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PRELIMINARY FLIGHT TESTS OF THE FARRAND OPTICAL SCANNER

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by

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SUMMARY

This report describes some preliminary flight tests of the Farrand Optical Scanner to determine the feasibility of supplementing pilot vision with an optical scanning device. The instrument was designed for installation in air carrier or commercial-type aircraft and to be operated by a crew member other than the pilot or copilot. Primarily, it was intended for use in the airport area where traffic congestion is a contributing factor to midair collisions.

Test results indicate that the maximum viewing range for the scanner is approximately 6 miles in clear weather using transport-type aircraft as a target. The average distance at which untrained subjects detected the target flying straight and level and overtaking the subject aircraft was 1.05 miles, while the average for trained subjects was 3.75 miles. The average distance for untrained subjects to detect a target on a converging course was 2.20 miles and for trained subjects it was 4.37 miles.

Nineteen subjects participated in 37 collision runs. Twelve subjects failed to detect the target aircraft during 12 of the 37 runs. There were no targets sighted by the subjects participating in the circular-convergence tests flown in the close proximity of an airport.

From the results of the tests, it can be concluded that the use of an optical scanning device as a supplemental aid to pilots' vision for detecting approaching aircraft shows some promise. The use of the scanner should be confined to those areas that normally are blind to both pilot and copilot, and the scanner operators should be given a period of training. A screen or pictorial-type presentation of the scanner picture should be investigated.

INTRODUCTION

Some advancement has been made in the past few years toward improving the visibility from aircraft cockpits. However, since airplanes maneuver in three-dimensional space, a pilot would have to be encased in a transparent bubble to see another aircraft at all of the angles from which it might approach. The bubble concept is out of the question with today's aircraft configuration, but the possibility of scanning all of the space about an airplane still exists.

At present, the only means of detecting a potential danger in areas normally blind to both pilot and copilot is to make clearing-turn maneuvers. Such maneuvers, if accomplished periodically and consistently, not only are costly operationally but they also add to the discomfort of the airline patrons. These maneuvers also would be hazardous when performed in a high density area.

This report describes an optical scanner, the flight tests that were conducted, and the results of the tests. The instrument was designed and constructed by the Farrand Optical Company, New York, N. Y. It was designed to study the feasibility of a device, to be operated by a third crew member, to scan the space around a transport-type airplane as an aid to the pilot in detecting the presence of other aircraft.

DESCRIPTION OF SCANNER

The optical design of the scanner is shown in the cross section, Fig. 1. The scanning prism rotates 360° about the vertical axis and a hand-operated crank rotates the prism. Four turns of the crank cause one complete rotation of the prism. The optic has a 76° cone of vision extending 56° above and 20° below the horizontal plane. Figure 2 shows the prism and rotating head as it appears on top of the fuselage. Figure 3 shows the scanner installation at the engineer's position. A desiccator was installed to prevent condensation forming on the lenses during flight at varying altitudes and in extreme temperature changes.

TEST PROCEDURE

It has been determined by previous studies and an analysis of midair collisions[1] that the most frequent angle of convergence for colliding aircraft is the direct overtaking of one airplane by another. Thus, the method used to test the scanner was influenced by these previous studies. The effectiveness of the scanner was measured by the distance at which a target airplane was detected by subject observers when the aircraft were flying collision courses simulating both airway and airport traffic conditions. Airway traffic was simulated by two aircraft on straight and level converging courses. The airport situation was simulated by a combination of straight and turning flight paths.

[1] R. Byron Fisher and Wayne D. Howell, "An Investigation of Some Parameters Related to Midair Collisions of Aircraft," CAA Technical Development Report No. 322 (in publication).

The tests were conducted in daytime only. Two phases of converging en route courses were flown, as illustrated in Fig. 4. The flights were made in the Indianapolis area using both VOR-DME and visual check points along each course for navigation. See Fig. 5. The two phases of airport traffic evaluation were conducted in a similar manner except that flight paths simulating straight-in approaches and left-hand turning departures were involved. The straight-in approach phase consisted of the subject's airplane flying a straight-in approach intercepted by the target aircraft which was flying a circular-departure pattern. The aircraft then changed their respective courses for the departure phase. In this case, the subject's airplane flew the circular-departure pattern and was intercepted by the target aircraft flying a straight-in approach. Typical flight paths used for the two phases of the airport condition are shown in Fig. 6.

Both male and female personnel of the Center acted as subject observers. All of the subjects were acquainted with flying and some held current pilot licenses. Two of the female subjects formerly were stewardesses. Since the scanner was designed for use by a third crew member, subjects were selected to include crew members that normally would act as observers on regular commercial flights.

An instruction sheet was supplied to each subject prior to the flight. Any questions the subject might ask during a short period of indoctrination with the scanner were answered by the accompanying project engineer. The subject was instructed to notify the supervising engineer each time an airplane was spotted during the evaluation flight. The pilots of each aircraft synchronized their progress along the flight paths by calling each check point via radio. When a subject saw the target airplane, the engineer would record the number of the nearest check point over which each airplane was flying and also the distance as indicated by the DME. The distance between the two aircraft could then be computed.

The engineer that accompanied each subject was in continuous contact with the pilots of both aircraft. Through radio communication and the remote-direction indicator on the scanner, the engineer could determine if the target spotted by the observer was the intended target flying the converging flight path. This same control and identification system was used for all flights.

Synchronous scanning indicators were installed on both the engineer's panel and the pilot's instrument panel to assist the engineer in determining the rate of scanning for each of the subjects as well as indicating the relative bearing to the target. A transmitter was attached to the scanner azimuth indicator to power both the engineer's indicator and the pilot's indicator.

A maximum threshold or range of 6 miles was established for the scanner in detecting a DC-3 type transport at an altitude of 5,000 feet in bright daylight with a clear blue sky as the background and the target airplane lighted by direct sunlight. To establish the threshold, the subject and target aircraft were flown on diverging courses of 45° separation and the light level was essentially constant during the flights. Two trained subjects were used and the maximum range, the distance at which the target passed from view, was the same for both flights.

