Further Evaluation of a Modified Controllable-Beam Runway Light

By

James H Harding

Flight Operations Division

Cecil B Phillips

and

Raymond C Herner

Airport Division

TECHNICAL DEVELOPMENT REPORT NO. 325

CIVIL AERONAUTICS ADMINISTRATION

TECHNICAL DEVELOPMENT CENTER

INDIANAPOLIS, INDIANA

October 1957

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, Secretary

CIVIL AERONAUTICS ADMINISTRATION
James T. Pyle, Administrator
D. M. Stuart, Director, Technical Development Center

TABLE OF CONTENTS

	Page
SUMMARY	1
INTRODUCTION	1
LIGHTING UNITS	2
INSTALLATION	4
FLIGHT TESTING	5
DISCUSSION OF RESULTS	9
CONCLUSIONS	12

FURTHER EVALUATION OF A MODIFIED CONTROLLABLE-BEAM RUNWAY LIGHT*

SUMMARY

This report describes the further evaluation of a new type of controllable-beam runway light reported in a previous publication. Since sufficient operation in low-visibility conditions s not achieved because of a sustained period of unrestricted weather, it was necessary to continue the project later in the year when visibility restrictions would be available more frequently.

A complete system of these experimental fixtures was installed along the instrument runway at General Mitchell Field, Milwaukee, Wisconsin. To insure full utilization of minimum weather conditions, a partial system of experimental lights also was installed along the first one-third of the instrument runway at Indianapolis. Flights were conducted under restricted visibility conditions along predetermined paths using Airport Surveillance Radar or VHF Omnirange and Distance Measuring Equipment for orientation and guidance. Using e systems, it was possible to determine the visual threshold of the lights from preselected directions and also to judge whether adequate guidance was realized at these

Under minimum weather conditions for circling approaches, it was determined that, with minor reservations, the lights gave adequate circling and straight-in guidance. When he visibility became restricted enough to limit operations to straight-in Instrument Landing ystem approaches, a compromise had to be reached between intensity and toe-in angle of beam to limit glare and still provide guidance. The narrow beam (approximately 6° down to 10 per cent of maximum intensity), in combination with the mechanism for controlling eam direction, invites unevenness in the light pattern on straight-in approaches. This condition was observed to be most critical when a thin layer of heavy ground fog existed. The first 1,200 feet of the Milwaukee system, where dual units were installed to produce the efect of a wider beam, gave better guidance than the rest of the system. In general, this system provided better circling guidance than any other runway lighting system observed during the time these tests were conducted.

INTRODUCTION

The Technical Development Center (TDC) of the Civil Aeronautics Administration completed a theoretical study of runway-light candlepower distribution requirements in 1952 and expressed the results in a set of ideal candlepower distribution curves that seemed to be obtainable in practice.[1] Engineers of the Line Material Industries, working independently, developed a new type controllable-beam runway light at about the same time that the Technical Development Center's study was published. Upon photometric examination, it was found that with minor modifications of the optical system this unit could be made to produce a light distribution pattern approaching that developed by the TDC study. Since this was true and the Line Material engineers were willing to modify a sufficient number of new lights for a complete experimental system, a practical means of evaluating the theoretical analysis was possible.

Working together, the Technical Development Center and the Line Material Industries, in cooperation with the Milwaukee County, Wisconsin, Board of Supervisors, installed a

---

*Manuscript submitted for publication September 1957.

[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.

TABLE I

RELATION BETWEEN LAMP VOLTAGE AND HORIZONTAL BEAM ANGLE

Switch Position	Lamp Voltage (volts)	Beam Intensity (per cent)	Beam Angle* (degrees)	Increasing Voltage (t_i) (min.)	Decreasing Voltage (t_d) (min.)
5	120.0	100.0	78.2		
				2.0	3.5
4	75.5	23.0	85.1		
				3.25	2.75
3	45.2	3.5	89.9		
				2.0	2.0
2	31.2	0.5	90.7		
				---	---
1	20.5	0.06	90.7		
				3.3	2.5
5	120.0	100.0	78.2		

*90° Position is parallel to runway centerline.

