EVALUATION OF A CONTROLLABLE-BEAM RUNWAY LIGHT

By
Marcus S Gilbert
and
H J Cory Pearson
Airport Division

Herman Adkins
Flight Operations Division

Technical Development Report No 238

Prepared by
CIVIL AERONAUTICS ADMINISTRATION
TECHNICAL DEVELOPMENT AND
EVALUATION CENTER
INDIANAPOLIS, INDIANA

June 1954

U S DEPARTMENT OF COMMERCE
Sinclair Weeks, Secretary

CIVIL AERONAUTICS ADMINISTRATION
F B Lee, Administrator
D M Stuart, Director, Technical Development and Evaluation Center

TABLE OF CONTENTS

This is a technical information report and does not necessarily represent CAA policy in all respects

EVALUATION OF A CONTROLLABLE-BEAM RUNWAY LIGHT

SUMMARY

This report discusses the evaluation of a new type of controllable-beam runway light. The light was designed to provide an approach to an ideal candlepower distribution, the values of the candlepower for various angles of view being derived from a functional analysis of runway-light requirements A sample of the new type of light was tested photometrically, and the results were compared with the ideal candlepower distribution determined by theoretical analysis.

A complete experimental system of these lights was installed along the instrument runway at General Mitchell Field, Milwaukee, Wisconsin. Flights were then made along fixed paths and under varying visibility conditions in order to determine whether the lights were actually visible from an airplane at selected reference points in the flight pattern. This installation was also used to check whether the system gives adequate guidance, as assumed in the analysis, if seen from these reference points.

Although the theoretically perfect distribution was not entirely realized, it was found that the lights gave satisfactory guidance for straight-in and circling approaches in both good and moderately restricted visibility Flight data obtained thus far under low visibilities were not sufficient to warrant conclusions about the utility of the lights under severely restricted conditions

INTRODUCTION

In 1952 the Technical Development and Evaluation Center of the Civil Aeronautics Administration completed a theoretical study of runway-light candlepower-distribution requirements.[1] This study resulted in a set of ideal-distribution curves that seemed obtainable in practice, and it raised the hope that a new light could be developed to produce this distribution. Such a development would provide not only a more satisfactory means of marking runways for operations under existing and anticipated flying conditions but also a sound basis for runway-lighting performance specifications. For this reason, the CAA Office of Airports requested that experimental models be produced and that they be tested under service conditions.

Working independently, engineers of the Line Material Company had completed the development of a new type of controllable-beam runway light at about the time that the TDEC study was published. This unit was designed to comply with CAA Runway Light Specification No. L-818, but an examination of the photometric distribution curves indicated that, with minor modifications of the optical system, the unit might be made to produce a distribution which would approach that developed by the TDEC study. If this could be accomplished, there would then be available a means whereby the distribution developed in the study could be given practical service testing.

Accordingly, an agreement was made whereby the Line Material Company would modify the design and furnish a sufficient number of new lights for a complete experimantal system which TDEC would install and evaluate. This evaluation was to include photometric and flight tests and a glare study.

The cost of a power-distribution system was an important consideration in the experimental installation, because power for approximately 120 lighting units using 120-volt, 500-watt multiple lamps would be involved. Since a load of this type requires an expensive underground-cable installation, a saving could be affected by installing the lights along a runway already lighted by 500-watt units, substituting the experimental lights for existing lights, using the old bases, and adding more lights where required. Preferably, this runway should be 200 feet wide, equipped with electronic aids for instrument landing, and located at an airport with a wide range of visibility conditions prevailing through the seasons Such a runway was located at General Mitchell Field, Milwaukee County, Wisconsin, and permission was obtained from the County Board of Supervisors to make the experimental installation.

---

[1] Marcus S. Gilbert and H. J. Cory Pearson, "An Analysis of the Candlepower Distribution Requirements of Runway Lights," CAA Technical Development Report No. 178, June 1952.