In an effort to determine the improvement in scanning that might be expected from a training program and from experience in use of the scanner, two subjects were trained in the use of the scanner. These two subjects were then given several hours of practice scanning in flight prior to making the test runs.

Ground training consisted of:

1. Study of photographs of outlines of aircraft on converging flight paths for various angles of convergence.

2. Study of a chart of aircraft outlines shown at various distances of separation.

3. Viewing motion pictures of aircraft on collision courses shown at simulated rates of closure.

4. Study of different attitudes of aircraft models used to simulate aircraft on converging courses.

5. Practice of operation of the scanner at a rotational speed of between 2 1/2 to 3 rpm.

Flight training consisted of:

1. Study of constant-angle convergence and profile of airplanes for straight and level flight.

2. Learning to distinguish a turn and bank attitude of a target that would require tracking.

3. Practicing operating the scanner at 2 1/2 to 3 rpm.

The rate of scan of from 2 1/2 to 3 rpm provides a sweeping speed that is slow enough to permit detection, yet fast enough to see another airplane three times when it approaches from 6 miles at 300 mph. The subjects were then judged good, fair, slow, etc., according to the rate used in scanning.

TEST RESULTS

The distances at which the target aircraft was detected for each course of the two collision conditions are shown in Figs. 7, 8, and 9. Of 37 collision courses flown, there were 12 passes in which the target airplane was not detected for a total of 32 per cent missed. The greatest number of misses was during Phase 2 of the simulated terminal-area conditions, Fig. 9, in which all five subjects failed to detect the target. Four out of six subjects failed to detect the target during Phase 1 of the terminal-area conditions, two subjects missed during the overtaking phase of the airway condition, and one subject failed to detect the target during the converging-course phase.

Figures 7 and 8 also provide a comparison of the detection ranges for the untrained subjects and the two trained subjects. The difference in average detection distance for the two phases of the airways flight, for both trained and untrained subjects, is readily apparent. This difference in detection distance is attributed to the difference in the total area of the target presented by virtue of the attitude of the target airplane with respect to the subject airplane. The attitude of the target airplane and the area visible in each phase of the simulated airway condition is shown in the upper right-hand corner of Figs. 7 and 8. Table I shows the conditions existing at the time the evaluation flights were made.

Previous work at this Center has shown that the average transport pilot can be expected to detect a target aircraft, converging at an angle of 30°, at approximately 3.5 miles separation. Using the scanner, trained subjects detected the target aircraft at an average separation distance of 4.37 miles, converging at an angle of 15° which normally is blind to the pilots of transport-type aircraft.[2]

Turbulence and haze normally are encountered in the vicinity of airports. Both conditions were encountered during the terminal-area tests of the optical scanner. Some nausea discomfort was experienced by the subjects during these tests. Although turbulence is considered to be the prime cause

[2] Wayne D. Howell, "Determination of Daytime Conspicuity of Transport Aircraft." CAA Technical Development Report No. 304, April 1957.

of nausea or airsickness, it is believed that the procedure of keeping one eye fixed against the eye piece of the scanner (monocular vision) and the irregular scanning rate resulting from hand operation of the scanner crank were contributing factors. It also is believed that nausea contributed to the effects of turbulence and haze as concerns the failure of the subjects to detect the target airplane during the terminal-area tests.

CONCLUSIONS

It is concluded that:

1. The use of an optical scanning device as a supplemental aid to pilots' vision for detecting approaching aircraft shows some promise.

2. The scanner should be limited in its rotation to cover only the area normally blind to both pilot and copilot.

3. A more constant rate of scan could be maintained with the use of a motor-driven rotator.

4. There is an indication that operating personnel should be trained.

5. A screen or pictorial-type presentation should be investigated.

TABLE I

SUPPORTING CONDITIONS

AIRWAY EVALUATION (PHASE I)

Subject Observer	Scanning Rate*	Air	Visibility (miles)	Atmosphere	Target Lighting	Background
A	Fair	Smooth	10	Light Haze	Direct	Lt. White
B	Fair	Smooth	10	Light Haze	Direct	Lt. White
C	Good	Smooth	15	Clear	Direct	Lt. Blue
D	Fair	Smooth	15	Light Haze	Direct	Lt. Blue
E	Fair	Smooth	Unlimited	Light Overcast	Direct	Lt. Blue
F	Fast	Smooth	Unlimited	Light Overcast	Direct	Lt. Gray
G	Good	Med. Turb.	Unlimited	Clear	Direct	Lt. Blue
H	Slow	Med. Turb.	Unlimited	Clear	Direct	Lt. Blue
I	Slow	Smooth	Unlimited	Clear	Direct	Lt. Blue
J	Poor	Smooth	Unlimited	Clear	Direct	Cl. Blue
R	Good	Smooth	15	Light Haze	Direct	Lt. Blue
S	Good	Smooth	15	Light Haze	Direct	Lt. Blue
T	Good	Smooth	15	Light Haze	Direct	Lt. Blue

AIRWAY EVALUATION (PHASE II)

Subject Observer	Scanning Rate*	Air	Visibility (miles)	Atmosphere	Target Lighting	Background
A	Fair	Smooth	10	Light Haze	Direct	Lt. White
B	Fair	Smooth	10	Light Haze	Direct	Lt. White
C	Good	Smooth	15	Light Haze	Direct	Lt. Blue
D	Fair	Smooth	15	Light Haze	Direct	Lt. Blue
E	Good	Smooth	Unlimited	Light Overcast	Direct	Lt. Gray
F	Fast	Smooth	Unlimited	Light Overcast	Direct	Lt. Gray
G	Good	Med. Turb.	Unlimited	Clear	Direct	Lt. White
H	Slow	Med. Turb.	Unlimited	Clear	Direct	Lt. White
I	Slow	Smooth	Unlimited	Clear	Direct	Cl. Blue
J	Slow	Smooth	Unlimited	Clear	Direct	Cl. Blue
R	Good	Smooth	15	Light Haze	Direct	Lt. Blue
S	Good	Smooth	15	Light Haze	Direct	Lt. Blue
T	Good	Smooth	15	Light Haze	Indirect	Lt. Blue