NOTE: In order to achieve repetition, it was necessary to tap the fixture to eliminate the tendency of the mechanism to hesitate in intermediate positions.

complete system of modified controllable-beam runway lights at General Mitchell Field, Milwaukee, Wisconsin.

A photometric analysis of the modified fixture was accomplished, and a flight-test program was initiated. The flight evaluation was hampered, for the most part, by unrestricted visibility. With such atmospheric conditions, it was impossible to determine if the desired visual threshold pattern actually had been achieved. Coverage and glare characteristics w[illegible] observed, and a preliminary report of these findings was published.[2] It was determined, however, that sufficient test data under restricted visibility conditions had not been obtained, and conclusions could not be drawn concerning the effectiveness under these conditions.

This is the final report on an evaluation program previously described in Technical Development Report No. 238.

LIGHTING UNITS

Two versions of the Line Material controllable-beam fixture were evaluated. They were similar in appearance and construction. In both fixtures beam movement was controlled by the resultant action of two bi-metallic coils, a helical coil, wired in series with the 500-watt lamp filament, and a spiral coil independent of the electrical system. Changes in voltage applied to the lamp caused changes in the current flowing through the helical coil and, by virtue of the correlated temperature fluctuations, caused the coil to change shape. The spiral coil was incorporated into the system to compensate for ambient temperature variations. The resultant force of these two coils was coupled to a pivoted base on which the lamp socket was mounted. This system made it possible to change the horizontal beam direction and the lamp intensity, on a fixed relationship basis, by adjusting a single voltage control. The relationship between lamp voltage (or switch position) and the horizontal direction of the beam is shown in Table I. The time required for the beam angle to

---

[2]Marcus S. Gilbert, H. J. Cory Pearson, and Herman Adkins, "Evaluation of a Controllable-Beam Runway Light," CAA Technical Development Report No. 238, June 1954.

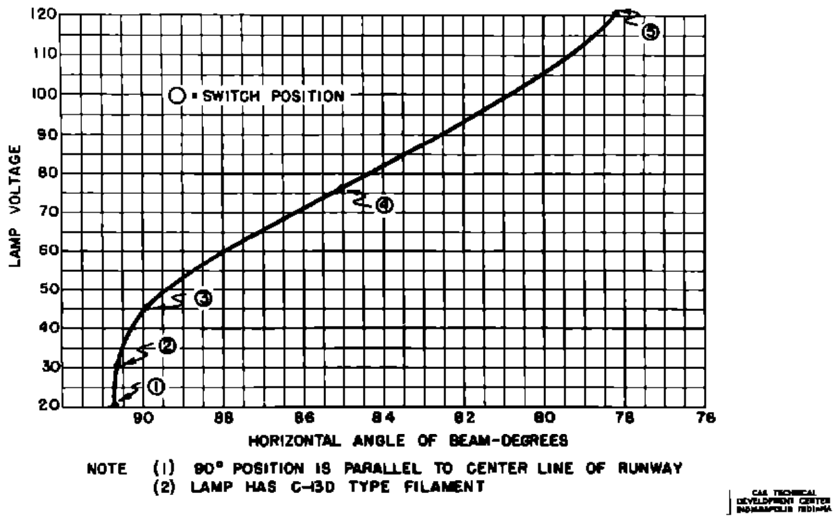


Fig. 1 Horizontal Beam Angle Versus Applied Voltage

stabilize as the voltage was changed from one step to the next is listed in both increasing (t_i) and decreasing (t_d) directions. Figure 1 represents the voltage-beam angle relationship for the entire voltage range.