INSTALLATION

Planning of the installation was co-ordinated with representatives of Milwaukee County, of the Line Material Company, and of the Office of Airports. Lighting units were mounted in pairs along the first 1,200 feet of the south end of the runway and had one unit of each pair turned slightly outward to give the combined effect of a wide-angle beam, which the analysis indicated was necessary for proper guidance on final approach. A reduced spacing of approximately 100 feet was used for the first 800 feet of the same end in order to enable the pilots on final approach to see a maximum number of lights under restricted visibility conditions. Figure 1 is a plan of the installation.

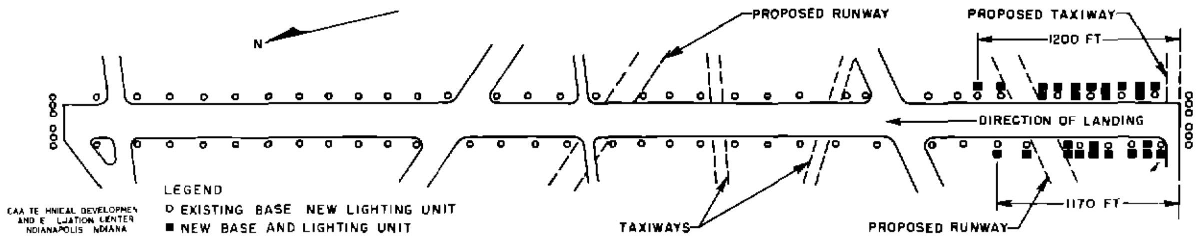


Fig. 1 Plan of Runway Showing Experimental Lighting

The installation of new runway-light bases and the modification of the electrical circuits to accommodate the extra lights were completed in 1952. The installation of the lights, of a new regulator, and of an indicating voltmeter in the control tower was made in the spring of 1953. The regulator was a high-speed, stepless, induction, voltage regulator equipped with a contact-making voltmeter for limiting maximum lamp voltage at high intensity and was connected to be controlled from the control tower. The indicating voltmeter in the tower was equipped with a dial calibrated in visual ranges.

Pairs of 25-candlepower lamps were installed at distances of 1/8, 1/4, 3/8, 1/2, 1, and 1 1/2 miles from the control tower for use as visibility markers. The installation pattern was such that the controller could identify the position of the farthest visible light. This was used as the reported visibility in these tests.

LIGHTING UNIT

The experimental lighting unit is spherical in shape and is less bulky than earlier controllable-beam runway lights. It differs in operation from the older models in that the movement of the beam is not accomplished by means of a motor-driven screw and is not separately controlled from the tower. Instead, this unit employs a bimetal coil coupled mechanically to a pivoted base on which the lamp socket is mounted. See Figures 2 and 3. With this arrangement, the beam direction control is accomplished automatically with the brightness control, so that the need for a separate three-phase control circuit is eliminated.

Because the bimetal coil is wired in series with the lamp socket, the increase in lamp current due to any increase in applied voltage will not only increase the light output but will also heat the bimetal. This will then uncoil, changing the position of the light center with respect to the fixed parts of the optical system so that the beam, as it becomes more intense, swings inward toward the opposite side of the runway. A second bimetal coil in each unit compensates for changes in ambient temperature.

Since increased intensities are required only when visibility drops and when atmospheric absorption and scatter are high and since the range from which the lights can be seen lessens, the beams are inclined inward at an angle increasing with increased absorption so that they will reach the pilot before they are absorbed and dissipated by the atmosphere. Similarly, as the visibility increases, the axes of the beams are directed further out toward parallel headings to avoid subjecting the pilot to unpleasant or dangerous glare and to effect better coverage of the approach area by utilizing the beams at their optimum headings.

Isocandle curves in CAA report No. 178[2] give the theoretical distribution requirements for night and day operations whereas Figures 4, 5, and 6 of the present report show isocandle

[2] Ibid.

Fig. 2 Close-up of Experimental Lighting Unit With Relamping Door Open

distribution of the experimental fixture as plotted from the results of photometric laboratory tests. These curves illustrate the effect of varying voltage on both beam intensity and direction. The use of the voltage settings given in Table I provides a range of candlepower values for operations under widely varying visibility conditions.