TABLE I (cont'd)

SUPPORTING CONDITIONS

AIRPORT EVALUATION (PHASE I)

Subject Observer	Scanning Rate*	Air	Visibility (miles)	Atmosphere	Target Lighting	Background
K	Fast	Med. Turb.	10	Light Haze	Indirect	Lt. White
L	Good	Med. Turb.	10	Light Haze	Indirect	Lt. White
M	Slow	Med. Turb.	15	Clear	Indirect	Cl. Blue
N	Fast	Med. Turb.	15	Clear	Indirect	Lt. White
O	Good	Smooth	Unlimited	Clear	Indirect	Lt. Blue
P	Slow	Smooth	Unlimited	Clear	Indirect	Lt. Blue

AIRPORT EVALUATION (PHASE II)

Subject Observer	Scanning Rate*	Air	Visibility (miles)	Atmosphere	Target Lighting	Background
K	Fast	Lt. Turb.	10	Light Haze	Direct	Lt. White
M	Slow	Lt. Turb.	15	Clear	Direct	Lt. Blue
N	Good	Smooth	15	Clear	Direct	Cl. Blue
O	Fair	Smooth	Unlimited	Clear	Direct	Lt. Blue
P	Slow	Smooth	Unlimited	Clear	Direct	Lt. Blue

*Poor - 1 rpm or less
Slow - 1 - 1 1/2 rpm
Fair - 2 rpm
Good - 2 1/2 - 3 rpm
Fast - over 3 rpm
Cl. - clear
Lt. - light