The basic differences in the two models tested were the lens masking and the number of internal reflectors. The production unit was designed by Line Material engineers to comply with CAA runway light Specification L-818. This fixture was spherical in shape, had three internal reflectors, and had a portion of each lens masked to obtain the required light distribution. The fixture, as modified to comply with the TDC recommendations, was similar in appearance except that it had four internal reflectors and clear lenses. Each unit was attached to its base by a frangible coupling to decrease the impact forces an aircraft would encounter should it accidentally strike the fixture. The three-reflector, painted-lens production model, shown in Fig. 2, was installed at Indianapolis, and the four-reflector, clear-lens experimental

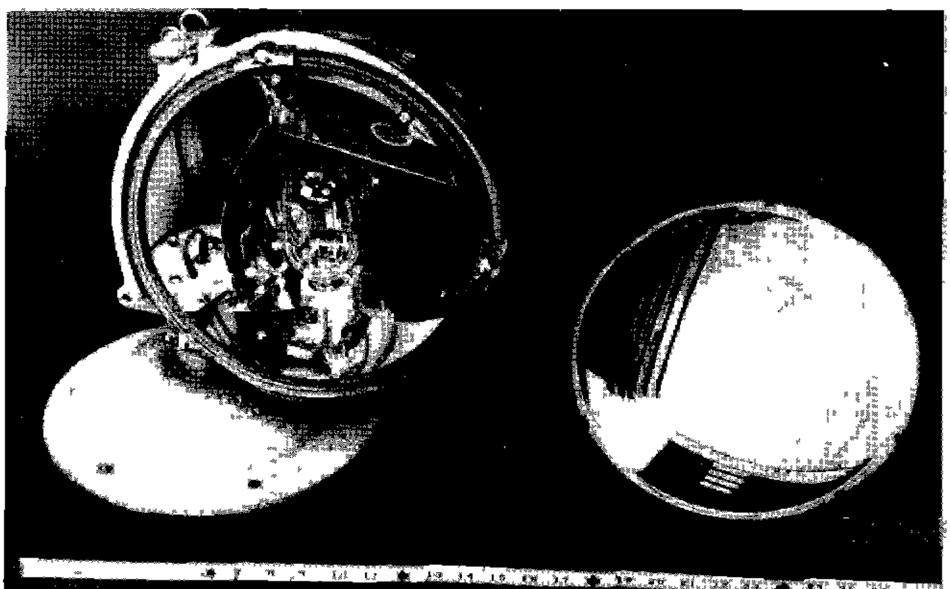


Fig. 2 Line Material Production Fixture with One Glass Lens Removed

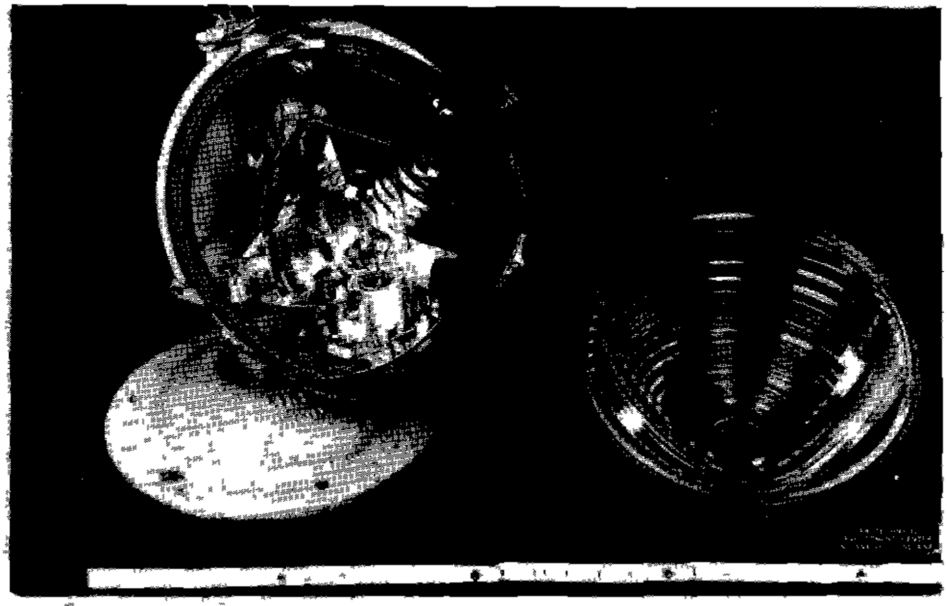


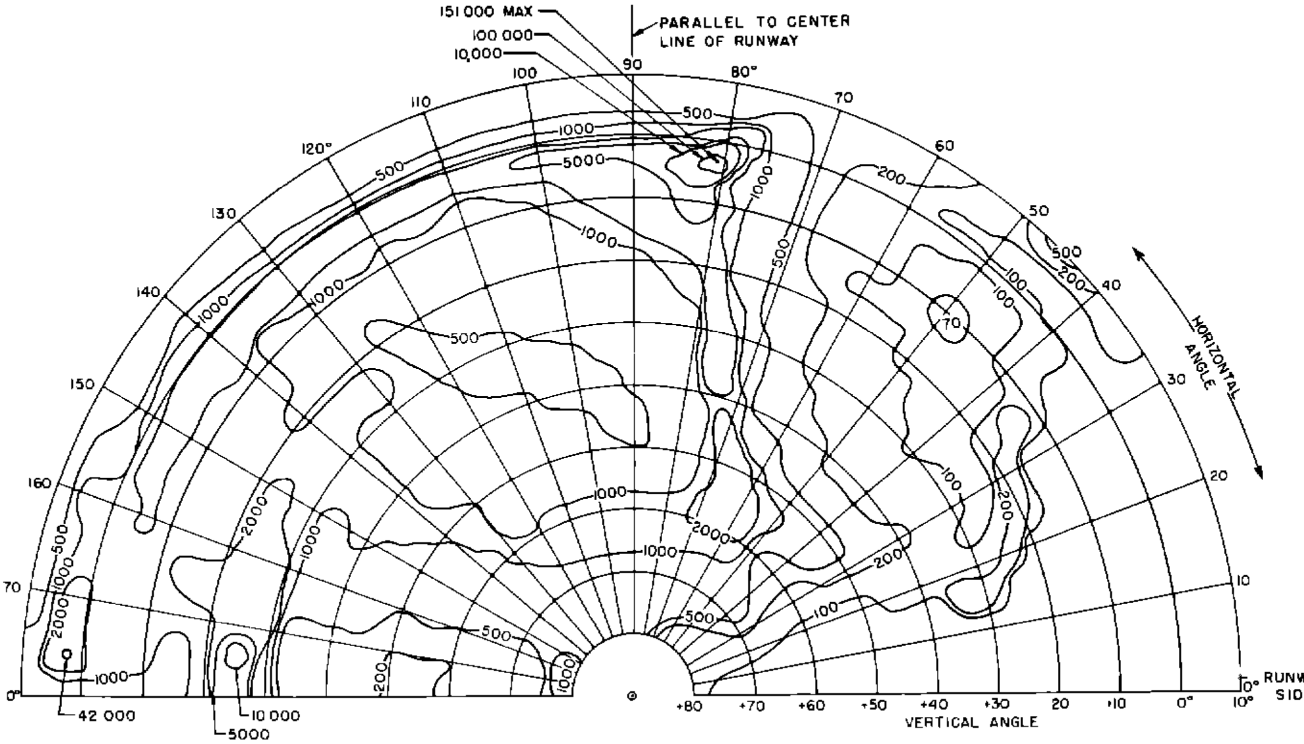
Fig. 3 Line Material Experimental Fixture with One Glass Lens Removed

unit, Fig. 3, was installed at Milwaukee. An isocandle distribution comparison of the production and experimental fixtures is presented in Figs. 4 and 5, respectively.