TABLE I

VOLTAGE STEPS CORRESPONDING TO LAMP-BRIGHTNESS PERCENTAGES

Voltage	Brightness (per cent)
120	100
95	50
75	20
50	4
36	0.8
26	0.16

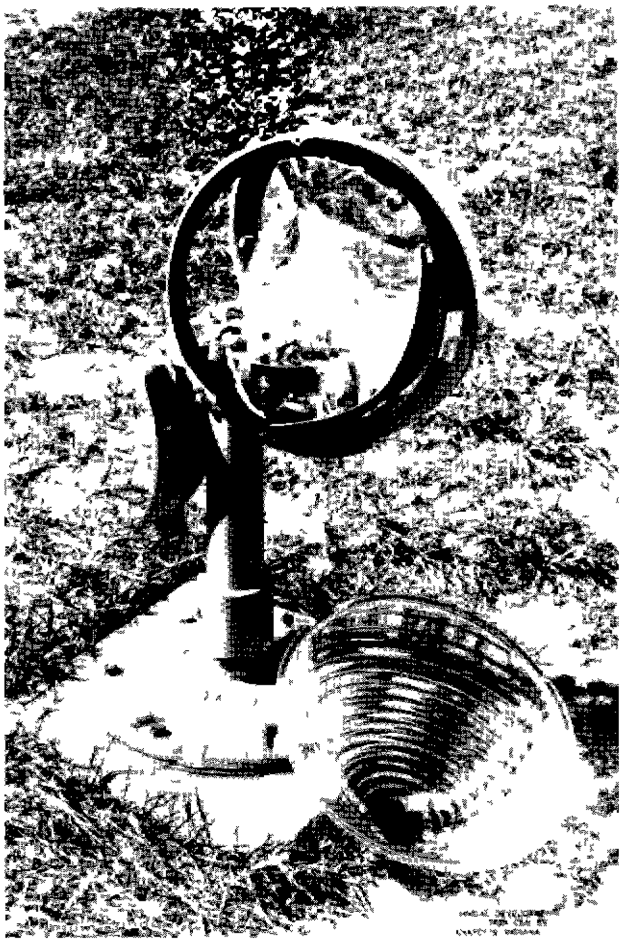


Fig. 3 Close-up of Experimental Unit With Lens Disassembled

A study of the isocandle curves shows that even the modified light did not entirely meet the theoretical distribution requirements. These requirements were approached, however, to a greater degree than in other lights currently in use.

FLIGHT TESTING

The program of test flying was planned to include observations by TDEC pilots in good visibility and in restricted visibility. The program also included the accumulation of reports and comments from commercial and itinerant pilots using the system.

Flight Paths.

For assistance in making the desired precise circling approaches, the TDEC pilots were furnished with pictorial-computer charts of the airport and vicinity on which exact paths were inscribed for them to follow. These charts fit the Type IV pictorial computer[3] installed

[3] Logan E. Setzer, "The CAA Type IV Rotatable-Panel Pictorial Computer," CAA Technical Development Report No. 195, April 1954.