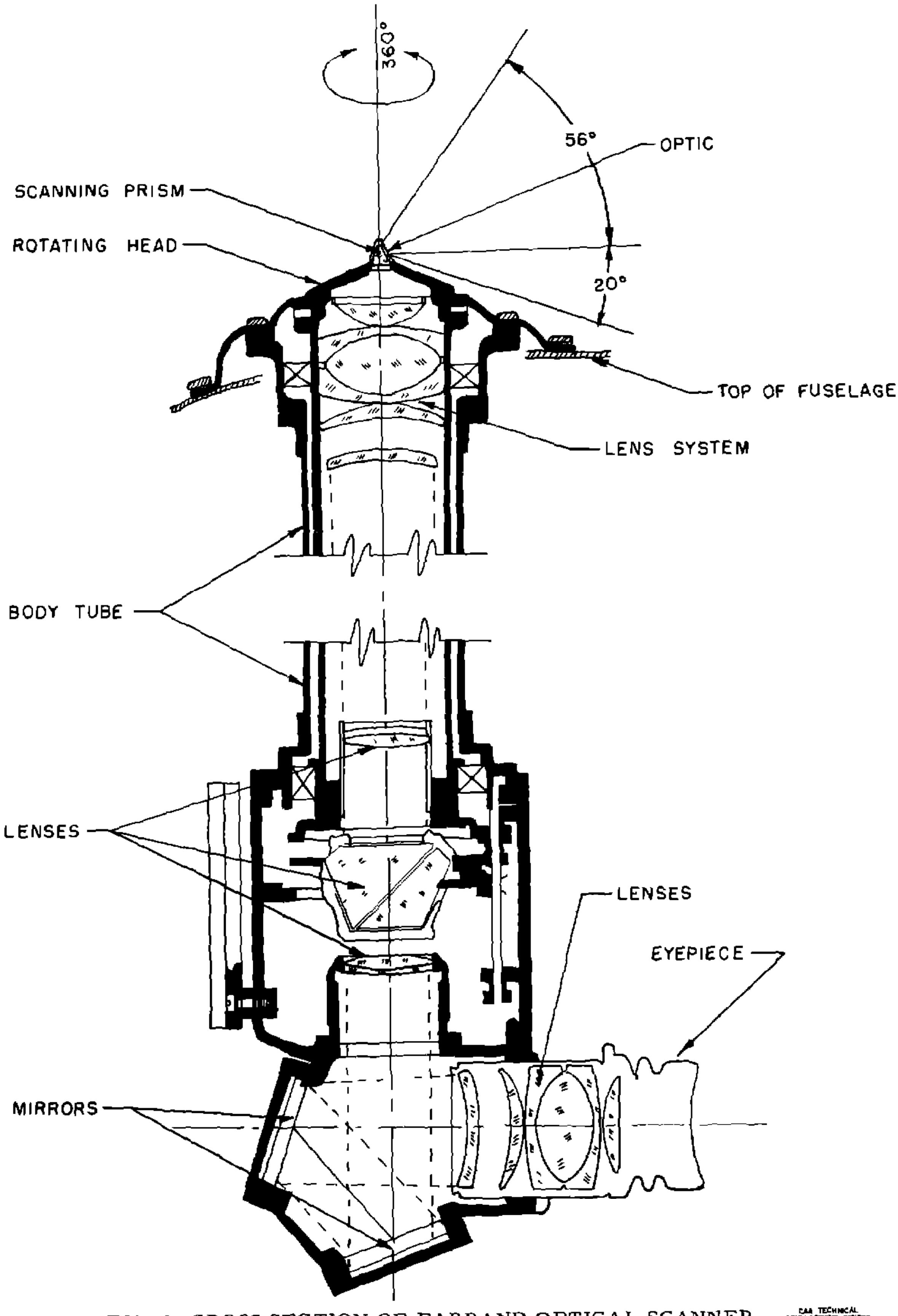


FIG 1 CROSS SECTION OF FARRAND OPTICAL SCANNER

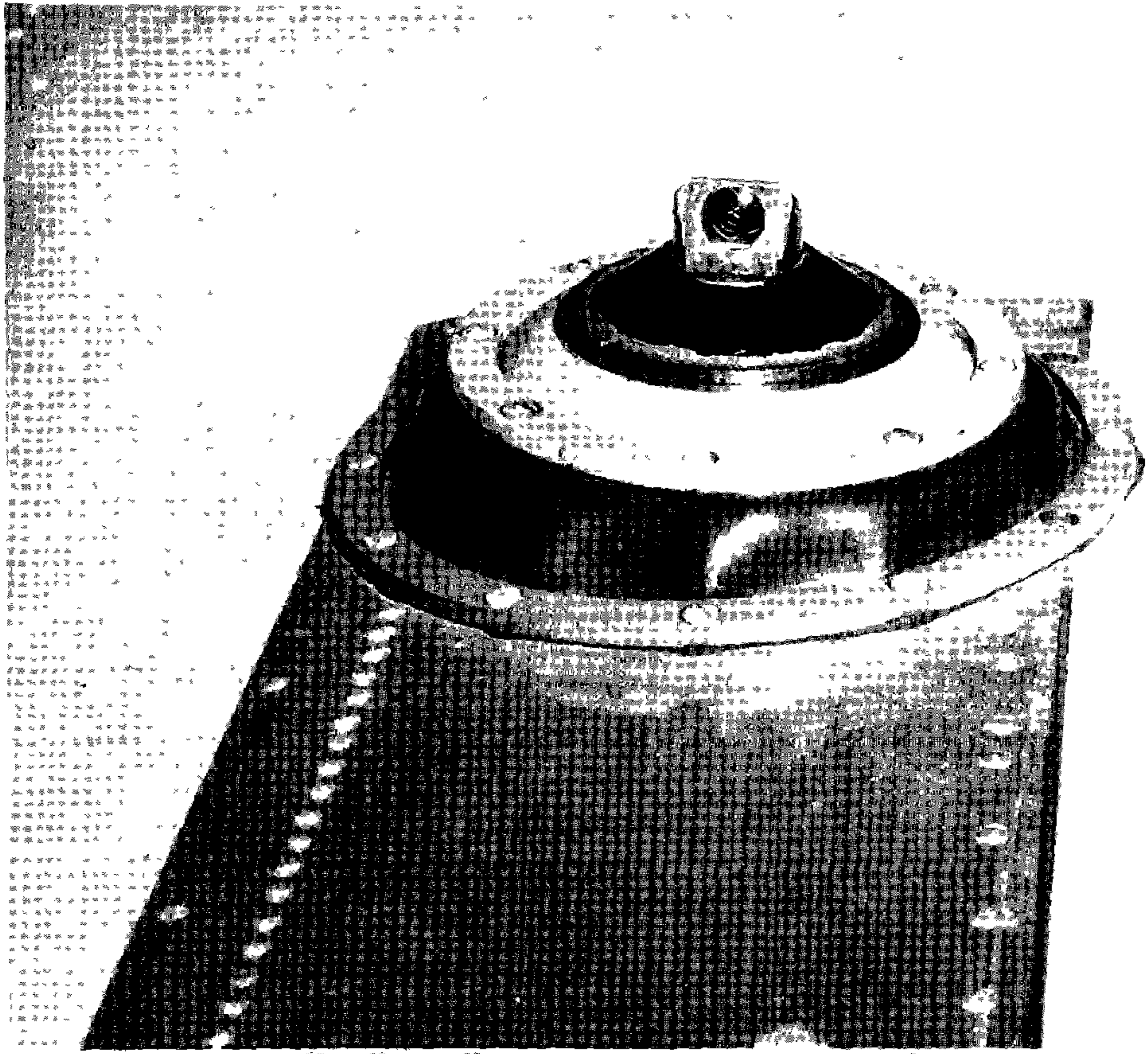


