DEVELOPMENT OF AN INSTRUMENT FOR MEASURING AIRCRAFT COCKPIT VISIBILITY LIMITS

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SUMMARY

After much investigation, and following the elimination of other prospective methods, a binocular strip-film camera was considered to be the most practical means for measuring and recording cockpit visibility limits in terms of angles of vision This report describes such a camera

A photographic record showing the outlines of the windows in aircraft cockpits, as seen by the pilot when he turns his head from extreme left to extreme right, can be easily and quickly made with the camera The camera automatically superimposes a grid of horizontal and vertical lines in increments of 5° on the picture, and in this way records the angles of vision in aircraft cockpits

The camera uses two lenses, the spacing of which is equal to the average distance between the human eyes Thus, the binocular effect of obstructions to vision, such as windshield posts, instruments, etc , is obtained

The camera is capable of recording the complete inside of a sphere except for the extreme polar regions, and performs with sufficient accuracy to permit a very close duplication of data while working in the crowded conditions of aircraft cockpits It is not restricted to utility in aircraft cockpits alone, but is equally useful in any type of similar enclosure, for example, the inside of an automobile

INTRODUCTION

Several years ago, the problem of vision from aircraft cockpits, as related to window size, type and location, began to receive increasing attention Such attention was precipitated as a result of mid-air collisions in which the pilots involved did not see the other aircraft at all, or until essentially at the instant of impact It also was evident that entirely different standards of vision were being used in the design of new aircraft, and that vision in some models was considered inadequate by pilots and regulatory authorities

During 1948, the Civil Aeronautics Administration Technical Development and Evaluation Center embarked on an investigation of this problem The purpose of the investigation was to establish, on some reasonable basis, definite standards of vision that would assure adequate visibility in aircraft, which — in turn — would promote safer operation of aircraft

Early in the investigation it became evident that it would be necessary to establish a standard means for measuring visibility Several existing instruments and techniques used to measure angles of vision were evaluated, but none were considered to be entirely satisfactory The instrument described herein was designed and constructed for use in the TDEC investigation, and for use by industry and regulatory personnel in the design and airworthiness certification of aircraft

The investigation being carried on at the TDEC is quite broad in scope, and one phase of the investigation already completed has been reported [1]

GENERAL CONSIDERATIONS OF INSTRUMENT DESIGN

Many types of measuring devices that have been used to record aircraft cockpit visibility have been evaluated One interesting type records the visual fields by placing a model of the aircraft cockpit inside a cylinder lined with sensitized paper [2] An exposure is then made by lighting a small lamp placed within the model at the location of the pilot's eye The zones of shadow on the film thus represent a cylindrical projection of the contours of the pilot's field of view Another type is an instrument called the Visiometer, which is made by fastening two protractors together [3] Measurements are made of the limitations imposed by the structural features of the aircraft and plotted on polar projections Another type studied uses a special sighting device incorporating peep-

[1]George L Pigman and Thomas M Edwards, "Airline Pilot Questionnaire Study on Cockpit Visibility Problems," CAA Technical Development Report No 123, September 1950

[2]E A Vannucci, "Diagram of the Pilot's Field of View," Atti Guidonia 19(42) 13-20, 1941

[3]Melvin N Gough, "The Measurement of the Field of View From Airplane Cockpits," NACA Report 514, 1935