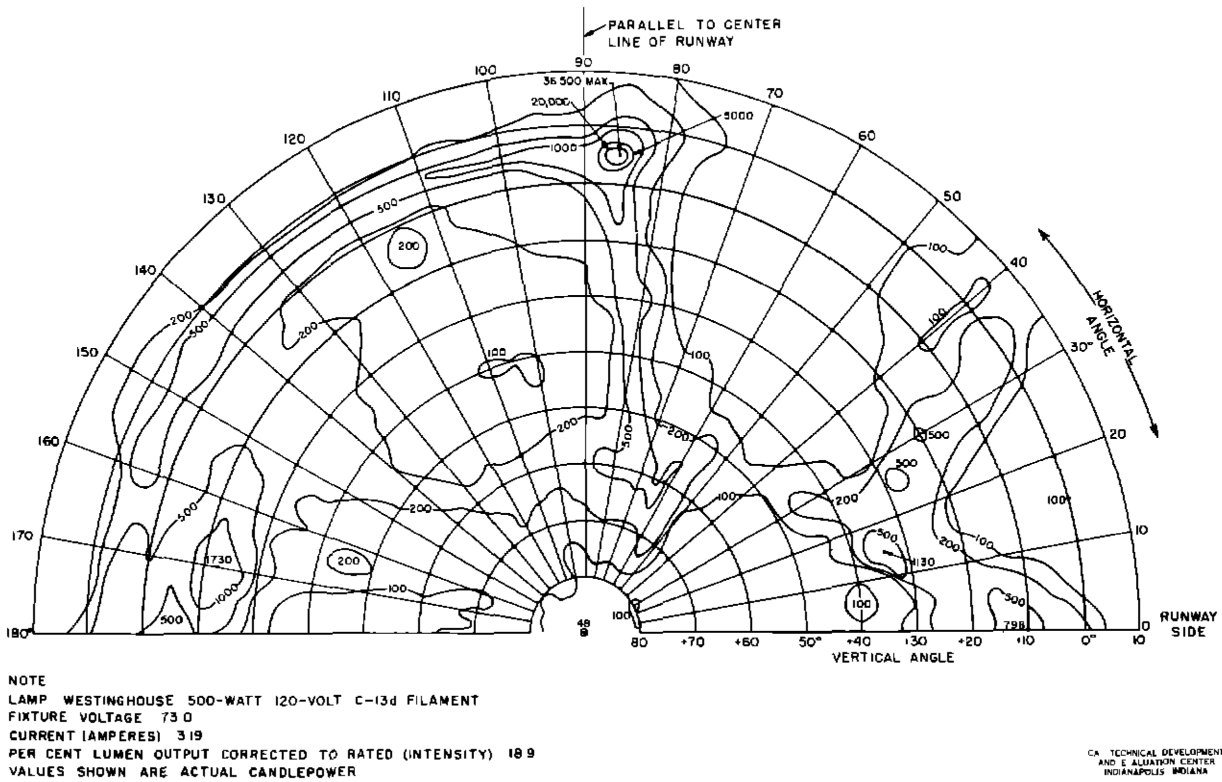


Fig. 4 Isocandle Distribution of Experimental Fixture at 3.19 Amperes

in the cockpit of the airplane. A counterrotating beacon, described in an earlier report,[4] was installed at the middle marker to assist in marking the paths. The circling patterns are shown in Fig. 7.

Flight-Test Results, TDEC Pilots.

TDEC pilots made seven flights to observe the lights. On only one of these flights was the visibility low enough to measure the limits of the system under restricted conditions. However, knowledge of the coverage and glare characteristics and related data were gained from each flight.

Flight One May 19, 1953, 8 30 p.m. to 9 10 p.m.

