vertical would be substituted for the pendulum. The movable contact arm 90 is moved by the pendulum to the right or left along the horizon potentiometer 89 as the base 30 tilts down or up and accordingly impresses a voltage on the vertical plates 48 causing a vertical deflection of the beam of the cathode ray tube proportional to the angle between the longitudinal axis of the aircraft and the horizontal. When the aircraft is descending, the beam is deflected by the voltage from the horizon potentiometer 89 above the center of the screen a distance proportional to the glide angle. The relay 84 also opens one of the series switches 83 connecting the grid 50 of the cathode ray tube to the receiver and closes one of the parallel switches 92 connecting the grid 50 to a source of bias potential 92a which increases the beam intensity from its normal level (insufficient to form a spot on the screen) to a spot forming level. The relay 84 also closes one of the parallel switches 93 short-circuiting a source of negative bias voltage connected to the grid 94 of a gaseous discharge device 95 in parallel with condensers 96 and series resistances 97 across the potentiometer power supply. The device 95 is normally biased off, permitting the charging of the condensers 96 to the voltage of potentiometer power supply. When the grid bias supply for the device 95 is shorted by one of the switches 93, the device 95 becomes conducting, shorting the condensers 96 and causing a negative voltage to appear across the resistance 97 which is applied through condensers 98 and switches 98a closed by relay 84 to the horizontal plates 44 of the cathode ray tube causing the beam to sweep from left to right across the screen 17 at the position above the center of the screen determined by the horizon potentiometer 89. This traces the horizon line on the screen of the cathode ray tube which provides by its position on the screen an indication of the glide angle of the aircraft.

The relay 84 is closed long enough for the above described sequence of operations. Upon opening of the switch 85, the switches are returned by the relay to the positions illustrated.

At the right-hand end of the horizontal scanning path, a switch 99 is closed by the arm 86 energizing a relay 100 associated with appartus for placing the course line on the screen of the cathode ray tube. The relay 100 opens the switches 86b associated with the vertical potentiometer and closes the switches on contacts 101 connected to a battery 101a which causes the deflection of the beam of the cathode ray tube to the bottom of the screen. The relay 100 opens one of the series switches 83 connected to the receiver and closes one of the parallel switches 92 connected to the bias supply 92a which raises the beam intensity to the spot forming level. The relay opens switches 102 in circuit with the horizontal potentiometer 45 and closes the switches on contacts 103 connected to a potentiometer 104 which has a movable contact arm 105 positioned by a compass 106 (Fig. 1) in accordance with the deviation of the longitudinal axis of the aircraft from the direction determined by the compass. If the longitudinal axis of the aircraft is in a direction to the left of the proper course, the arm 105 is moved by the compass in the direction to cause the deflection of the beam to the right of the center of the screen indicating to the pilot that the aircraft should be steered to the right to bring it on the proper course. The relay also closes one of the parallel switches 93, controlling the device 95, and closes switches 107 on contacts 108 connected to the vertical plates 48 of the cathode ray tube. The negative voltage appearing across the resistance 97 upon the closing of the switch 93 is applied through the switches 107 to the vertical plates of the cathode ray tube to cause deflection of the beam from the bottom to the top of the screen 17 and trace the course line in the position determined by the course potentiometer.

The horizon and course lines are placed on the screen respectively in horizontal and vertical lines independent of tilting of the aircraft about its horizontal axis because the aircraft during landing will usually be in a level plane through the longitudinal axis. The complication of the apparatus necessary to make the horizontal course lines respectively parallel and perpendicular to the horizon is not usually necessary.

To make a blind landing utilizing the radio vision apparatus, it is necessary that the pilot receive information as to the desired landing direction, for example by radio communication, since there is a 180 degree ambiguity in the information presented on the viewing screen 17 of the cathode ray tube. The pilot accordingly

must maneuver the aircraft to a position for landing in the proper direction—rather than in the opposite direction.