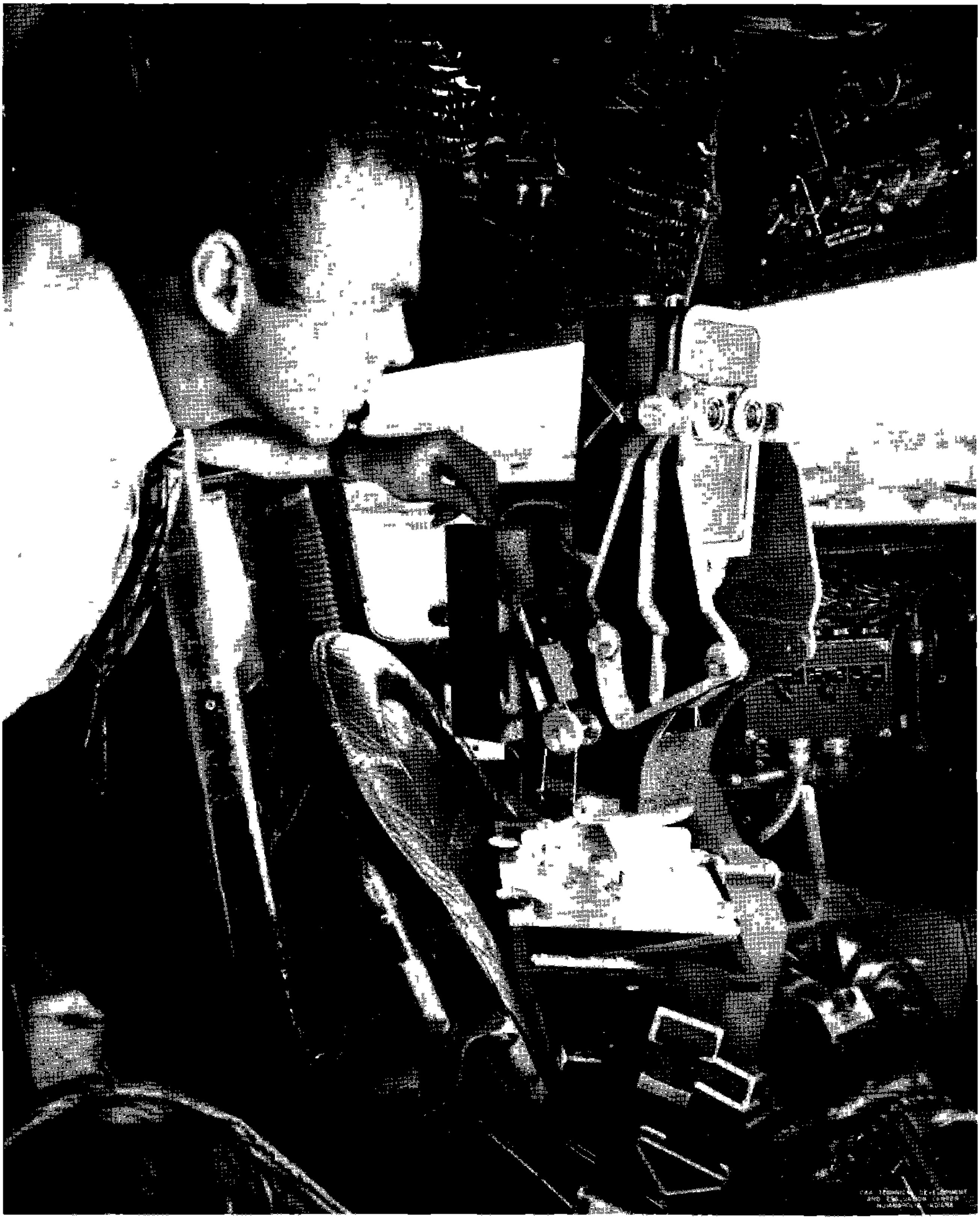

Fig 1 Binocular Cockpit Visibility Camera Set Up In Douglas DC-3 Cockpit

holes and protractors to locate points for plotting [4] Another instrument consists of a self-leveling vertical scale for reading angles of elevation and depression, and a directional gyro to provide the azimuthal scale [5] Estimations are made at 5° intervals, and the data are plotted on graph paper In still another design, a pinhole camera photographically records the visual fields [6] The image is superimposed on a grid which permits the angles of vision to be read directly from the film Several shots are required to measure the entire cockpit

None of the devices afore-mentioned possesses all the features which are considered to be necessary and desirable for a standard instrument to be employed for the purpose of measuring cockpit visibility In this respect, such an instrument should consistently provide accurate results, which can be obtained quickly and with comparative ease in the crowded confines of aircraft cockpits, allow easy interpretation of the final record, permit a record to be made showing the effect of pilot head and shoulder movement and produce a record which shows the effect of structural and cockpit equipment obstructions on the pilot's field of vision as seen by a pilot with both eyes

In developing the present camera, a mock-up model, using only one lens, was made from a converted "Cirkut" camera This was an extremely large and bulky instrument, and served only to prove the basic theory However, it was possible to establish a correct rotating speed and film movement relationship The width of the exposure slot also is very critical and was established in the mock-up camera The present camera was designed and built at the CAA TDEC at Indianapolis, Indiana

DESCRIPTION OF THE BINOCULAR COCKPIT VISIBILITY CAMERA

Illustrated in Fig 1 is the binocular cockpit visibility camera which was designed for use as a standard means of measuring and recording cockpit vision angles It weighs 46 pounds Assembled on the tripod, its maximum dimensions are 15 inches in width, 15 1/2 inches in depth and 35 3/4 inches in height The two lenses are approximately 30 inches above the feet of the tripod, thereby placing them at the eye-level of the average seated pilot

The camera can be conveniently set up in the pilot's seat and secured in place by using the pilot's seat belt The forward leg of the three-leg mount is adjustable to permit initial leveling Final leveling is accomplished by using the four screws on the transit head-type mount adjustment In this camera, the film moves at a speed of 0 465 inches per second, and the entire camera rotates about a vertical axis at a rate of 1 revolution every 36 seconds, or 10° per second

A schematic diagram, showing the arrangement of the optical system, can be seen in Fig 2 The optical system, shown