FIG. 2 SCANNER ROTATING HEAD SHOWING PRISM AND OPTIC

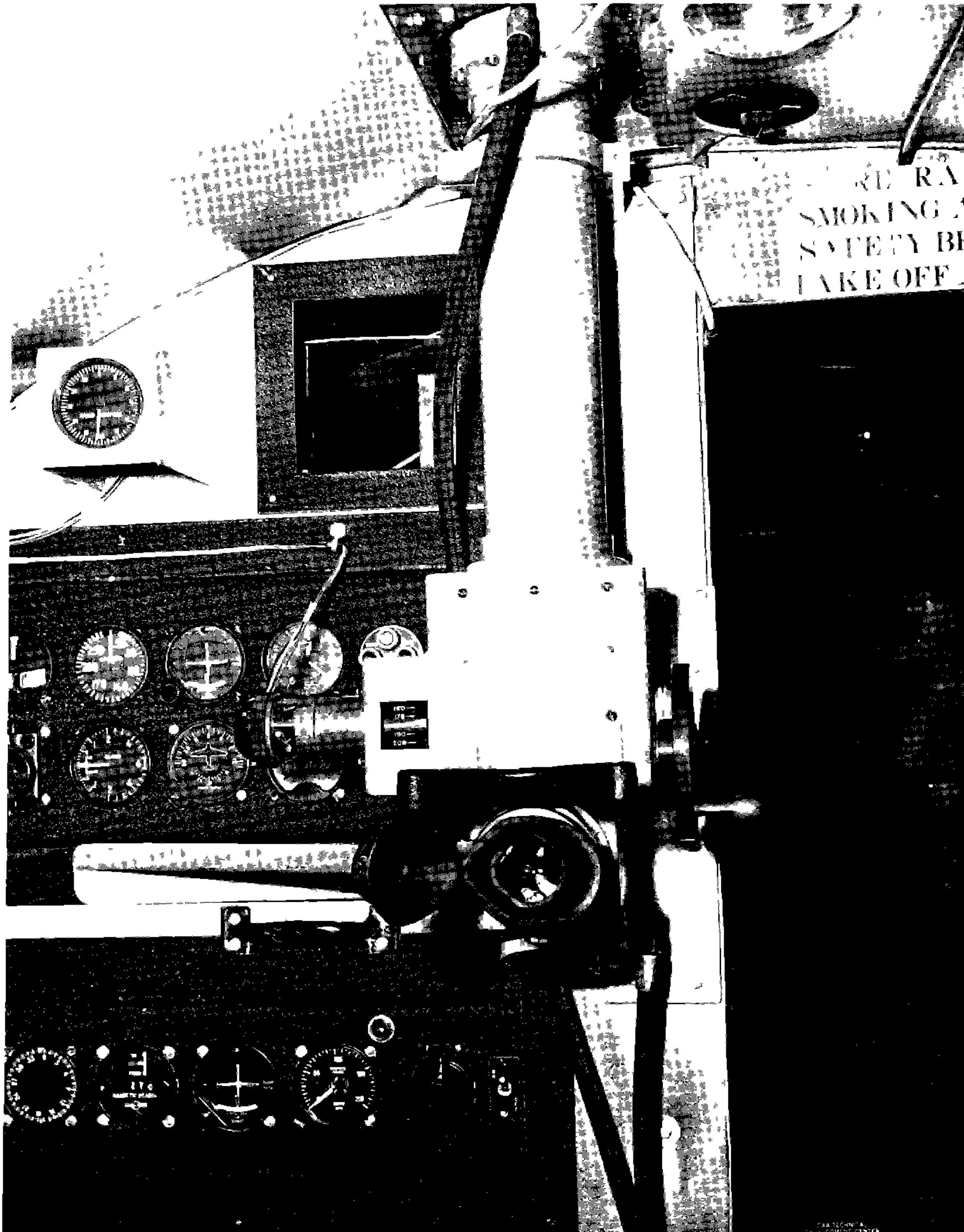
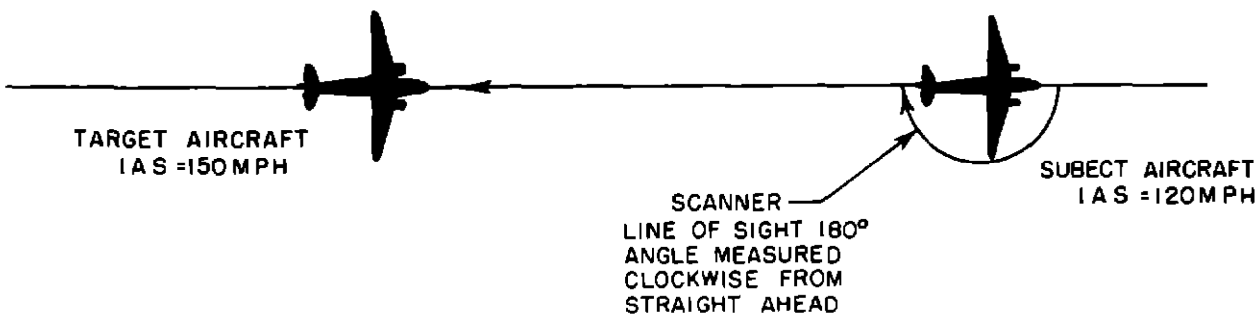