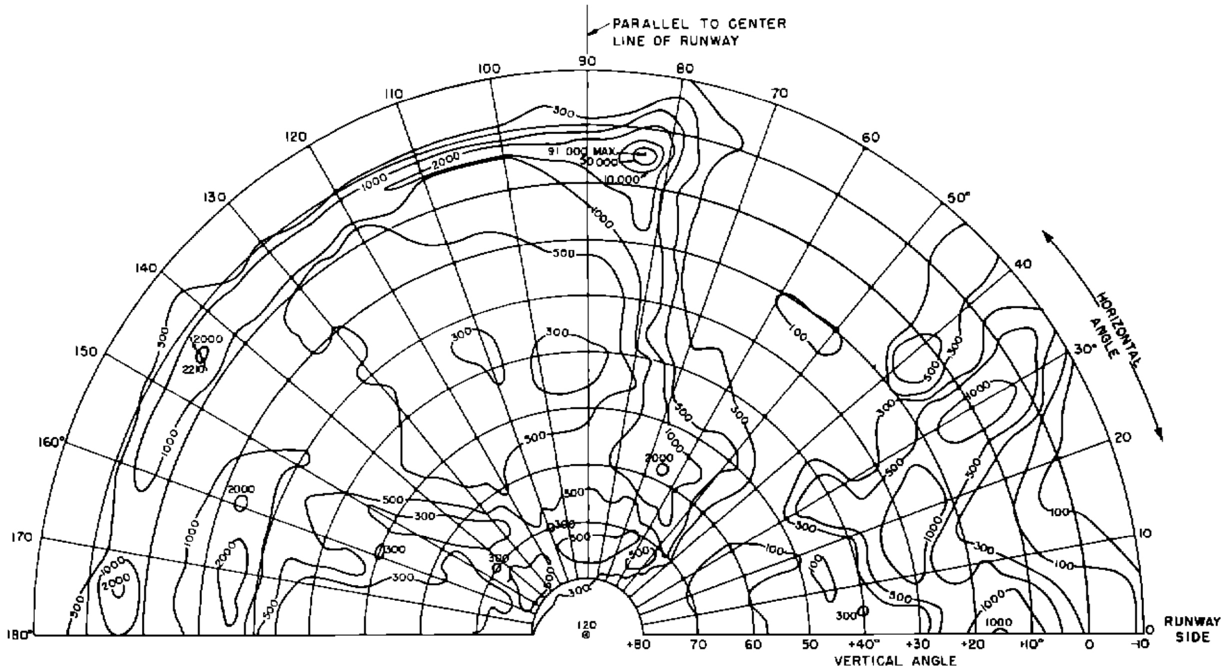
Two Line Material Company personnel and two Milwaukee County officials joined TDEC personnel, and a flight was made to observe the controllable-beam runway lights. Low-visibility evaluation was impossible because clear weather conditions existed. The lights were observed from a distance of ten miles from the airport to the point of touchdown, and the instrument landing system (ILS) was used as a reference

Flight Two May 19, 1953, 9 30 p.m. to 10 00 p.m.

After completion of the first flight, another group of observers boarded the plane for a view of the lights. Four ILS approaches were made, and one circle three miles in radius

---

[4] H J. Cory Pearson and Marcus S Gilbert, "An Experimental Counterrotating Marker Beacon," CAA Technical Development Report No. 150, February 1952.



NOTE
LAMP WESTINGHOUSE 500 WATT 120-VOLT C-13d FILAMENT
FIXTURE VOLTAGE 96 2
CURRENT (AMPERES) 3 72
PER CENT LUMEN OUTPUT CORRECTED TO RATED (INTENSITY) 47 1
VALUES SHOWN ARE ACTUAL CANDLEPOWER

CAA TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS INDIANA

Fig. 5 Isocandle Distribution of Experimental Fixture at 3.72 Amperes

was flown around the airport to determine light distribution and relative intensity. Unlimited visibility conditions again prevailed.

Flight Three June 1, 1953, 3 30 p.m. to 4 10 p.m.

The purpose of this flight was to establish a standard ground course or pattern to follow when evaluation flights were made under adverse weather conditions. This course was then reproduced on a disclike map and was placed in a Type IV pictorial computer on the pilot's instrument panel. With the pictorial computer and its associated components in operation, the pilot could repeatedly fly the same course regardless of weather conditions. No actual evaluation was made because clear weather conditions prevailed.

Flight Four October 22, 1953, 5 20 p.m. to 7 40 p.m.

Four circular approaches were made to the field under visibility conditions reported as five miles. The lights were visible throughout the entire circling procedure. A straight-in ILS approach was made prior to the return to Indianapolis.

Flight Five February 11, 1954, 6 05 p.m. to 7 05 p.m.

Three ILS approaches were made to observe the lights while the plane was inbound toward the runway from the outer marker. Two circles three miles in radius were flown around the field to view side-lighting conditions. A distance check was flown to the Kenosha fan marker 28 miles from the field. The lights were still visible from this point. Again, the visibility presented no restrictions and was reported as being greater than 15 miles with the ceiling at 3,000 feet.