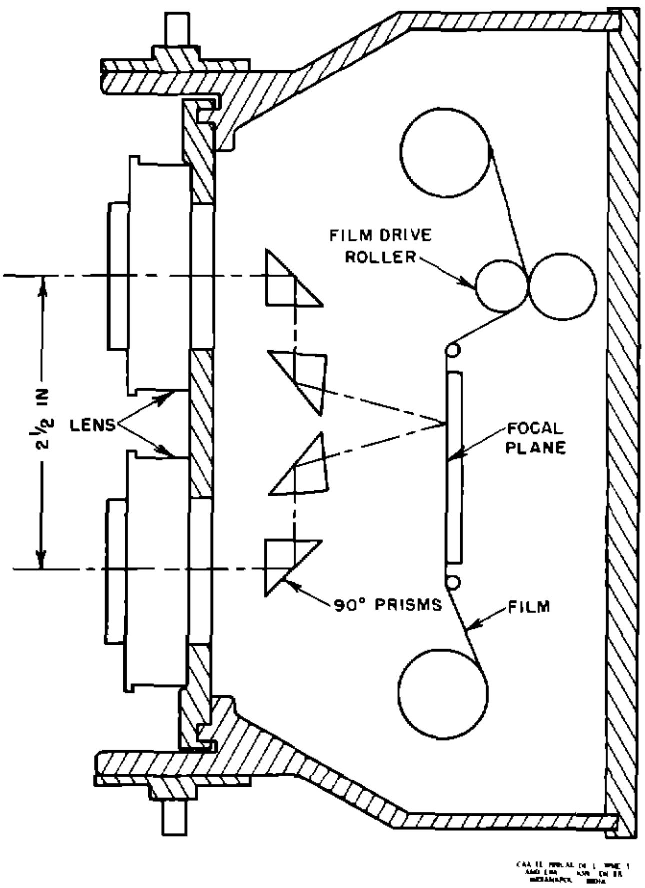

Fig 2 Section Through Camera Showing Optical Arrangement

[4] W B Klemperer, "Cockpit Visibility Limits," Douglas Aircraft Company Report No 2678

[5] M Leyzorek, "Hand-Held Instrument for Measuring Visual Fields From Aircraft," AAF Air Technical Service Command, Engineering Division, Memorandum Report No TSEAL 3-695-48C, 11 April 1945

[6] Jean St Thomas, "Four Cameras for Research in the Aeronautical Field," Photographic Engineering 1 76-93, July 1950