As the aircraft approaches the airport in level flight from the proper landing direction, the images from the beacons produce a single spot as indicated in Fig. 4, displaced below the horizon line a distance representing the angle between the horizon and a line of sight to the airport. The pilot continues level flight until this distance becomes equal to the proper glide angle for the aircraft, at which time the glide is started toward the airport. As indicated in Fig. 5, the images of the beacons shift to the center of the viewing screen and the horizon line moves above the center of the screen a distance proportional to the glide angle. As the aircraft approaches the airport, the glide angle is decreased, as represented in Figs. 6, 7, and 8, and the images of the beacons separate until at the position represented by Fig. 8 the images of the beacons 15*a*, 15*b* at the near end of the runway begin to disappear at the outer edges of the screen. Since the field of vision is 60 degrees wide, the pilot knows at this time that the lines of sight from the aircraft to the beacons at the near end of the runway form an equilateral triangle with a line (of known length) connecting the beacons. This information, in conjunction with the displacement of the images of the near beacons 15*a*, 15*b* below the horizon line determines both the distance to the near end of the runway and the height above the ground. By making visual landings and observing the images on the viewing screen, marks may be placed on the screen indicating the region at which the images of the near beacons should disappear at the sides of the screen for a proper landing for the particular aircraft. When the images of the near beacons disappear on the screen in the proper region, the pilot knows both the height of the aircraft and the distance to the near end of the runway. As the aircraft lands, the nose is raised to decrease the landing speed and the horizon line and the images of the beacons 16*a*, 16*b* drop below the center of the screen. As the aircraft approaches the end of the runway, the images of the far beacons 16*a*, 16*b* begin to separate and just begin to disappear at the position represented in Fig. 11 at which the line of sight from the aircraft to the respective beacons forms an equilateral triangle with a line connecting the beacons. This gives the length of runway remaining.

The images of the beacons are not point images, as would be possible with visual images of markers defining the runway. The determination of the position of any particular beacon is subject to some inaccuracy. However, due to the assistance provided by the horizon and course lines which accurately represent the glide angle and course and due to the fact that the images of the beacons are widely separated at the critical times, it is expected that a pilot of average skill will have no difficulty in making blind landings after observing the screen while making a few visual landings.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. In a blind landing system in which a plurality of spaced broadcast beacons are located about the area in which said landing is to be effected, a viewing screen carried by the craft, means to scan a fixed predetermined area ahead of said craft for radio waves produced by said beacons and to produce a point of light on said screen at a position corresponding to the direction to each beacon from which said waves are received, said points merging into substantially a single point on said screen at a position corresponding to the direction of said area when the craft is at sufficient distance therefrom and separating into a plurality of points when said craft approaches said area, means additionally to produce two lines of light at right angles to each other across said screen and intersecting each other at a desired point when the plane is in level flight on a predetermined course, and means controlled by the orientation of said craft to cause each of said lines to move bodily in either of its two broadside directions in accord with the movement of said craft in the vertical or horizontal plane, whereby the pilot by observation of said screen may approach said area from a distance and locate his craft with respect to a predetermined course through said area, observe his glide angle with respect to said area and effect a landing at a desired position relative to said beacons.

2. In a blind landing system in which a plurality of spaced broadcast beacons are located about the area in which said landing is to be effected, a viewing screen carried by the craft, means to scan a fixed predetermined area ahead of said craft for radio waves produced by said beacons and to produce a point of light on said screen at a position corresponding to the direction to each beacon from which said waves are received, said points merging into substantially a single point on said screen at a position corresponding to the direction of said area when the craft is at sufficient distance therefrom and separating into a plurality of points when said craft approaches said area, and means controlled by the orientation of said craft to produce two additional separate indicia intersecting on said screen and moving over said screen in directions at right angles to each other in accord with the movement of the craft with respect to predetermined directions in the horizontal and vertical planes respectively, whereby a pilot by observation of said screen may approach said area from a distance and locate his craft with respect to a predetermined direction through said area, select a glide angle relative to said area and effect a landing between said beacons.

3. In a blind landing system in which a plurality of continuously radiating spaced broadcast beacons are located about the area in which said landing is to be effected, a viewing screen carried by the craft, means to scan a fixed predetermined area ahead of said craft for radio waves produced by said beacons and to produce a point of light on said screen at a position corresponding to the direction to each beacon from which said waves are received, said points merging into substantially a single point on said screen at a position corresponding to the direction of said area when the craft is at sufficient distance in any direction therefrom and separating into a plurality of points when said craft approaches said area, and means controlled by the orientation of said craft to produce two additional indicia intersecting on said screen moving over said screen and in directions at right angles to each other in accord with the movement of the craft with respect to predetermined directions in the horizontal and vertical planes respectively, whereby a pilot by observation of said screen may approach said area from a distance and locate his craft with respect to a predetermined direction

through said area, select a glide angle relative to said area and effect a landing between said beacons.