INSTALLATION

A complete system of Line Material controllable-beam experimental fixtures was installed at General Mitchell Field, Milwaukee, Wisconsin. The lighting units were mounted in pairs along the first 1,200 feet of the south end of the instrument runway (1-19) with one unit of each pair turned slightly outward to give the combined effect of a wide-angle beam, which the original analysis indicated was necessary for adequate guidance on the final approach. The longitudinal spacing between lights was reduced from the standard 200-foot spacing to approximately 100 feet for the first 800 feet of the system in order to enable pilots to see a maximum number of lights under restricted visibility conditions. A plan of the installation is shown in Fig. 6. In this installation, the tower operator adjusted the intensity of the lights by referring to an indicating voltmeter while controlling a high-speed, stepless, induction voltage regulator. The dial of the voltmeter, being calibrated in visual ranges, made it possible for the operator to adjust the lamp intensity and consequently, the beam toe-in according to the meteorological conditions. This brightness control procedure was followed unless a pilot requested otherwise. Figure 7 shows the relationship between light output and lamp voltage with this control system. Numbers 1 through 5 on the curve refer to conventional control switch positions.

An abbreviated system of production fixtures was installed at Indianapolis in a temporary fashion to facilitate the collection of data when unpredictable low-visibility conditions occurred and to permit service evaluation in connection with other flight operations. This system extended along the first one-third of the instrument runway (4-22) and the fixtures were placed at 200-foot longitudinal spacing on portable bases just outboard of the existing L-819 runway lights. The circuit used to energize the experimental system was separate from the L-819 system and was controlled from the tower by a five-step brightness switch. This arrangement permitted either individual or simultaneous operation of the two systems for comparison purposes.



NOTE
LAMP WESTINGHOUSE 500-WATT 120-VOLT C 13d FILAMENT
FIXTURE VOLTAGE 115 5
CURRENT (AMPERES) 4 28
PER CENT LUMEN OUTPUT CORRECTED TO RATED (INTENSITY) 92 0
VALUES SHOWN ARE ACTUAL CANDLEPOWER

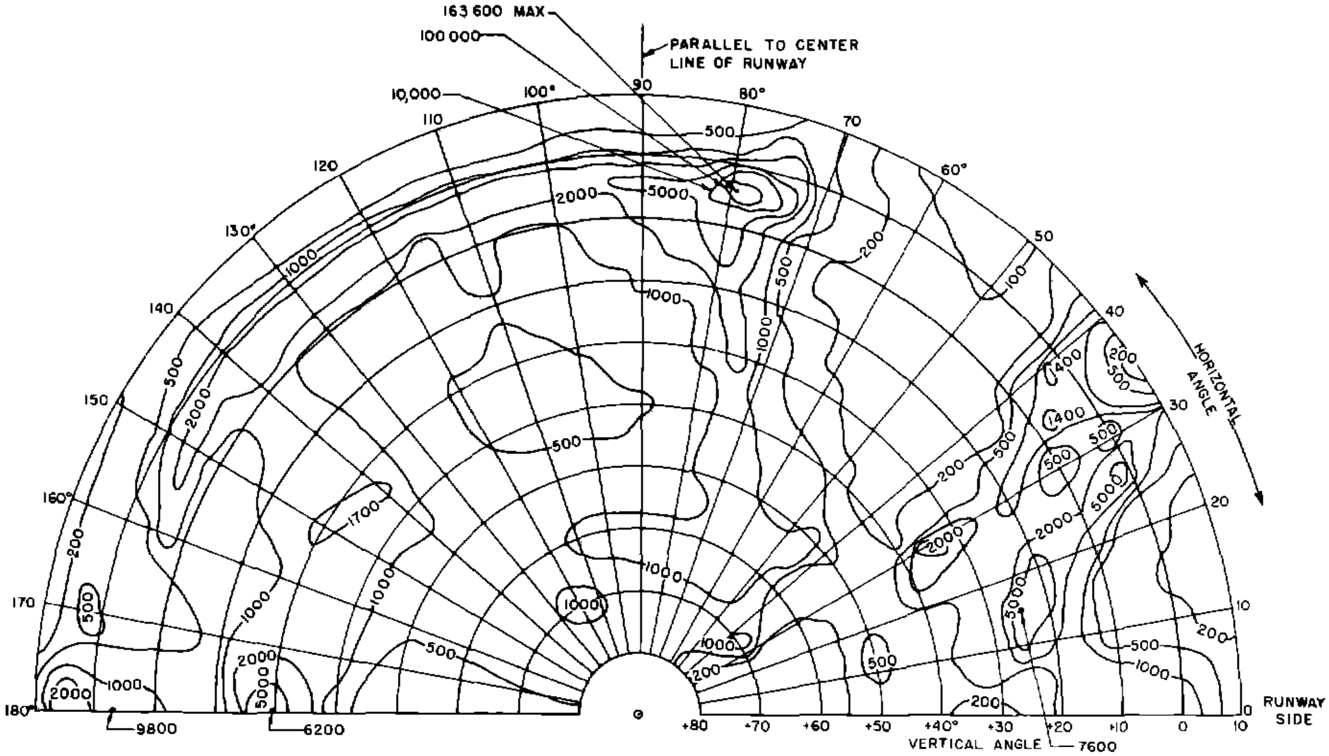
Fig. 4 Isocandle Distribution of Line Material Production Fixture Operated at 115.5 Volts