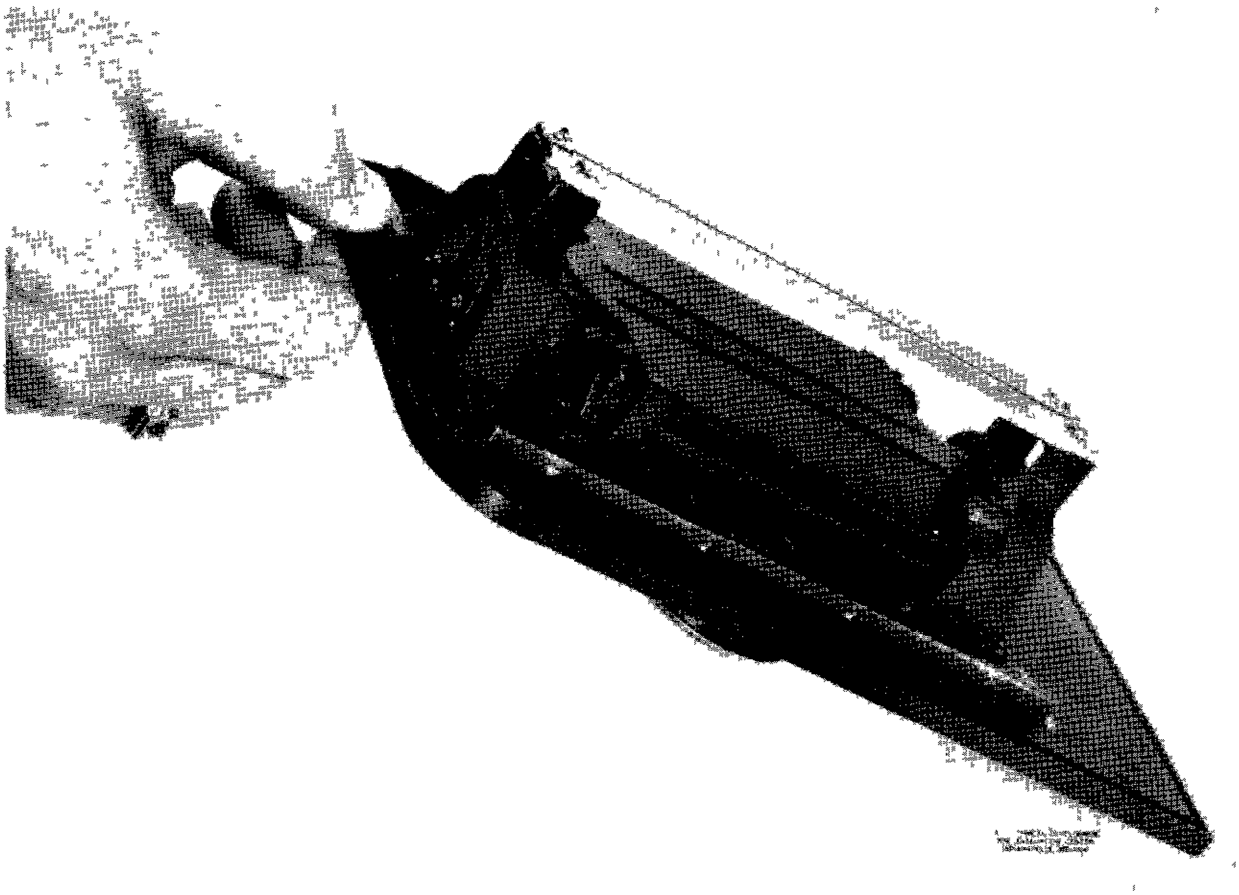

Fig 3 Complete Optical Assembly

in Fig 3, was designed as an integral unit with the face or front of the camera and, by removing six screws in front and three screws in the back, the entire optical system may be removed for cleaning or collimating The lenses used in the binocular camera are Wollensak 65 mm, F 6 8, Raptar wide angle, mounted in Alphax shutters The angular coverage is 88 1/2° The lenses were matched on an optical bench to select two of them with exactly the same focal lengths They are mounted in the camera on a flat surface so that their optical axes are parallel The distance between the two optical axes is 2 1/2 inches, which is the average interocular distance separating the human eyes The axis about which the camera moves when the elevation adjustment is made passes through the second nodal point of the lenses, so that there will be no shift of image when the vertical angle of the camera is changed The elevation adjustment is shown in Fig 4 The camera rotates about a vertical axis that is normally located 3 1/3 inches from the lenses This dimension corresponds to the mean distance between the front of the human eye and the odontoid process, i e , the pivot about which the skull rotates in the vertebral column By moving the camera to a position shown in Fig 5, the lenses rotate about an 8 1/3-inch radius instead of the 3 1/3-inch radius This adjustment is used to record the cockpit vision angles as they would appear to the pilot if he moved his head five inches forward of his normal position In designing the camera in this manner, it was assumed that the pilot will move his head and eyes in the direction he is seeking increased vision

The four prisms, shown in Fig 2, are adjustable for vertical collimation, and they are rotatable to permit the images to be

[7] M V Hall and L J Greenbaum, Jr , "Areas of Vision and Cockpit Visibility," Office of Aviation Safety, CAA