4. In blind landing system in which a plurality of spaced radiating radio beacons are positioned about an area on which landing is to be effected, of a cathode ray device having a viewing screen, means to scan the area ahead of an aircraft for received radio waves and to control said cathode ray device to produce a spot on said screen positioned in accord with the direction to each beacon from which such waves are received, the direction of said area being indicated by substantially a single spot resulting from merging of said spots when said aircraft is distant from said area and the directions of the individual beacons being indicated by individual spots when said craft approaches nearer said beacons, and means controlled by the orientation of said craft to produce two additional intersecting indicia on said screen one moving horizontally in accord with the direction of movement of said craft in the horizontal plane with reference to a predetermined direction in said plane and the other moving vertically in accord with the angle of climb or glide of said craft, whereby the operator by observing said screen may approach said area, locate his plane with respect to a predetermined direction through said area, glide his craft with respect to said area and land at a desired point with respect to said beacons.

5. In a blind landing system in which radio beacons are located about the area in which landing is to be effected, said beacons radiating waves of a high frequency throughout paths of approach for aircraft, and two or more of said beacons being located on each side of a predetermined landing course through said area, a cathode ray device carried by an aircraft having a viewing screen, a directional antenna, means to scan the area ahead of said craft with said antenna and correspondingly to deflect the ray of said device across said screen, means to control the intensity of said ray in accord with the instantaneous intensity of said waves received on said antenna during said scanning thereby to produce spots on said screen at locations corresponding to the directions from which said waves are received, means to cause the waves radiated from beacons on the same side of said course to be in phase, and means to cause the waves from beacons on one side of said course to have a predetermined phase angle with respect to the waves from beacons on the opposite side of said course, whereby when said craft is on said course extending across said area the spots produced by beacons on one side of the course tend to blend into an elongated area on the corresponding side of said screen and spots produced by beacons on opposite sides of said course tend to separate.

6. In a system for guiding aircraft to a landing area near a radiating beacon, the combination of a viewing screen, means carried by an aircraft responsive to waves received from said beacon to produce on said screen an indicium moving in a predetermined direction across said screen in accord with the direction from which said waves are received, means controlled by the horizontal orientation of said craft to produce a second indicium moving across said screen in the same direction in accord with the direction of movement of said craft relative to a predetermined direction in the horizontal plane, and means controlled by the vertical orientation of said craft to produce a third indicium positioned on said screen in a direction at right angles to said first direction and moving in accord with the angle of ascent or descent of said craft relative to the horizontal, whereby said craft may be guided to a predetermined course through said area and by relating the positions of said indicia a glide path may be chosen from the craft to effect a landing along said course on said area.

7. In a system for guiding aircraft to a landing area near a radiating beacon, the combination of a viewing screen, means on said aircraft responsive to waves from said beacon to produce an indicium moving over said screen in a predetermined direction in accord with the direction from which said waves are received, and means controlled by the vertical orientation of said craft to produce a second indicium positioned on said screen and moving in accord with the angle of ascent or descent of said craft with respect to the horizontal, whereby the relative movement of said indicia constitutes an indication from which a proper glide path to said area may be selected.

8. The combination, in an aircraft guiding system, a cathode ray device having a viewing screen, directive radio receiving means, means to scan the area forward of said craft by said radio receiving means and to correspondingly deflect the ray of said device over said viewing screen, means responsive to received waves to control said cathode ray device to produce indicia on said screen at positions corresponding to the direction from which radio waves are received, means controlled by the orientation of said craft and operative at alternate intervals during said scanning operation to produce first and second voltages in sequence, said voltages being functions of the angular position of said craft with respect to vertical and horizontal reference planes respectively, means utilizing said first voltage to produce a vertical deflection of said ray at a position on said screen corresponding to the direction of movement of said craft with respect to said vertical plane and means utilizing said second voltage to produce a horizontal deflection of said ray at a position on said screen corresponding to the angle of ascent or descent of said craft with respect to said horizontal plane.

9. The combination, in an aircraft guiding system, a cathode ray device having a viewing screen, directive radio receiving means, means to scan the area forward of said craft by said radio receiving means and to correspondingly deflect the ray of said device over said viewing screen, means responsive to received waves to control said cathode ray device to produce indicia on said screen at positions corresponding to the directions from which radio waves are received, means controlled by the orientation of said craft and operative at alternate intervals during said scanning operation to produce first and second voltages in sequence, said voltages being functions of the angular position of said craft with respect to vertical and horizontal reference planes respectively, means utilizing said first voltage to produce a vertical deflection of said ray at a position on said screen corresponding to the direction of movement of said craft with respect to said vertical plane, means utilizing said second voltage to produce a horizontal deflection of said ray at a position on said screen corresponding to the angle of ascent or descent of said craft with respect to said horizontal plane,

and means to intensify said ray during said horizontal and vertical deflections.