FLIGHT TESTING

The following chronological report lists the data obtained from a series of flight tests. All mileages given are statute, and all ceiling heights and aircraft altitudes are given as feet above field level. At Indianapolis, the standard system of L-819 lights was used only as noted.

March 8, 1956, 8 p.m., Indianapolis. Weather ceiling and visibility unlimited (CAVU), no moon. The experimental and standard L-819 lights were turned on position 5 (full brightness) as TDC aircraft N-181 left the Indianapolis VHF Omnirange (VOR), 6.9 miles from the airport. This approach was at 90° to the instrument runway (4-22) which was ideal for determining circling guidance furnished by the system. From this position, the experimental lights obscured the L-819 lights in their vicinity. An approach and landing was accomplished on runway 22 (in the opposite direction to an ILS approach). The L-819 lights were turned off and the experimental lights were graduated from position 5 (full intensity) down to position 1 (lowest intensity) and back to position 5 during the approach. Under the prevailing atmospheric conditions, glare was experienced at positions 4 and 5. At position 1 the light was barely visible. Position 2 was usable, and position 3 was adequate.

March 16, 1956, 9 55 a.m., Indianapolis. Weather ceiling 700 feet, visibility variable from 1/2 mile to 1 1/2 miles in light snow and fog. Two to three inches of snow on the ground. Several counterclockwise circles were flown around the field in TDC aircraft N-183 at a radius of 1 mile, using the glide path Distance Measuring Equipment (DME), and at an altitude of 400 feet. (This represented minimum circling conditions at Indianapolis.) Because of daylight operations and also the high level of background brightness, the tower operator was requested to switch all lights to brightness step 5. As will be explained later, the intensity of the experimental system actually was reduced to step 4 while the TDC aircraft was flying. The experimental lights were not visible until the aircraft was within plus or minus 5° of the



NOTE
LAMP WESTINGHOUSE 500-WATT 120 VOLT C-13d FILAMENT
FIXTURE VOLTAGE 115 5
CURRENT (AMPERES) 4 14
PER CENT LUMEN OUTPUT CORRECTED TO RATED (INTENSITY) 92 0
VALUES SHOWN ARE ACTUAL CANDLEPOWER

CAA TECHNICAL DEVELOPMENT CENTER INDIANAPOLIS, INDIANA

Fig. 5 Isocandle Distribution of Line Material Experimental Fixture Operated at 115.5 Volts

extended runway centerline. The brightness appeared to be lower than expected. The L-819 lights were then operated on step 5 for comparison. They were equal or at times slightly superior in appearance to the experimental lights. This observation gave rise to the thought that there might have been an equipment malfunction somewhere in the system.

After landing, the aircraft was taxied both ways through the system to obtain more detailed information about the light intensity and cutoff pattern. At this close range, it again was noticed that the brightness of the experimental lights was below that of the L-819 system. The pattern cutoff seemed to be sharper than necessary.