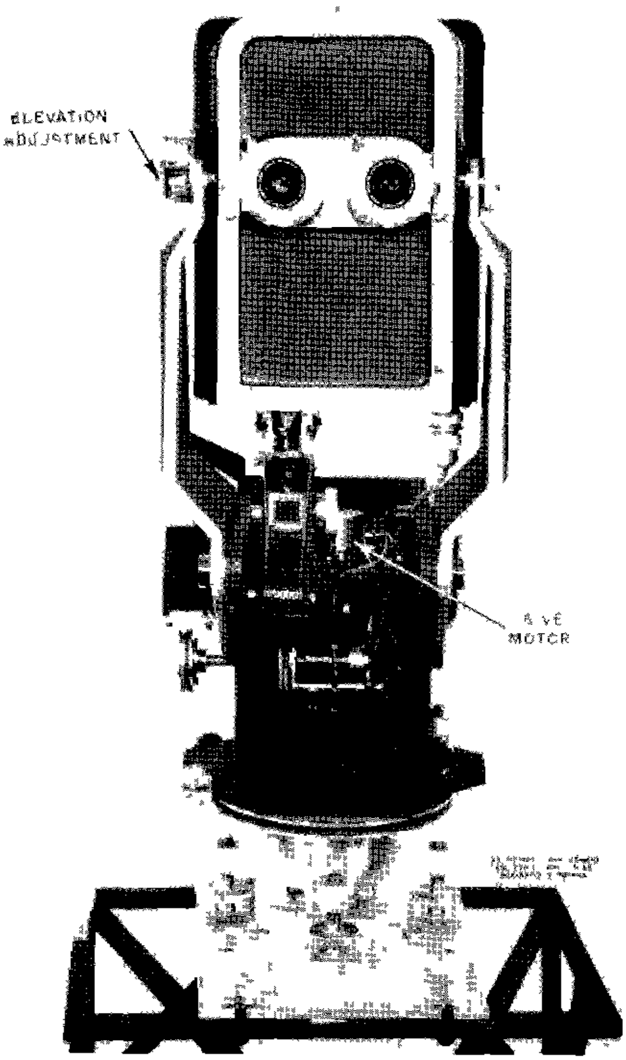

Fig 4 Front View of Binocular Cockpit Visibility Camera

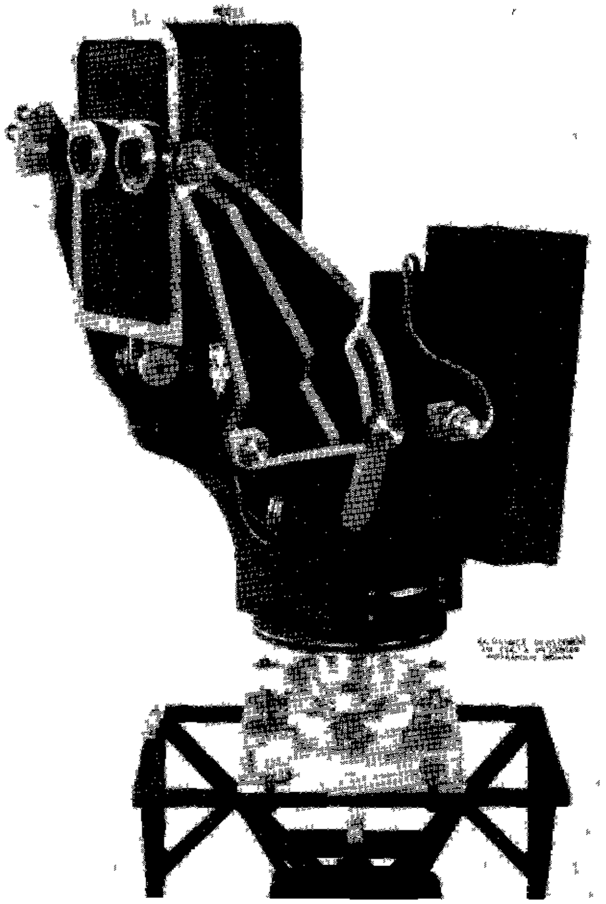

Fig 5 Camera Set in Five-Inch Forward Position to Simulate Pilot Head Movement

superimposed at a prescribed distance A distance of 200 feet was arbitrarily selected as the "infinity" at which images are superimposed All objects viewed by the camera beyond 200 feet are superimposed, whereas all objects viewed nearer than 200 feet appear double The distance between the two images increases as the object is moved closer to the camera The lenses are fixed focus and set for an object distance of 21 inches However, since f 22 or f 32 is the aperture size normally used, the resolving power at infinity is adequate to determine the location of the horizon

The film used in the camera is standard 6-inch by 5-foot or 10-foot Cirkut camera film A contact print of a Convair 240 cockpit is shown in Fig 6 The horizontal and vertical grids are located at 5° increments and are superimposed on the film as the cockpit visibility picture is taken The horizontal grid is produced by the insertion of a Plexiglas grid between the film and the lens in the 1/16-inch wide slot A, which may be seen in Fig 7 The vertical, or azimuth, grid is made by firing an argon lamp through the 0 005-inch wide slot B, also shown in Fig 7 The actuating cam, which is located on the film drive shaft, fires the argon lamp at 5° intervals of rotation Also shown in Fig 7 is the soft rubber roller that is used to drive the film

Evenly-distributed light over the entire length of the slot is obtained by using a Plexiglas tube with a white line painted on one side of it Both argon and neon lamps were tested, and it was found that the Super XX film was considerably more responsive to the argon lamp The lamp is located in the lamp box shown in Fig 7 The argon lamp