FIG 3 OPTICAL SCANNER INSTALLED IN A DC-3 AIRPLANE

DIRECT OVERTAKING CONDITION



15° CONVERGENCE ANGLE OVERTAKING CONDITION

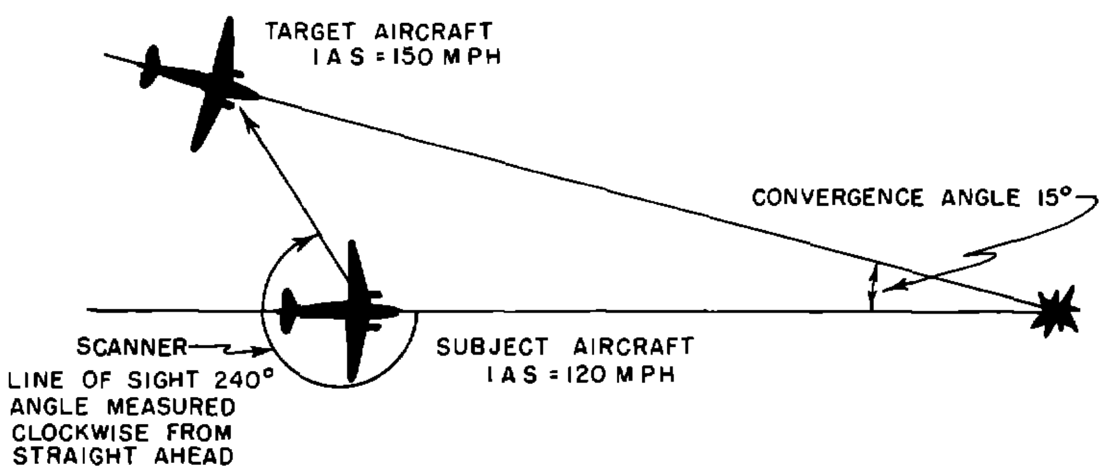


FIG 4 CRUISE CONDITION FLIGHT PATH

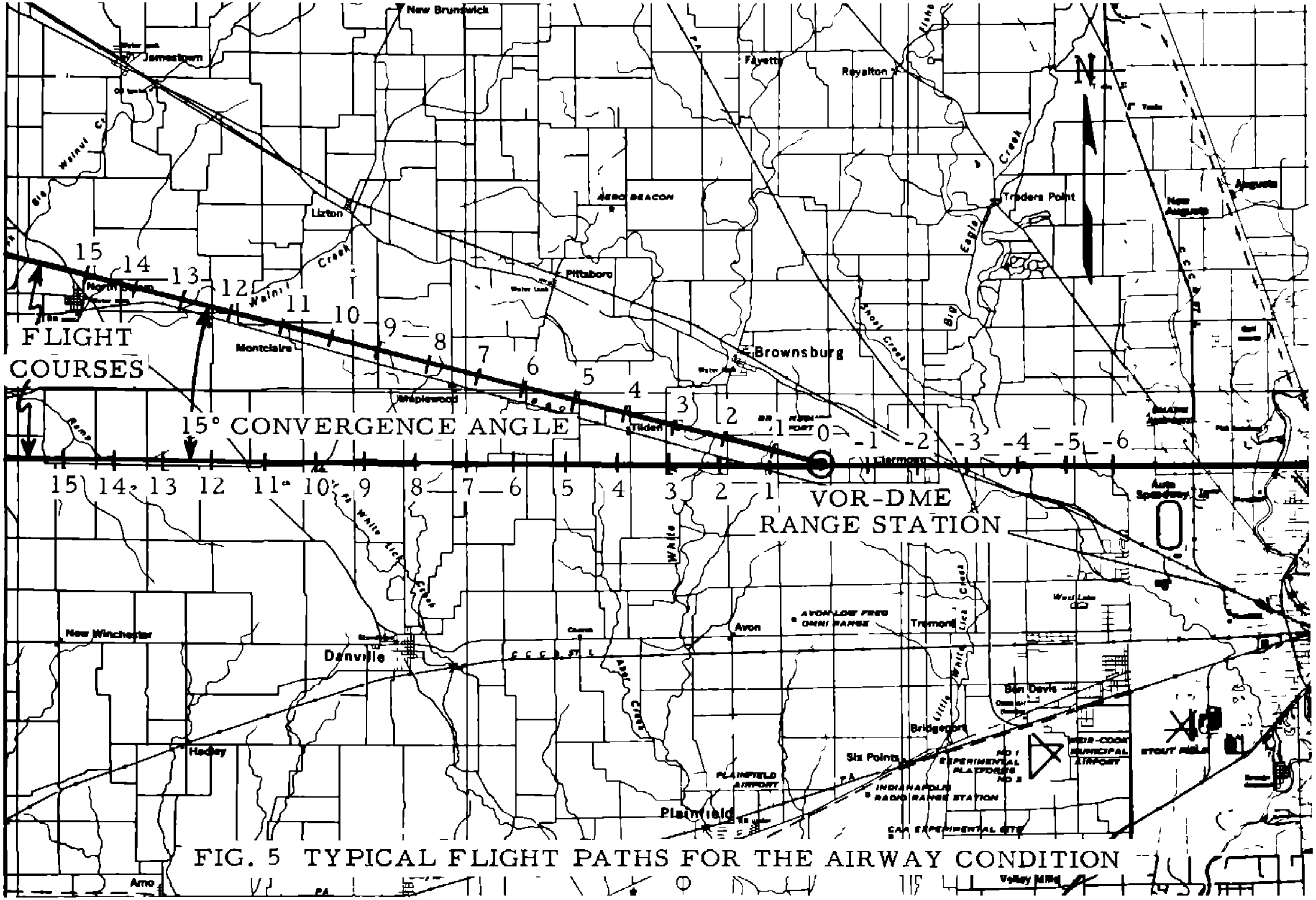


FIG. 5 TYPICAL FLIGHT PATHS FOR THE AIRWAY CONDITION

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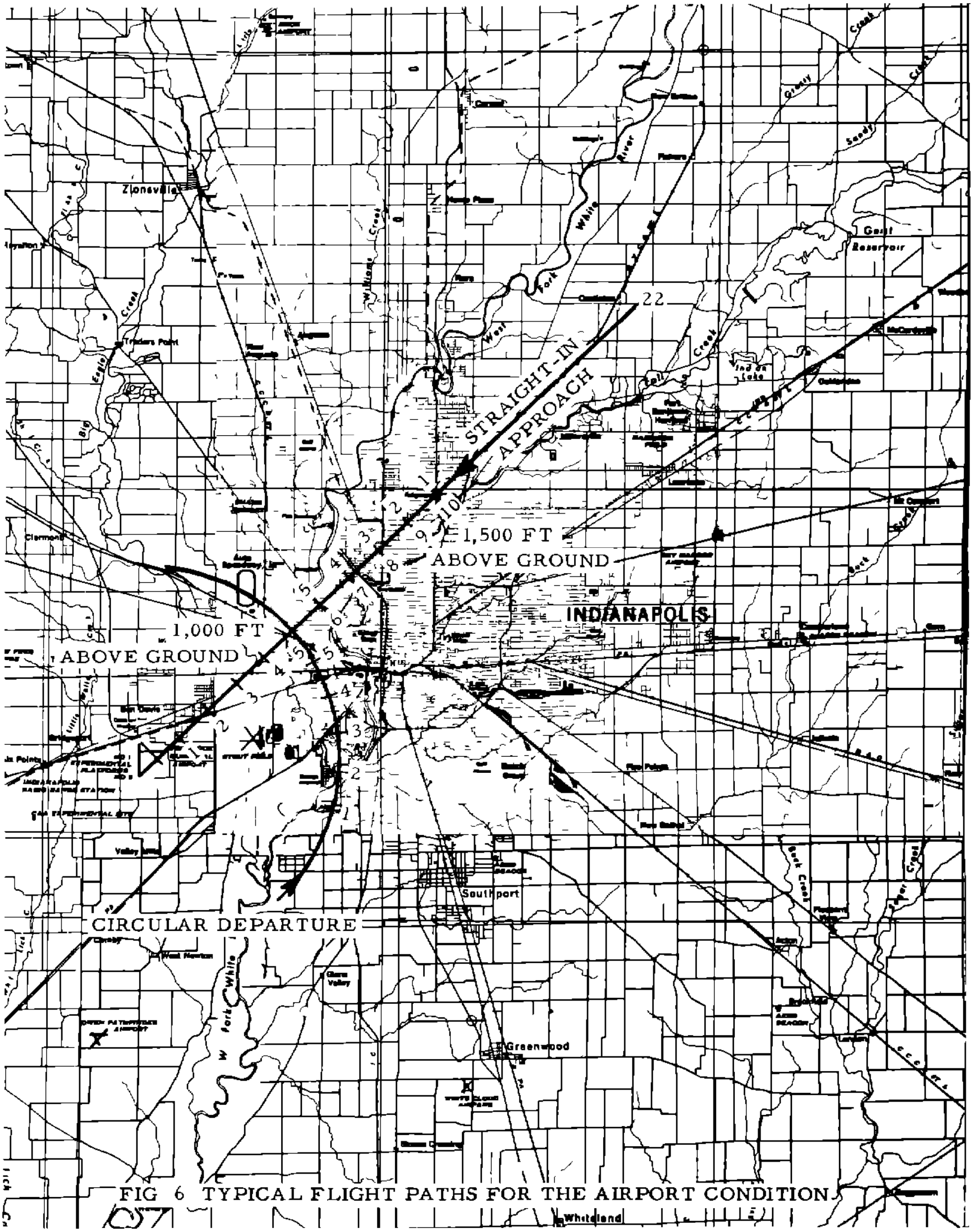