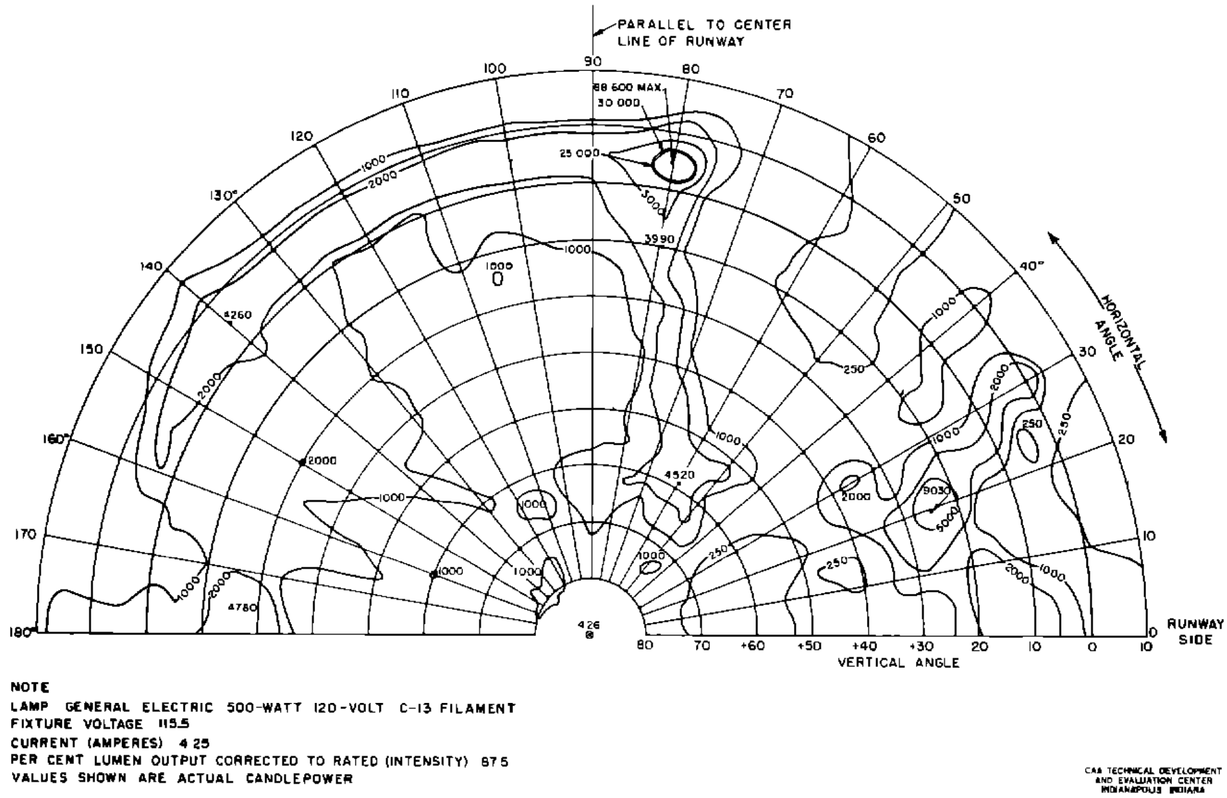


Fig. 6 Isocandle Distribution of Experimental Fixture at 4.25 Amperes

Flight Six February 11, 1954, 7 10 p.m. to 9 00 p.m.

The preceding flight was discontinued to await an expected change in the weather. Snow began to reduce the visibility somewhat, and the observations were resumed. During this flight, the visibility ranged from 4 to 12 miles in snow showers. The restriction was not great enough to limit the visibility to the one-mile condition desired in order to evaluate the lights. However, under the existing conditions, the lights were visible from the Grantsville fan marker 12 miles south of the airport. The distance checking was continued to the Kenosha marker 28 miles south, but the lights could not be seen because of the visibility restriction. Two circles were flown around the field to observe the side lighting under these conditions.

Flight Seven February 26, 1954, 5 00 p.m. to 6 00 p.m.