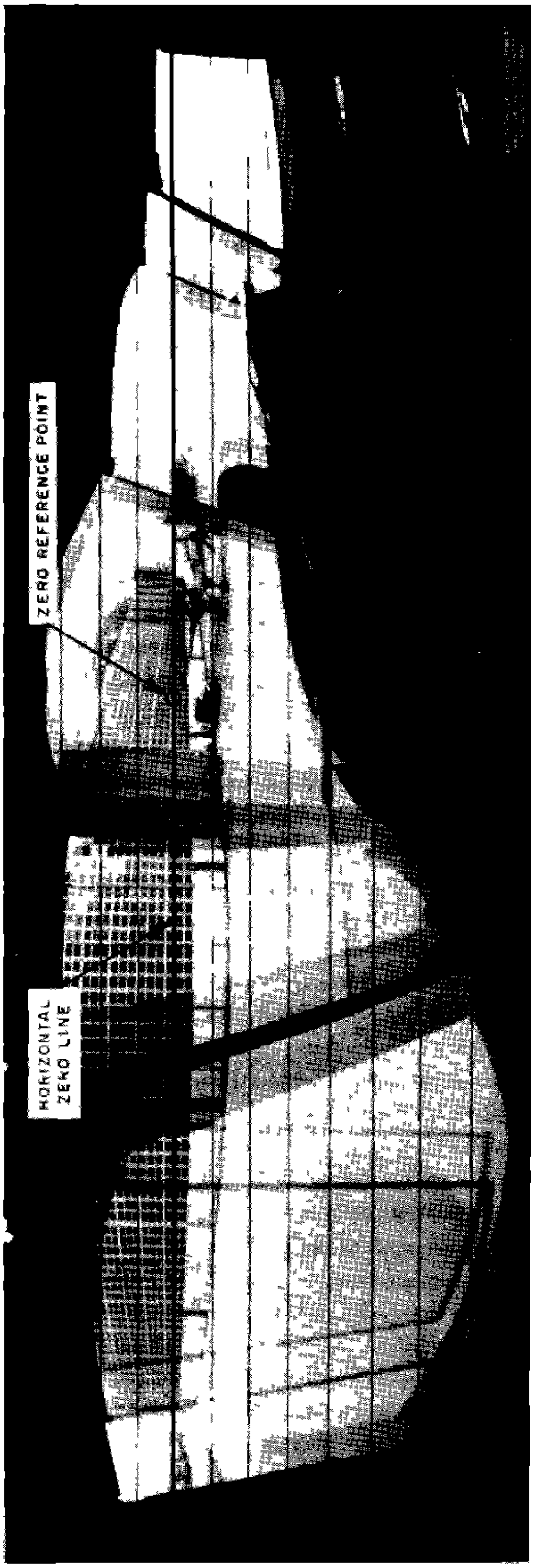

Fig 6 Cockpit Visibility Record of Convair 240 Airplane

is fired by the discharge of an 8-microfarad condenser charged to 270 volts The power is obtained from four 67 1/2-volt B batteries connected in series and housed in the battery box shown in Fig 8 The camera is rotated and the film is advanced by the electric-drive motor shown in Fig 4 This motor is powered by four 6-volt batteries connected in series. Batteries are shown in Fig 8

USE OF THE BINOCULAR COCKPIT VISIBILITY CAMERA

The camera is very simple to use and visibility records can be made very quickly The camera can be loaded and unloaded inside or outside of the airplane It is necessary only to level the camera in the pilot' s seat at the designed mean eye position and check the angle of coverage using the open sights shown in Fig 9 If the visibility angles are greater than 88 1/2°, it is necessary to make two sweeps with the camera at different elevation settings, also shown in Fig 9 A composite picture is then made by joining the two photographs together at the bisector of the two elevation angles at which the sweeps were made Such a record of a Boeing 377 airplane is shown in Fig 10

While making a cockpit visibility record, the airplane should be parked so that the sun' s rays strike the airplane from above and from the rear, and it is desirable that as much as possible of the horizon be visible from the cockpit However, it is not necessary to level the airplane This is compensated for, through use of a zero reference point on the windshield, which permits correction of the photographic record so obtained for any attitude of the airplane Zero reference points are indicated in Figs 6 and 10 The zero reference point is a point on the windshield straight ahead of the camera It is defined by the intersection of a horizontal and vertical plane The horizontal plane is at camera lens level The vertical plane is parallel to the plane of symmetry of the airplane and includes the axis of rotation of the camera

It is necessary to record the angle of inclination of the longitudinal axis of the airplane at the time the record is made With this inclination angle known, it is simple to correct the horizontal zero line for level flight attitude The horizontal zero line is a line drawn through the zero reference point, as shown in Figs 6 and 10 It is then evident that an additional correction is possible, to show the visibility angles permitted by the airplane structure with the aircraft in other attitudes