10. In a blind landing system for aircraft in which carrier wave radiators are positioned at opposite sides of a landing area, the carrier wave radiated by said radiators being modulated at the same frequency but in opposed phase relation, the combination of a viewing screen, means to scan the area forward of a craft to be landed on said area for carrier waves from said radiators, means to demodulate said carrier waves to reproduce oscillations of the frequency of said modulation, and means responsive to said oscillations to produce a spot on said screen positioned in accord with the direction from which the received carrier waves arrive and of area dependent on the intensity of said oscillations, whereby a single spot is produced when said craft is at such a distance from said area that waves from the different radiators arrive from substantially the same direction and as said craft approaches said area said spot divides into two spots moving apart as the directions to different radiators diverge, the definition of said two spots being enhanced by the opposed phase relation of oscillations received from said two radiators.

11. In a blind landing system for aircraft, the combination of a pair of carrier wave radiators positioned at opposite sides of an area on which landing is to be effected, the carrier wave radiated by said radiators being modulated in opposed phase, a cathode ray device having a viewing screen carried by a craft to be landed, directive means to scan the area forward of said craft for waves from said radiators, means to deflect the ray of said device over said screen in accord with the scanning movements of said directive means, means to demodulate the received carrier wave and to intensify said ray in accord with the intensity of the reproduced modulation products whereby when the craft is sufficiently close to said radiators that waves therefrom arrive from different directions different spots are produced on said screen one corresponding to each of said directions, the definition between said spots being increased by the opposing phase of the modulations of the carrier waves received from the two radiators when said directive scanning means is directed in a direction between said radiators.

12. In a blind landing system for aircraft, the combination of a pair of carrier wave radiators positioned at opposite sides of an area on which landing is to be effected, the carrier wave radiated by said radiators being modulated in opposed phase, a cathode ray device having a viewing screen carried by a craft to be landed, directive means to scan the area forward of said craft for waves from said radiators, means to deflect the ray of said device over said screen in accord with the scanning movements of said directive means, means to demodulate the received carrier wave and to intensify said ray in accord with the intensity of the reproduced modulation products whereby when the craft is sufficiently close to said radiations that waves therefrom arrive from different directions different spots are produced on said screen one corresponding to each of said directions, the definition between said spots being increased by the opposing phase of the modulations of the carrier waves received from the two radiators when said directive scanning means is directed in a direction between said radiators, and means to maintain constant the average intensity of said reproduced modulation products

as said craft approaches said radiators while permitting variation in intensity of said modulation products with variation in intensity of the received carrier wave as the direction of said directive scanning means is varied across said scanned area forward of said craft.

13. In a blind landing system for aircraft, the combination of a pair of carrier wave radiators positioned at opposite sides of an area on which landing is to be effected, the carrier wave radiated by said radiators being modulated in opposed phase, a cathode ray device having a viewing screen carried by a craft to be landed, directive means to scan the area forward of said craft for waves from said radiators, means to deflect the ray of said device over said screen in accord with the scanning movements of said directive means, means to demodulate the received carrier wave and to intensify said ray in accord with the intensity of the reproduced modulation products whereby when the craft is sufficiently close to said radiators that waves therefrom arrive from different directions different spots are produced on said screen one corresponding to each of said directions, the definition between said spots being increased by the opposing phase of the modulations of the carrier waves received from the two radiators when said directive scanning means is directed in a direction between said radiators, and further means to increase said definition said further means comprising an amplifier for said demodulation products between said demodulating means and said cathode ray device, said amplifier having output increasing as the square of the input to the amplifier.

14. In a blind landing system, a plurality of carrier wave radiators positioned at opposite sides of a landing course, the carrier wave radiated by radiators on the same side of said course being modulated in phase and in phase opposite to the modulation of the radiation from radiators on the opposite sides of said course, a directive radio scanning system carried by an aircraft and arranged to scan the area forward of said craft for waves from said radiators, a cathode ray device having a viewing screen, means to deflect the ray of said device over said screen in accord with the scanning movements of said directive scanning means and to modulate said ray in accord with the intensity of the modulation of said received waves whereby when said craft approaches said course from a direction extending between said oppositely modulated radiators a spot first appears on said screen, said spot thereafter dividing into two elongated spots due to blending of spots produced by in-phase modulation of beacons on one side of said course, and the definition between said spots being enhanced by the opposed phase modulation of radiation from radiators on the opposite sides of said course.

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Certificate of Correction

Patent No. 2,451,793. October 19, 1948.

ERNST F. W. ALEXANDERSON ET AL.

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 6, line 41, for the word "resistance" read *resistances*; line 72, same column, after "82*a*" strike out *to*; column 7, line 23, for "signals" read *signal*; column 10, line 69, claim 3, after "screen" strike out "and" and insert the same in line 68, before "moving";

and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 28th day of June, A. D. 1949.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.

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