FIG 6 TYPICAL FLIGHT PATHS FOR THE AIRPORT CONDITION

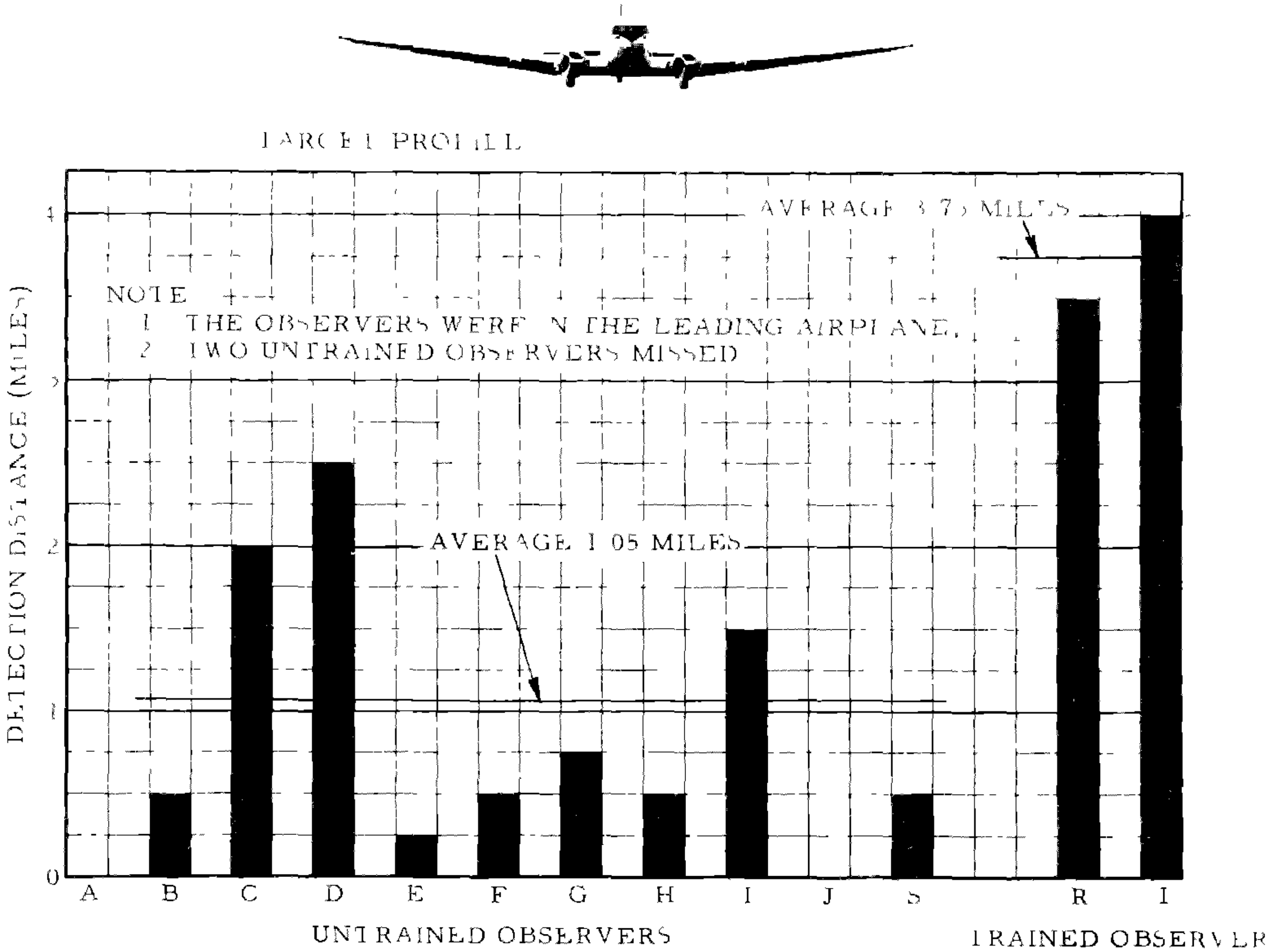

FIG. 7 INDIVIDUAL SCANNING PERFORMANCE, CRUISING CONDITION OVERTAKING

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