The flight was made from Indianapolis to Milwaukee with the intention of waiting until the visibility reduced to one mile. As soon as the predicted snow began to fall, the observations began. The weather was reported as "Precipitation ceiling 2,600 feet, overcast, in light to moderate snow, with three-mile visibility." The actual air-to-ground visibility differed from that reported by the tower as a result of warm ground temperature dissipating the falling snow at low altitude. Under air-to-ground visibility conditions of 2 to 2 1/2 miles, the runway lights at full intensity were visible 3 miles from the end of the runway on an ILS approach. These lights could be seen before the low-intensity approach lights came into view. The approach lights consisted of the red-neon bar system projecting 1,550 feet outward from the threshold of the runway along the extended left edge.

The Milwaukee VOR station was used as an originating point, and radials of ± 15° and ± 20° with the VOR-to-runway radial were flown to determine the visible threshold of the lights. Cross bearings from the ILS middle-marker compass locator were taken as soon as the lights first became visible and again as they became obscure. The visibility varied

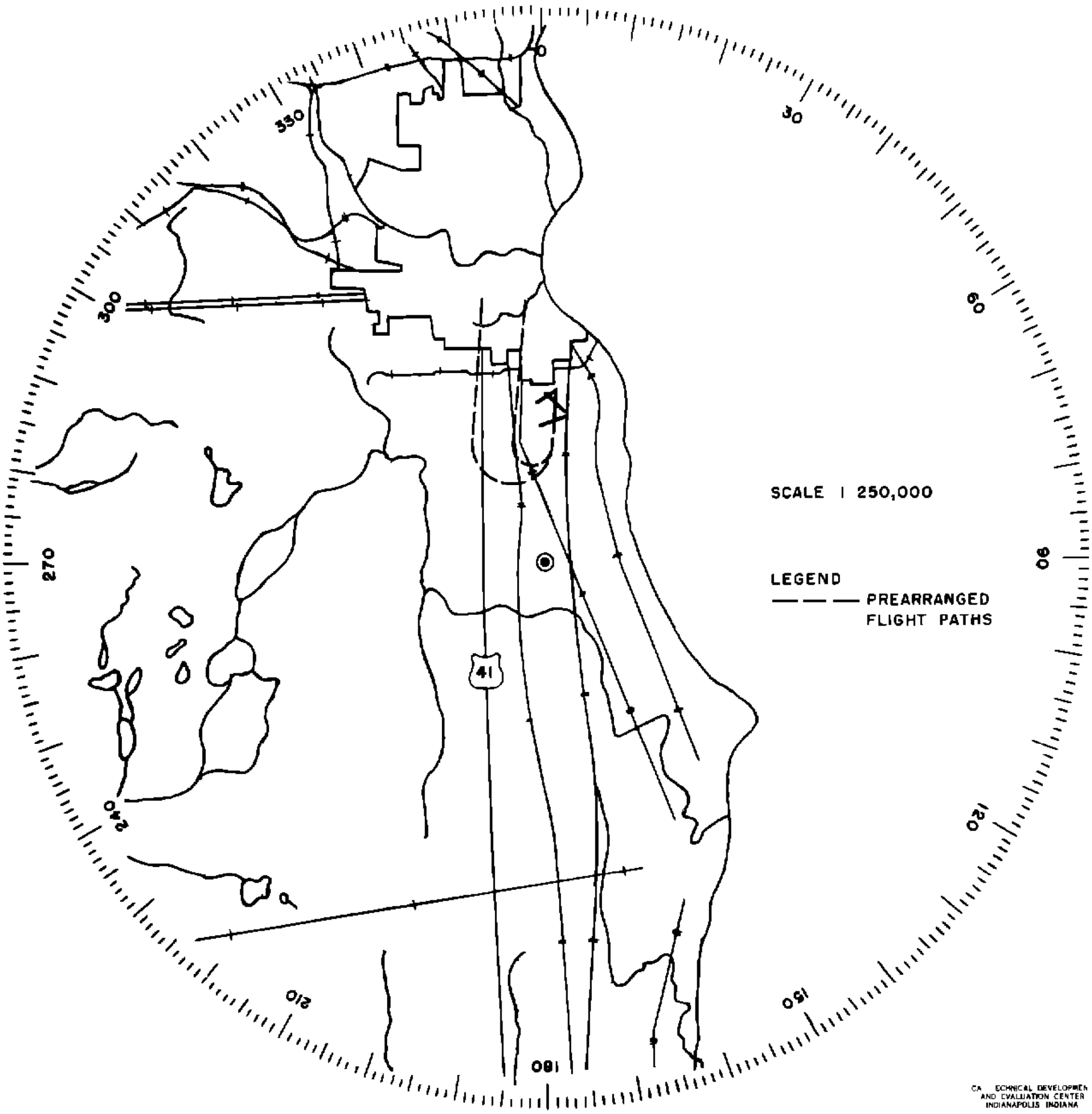


Fig. 7 Chart of Milwaukee Approaches

from 3/4 to 2 miles. An altitude of 600 feet above the ground was maintained since this is the minimum specified circling-approach altitude for General Mitchell Field.

Circles around the field were flown at 600 feet above the ground. The radii of these circles ranged from 1 to 2 1/2 miles from the center of the field. In addition to the lights on the ILS (North-South) runway, the conventional lights on the Southeast-Northwest (13-31) runway were lighted. Guidance along runway 1-19 was realized throughout the entire circle, while guidance along 13-31 was evident only when the aircraft was within ± 10° of the runway centerline extended.

GPO 808628 2

Comments of TDEC Pilots.

1. On ILS approaches, the experimental lights at full intensity became visible before the neon-bar approach lights were seen.

2. On a circling approach, it was possible to be in such a position that the lights on the near side of the runway only were seen, that is, when the aircraft was on the downwind leg. This condition does not hamper orientation, provided the pilot's attention is not diverted too long from contact flying before he reaches a position where the lights along the far side of the runway become visible. Should his attention be directed to the cockpit for too long a time, it is conceivable that when he looks back the single row of lights could be misconstrued for something other than runway lights. This would be true under very poor visibility conditions only.