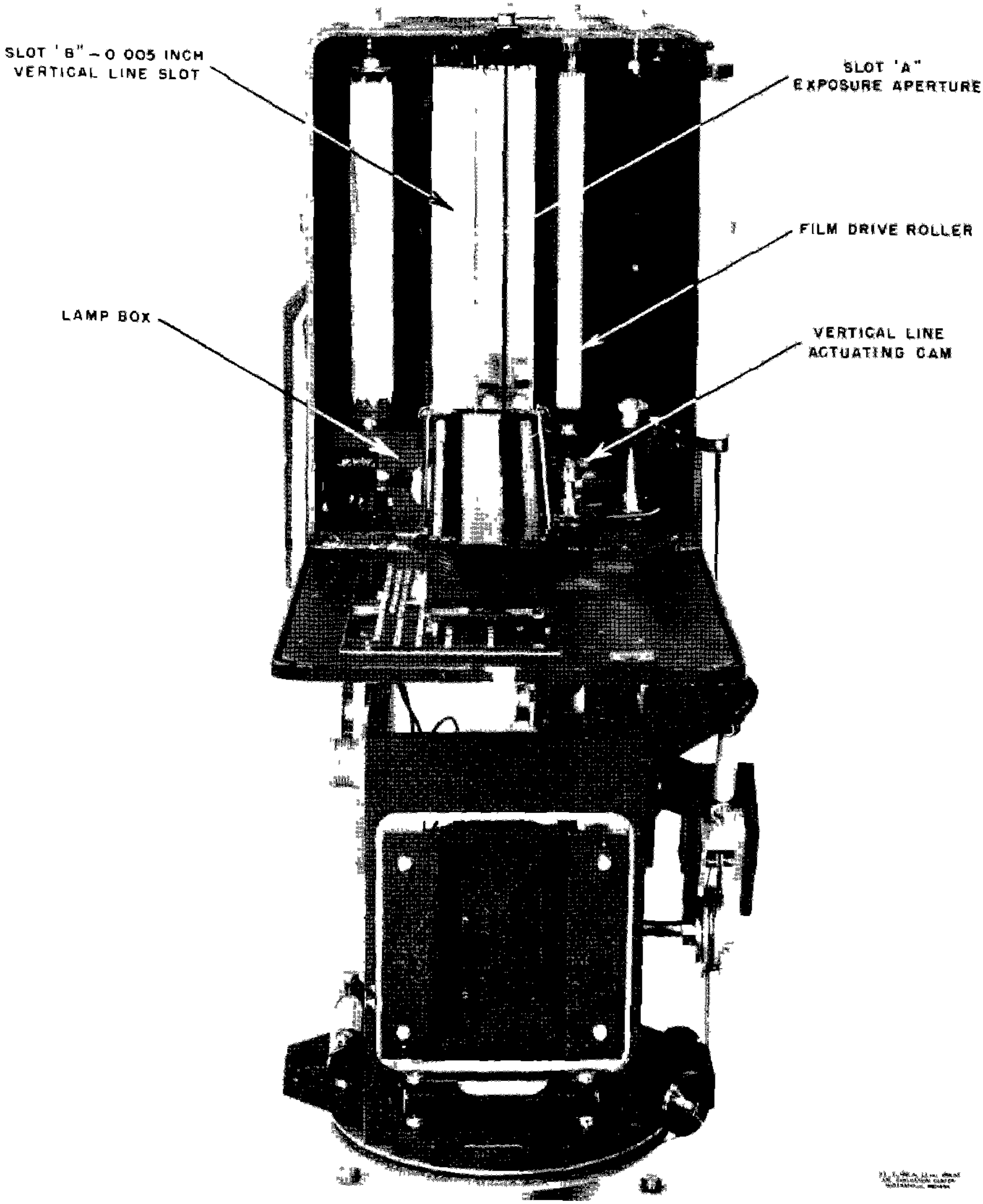

Fig 7 Rear View of Binocular Cockpit Visibility Camera With Back Open

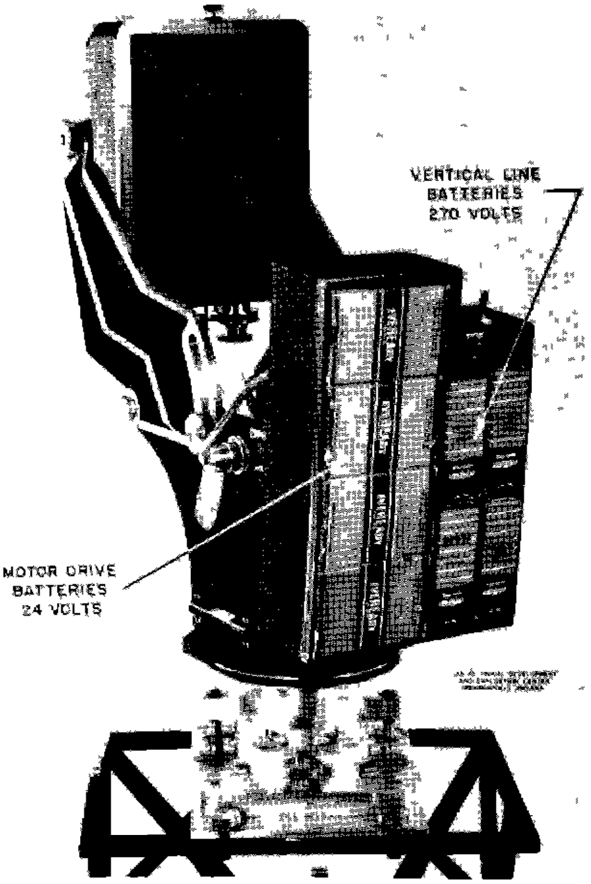

Fig 8 Battery Box With Cover Removed

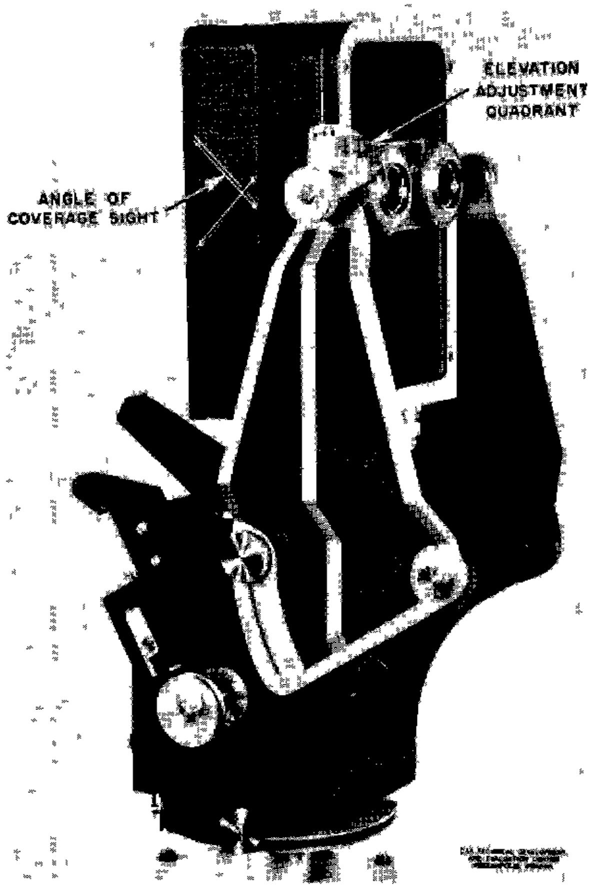