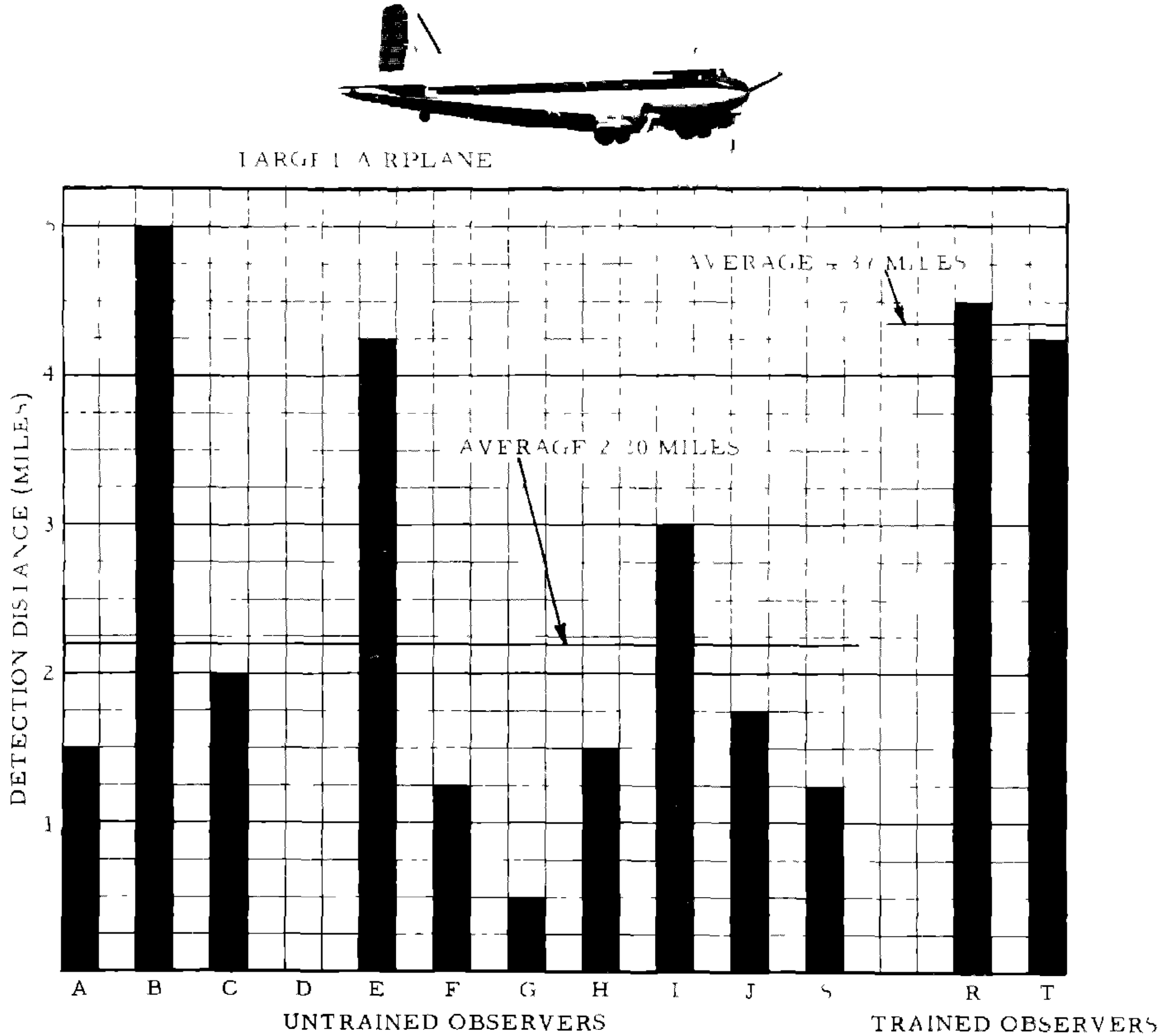

FIG 8 INDIVIDUAL SCANNING PERFORMANCE, CRUISING CONDITION
15° CONVERGING COURSES

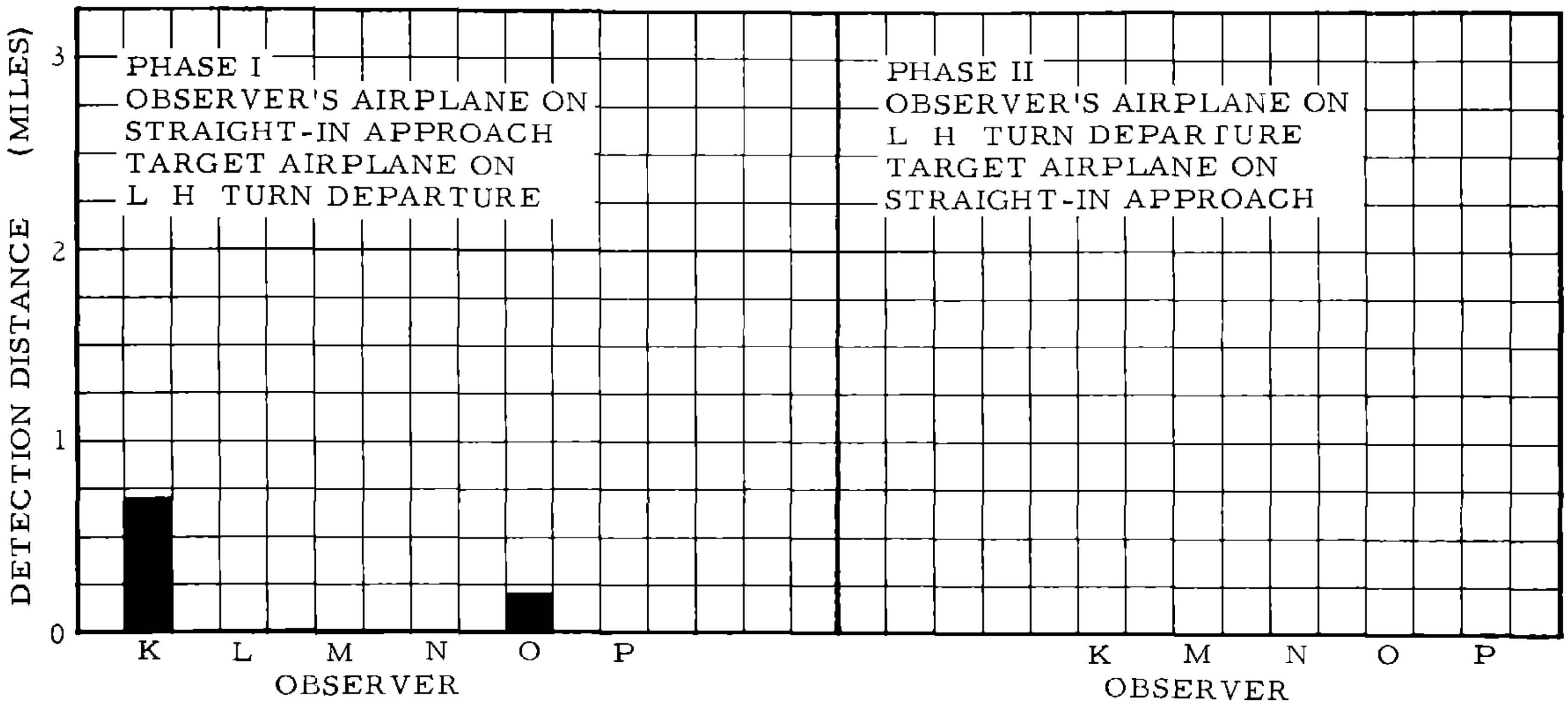

FIG 9 INDIVIDUAL SCANNING PERFORMANCE TERMINAL AREA CONDITIONS