3 On an ILS-equipped airport where runways in addition to the ILS runway are used under all but minimum weather conditions, it is suggested that the Line Material Company lights would afford a greater advantage if used on a runway which is at the greatest angle to the ILS runway. Weather conditions being suitable, this would permit a pilot to use the ILS system until he reached the minimum circling-approach altitude and then to continue his approach visually to land on the runway so equipped.

4. When all factors are considered, it is the opinion of the TDEC pilots that this lighting system gave the best circling-approach guidance of any lighting installation in use up to the time this evaluation was completed.

Comments of Other Pilots.

Comments from commercial and itinerant pilots are condensed and tabulated in Table II. These reports were all made in good weather with reported visibilities above seven miles. All of the percentages listed represent the brightness setting of the lamps when the lights were reported as visible, glaring, bright, or satisfactory. As usually happens in a compilation of this type, some of the comments appear inconsistent or contradictory. Taken together, however, they do give some evidence of the visual and glare ranges of the lights under good weather conditions.

The lights were operated at varying brightnesses from 1 per cent to 100 per cent in order to obtain reactions concerning visibility and glare limits. Reports indicating that the lights were too bright are listed under "Glare." Where reduced brightnesses were used for landings and take-offs, the new settings are listed under these headings. None of the landings required more than 5 per cent brightness. Take-offs were made without complaint with brightnesses as high as 50 per cent, although this brightness was reported glaring for landings.

CONCLUSIONS

1. The light fixture being tested approaches but does not entirely satisfy the theoretical requirements.

2. The light as used is an effective unit for providing off-runway lighting for circling approaches in good or moderately restricted visibility.

3. The light is also effective for straight-in approaches in good or moderately restricted visibility.

4. The means of controlling beam direction with brightness is mechanically satisfactory.

5. There was not sufficient test operation under low visibility conditions to justify conclusions concerning the effectiveness under these conditions.

GPO 808628 1