Fig 9 Side View of Binocular Cockpit Visibility Camera

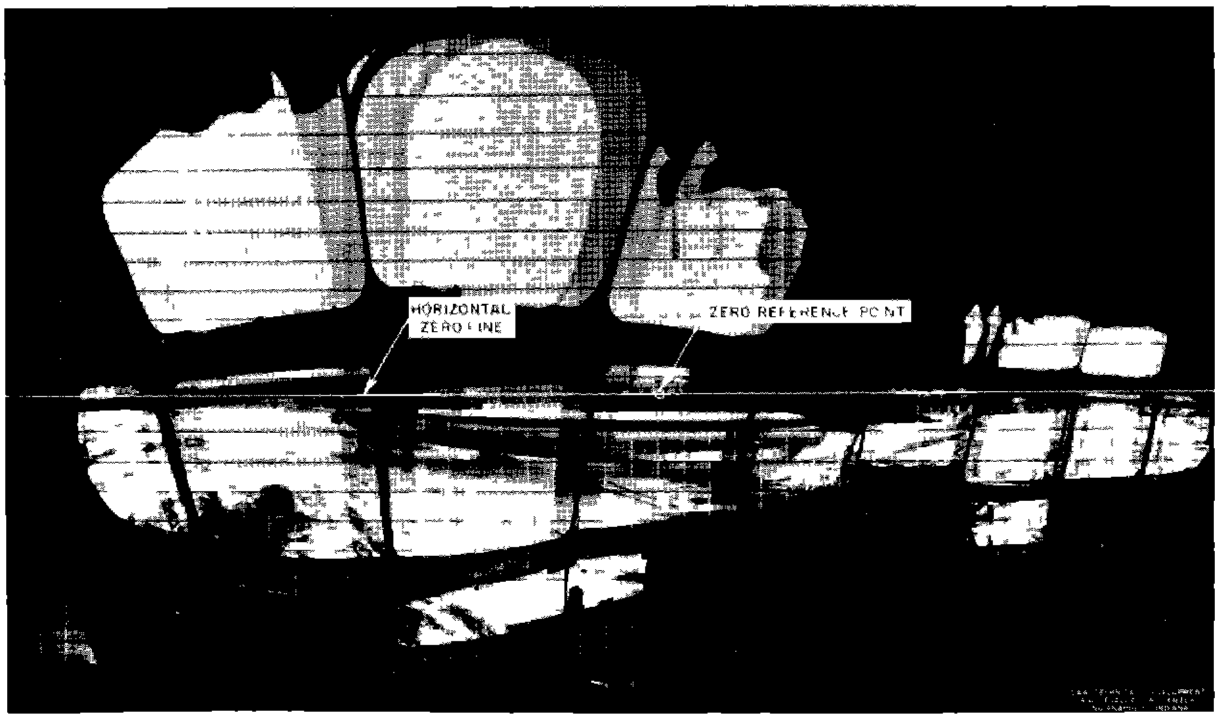

Fig 10 Composite Cockpit Visibility Record of Boeing 377 Airplane

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