The control tower operator was questioned to determine if the experimental system actually was on step 5. He stated that the switch was on position 5, however, the brightness did not appear to be as high as it had been earlier in the morning at the same setting. He explained that the system had been operated prior to our test for observation by Eastern Air

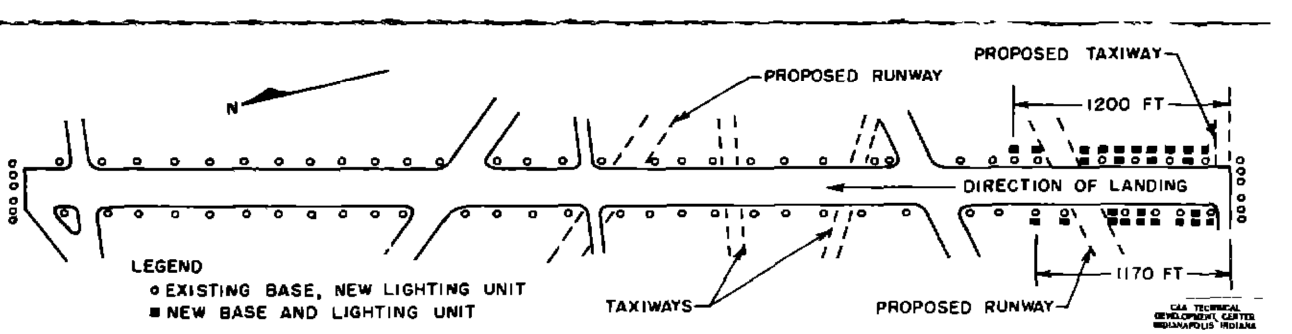


Fig. 6 Plan of General Mitchell Field Runway Showing Experimental Lighting

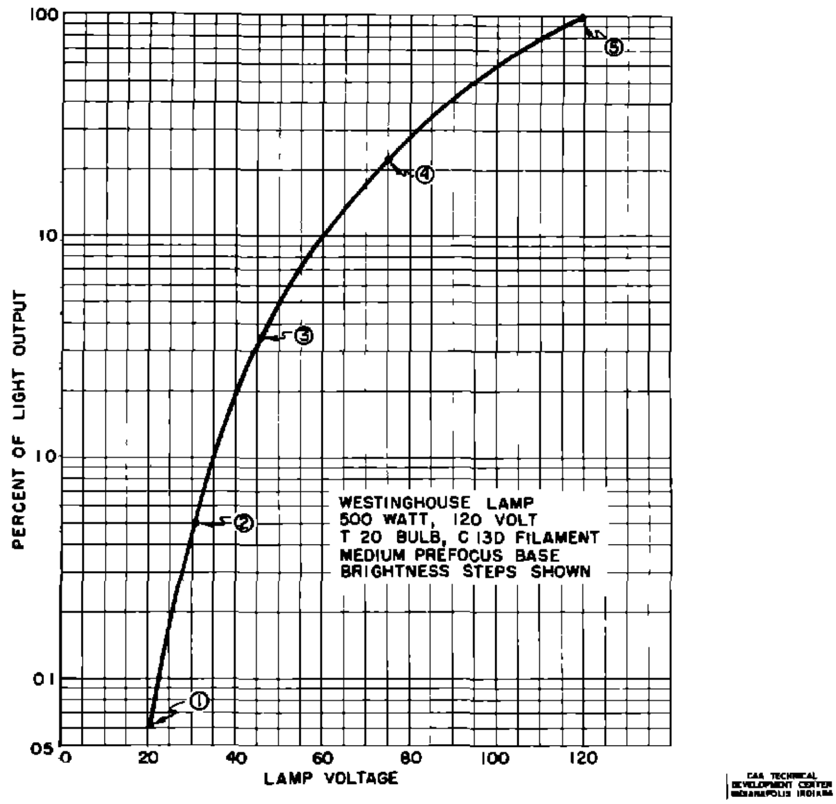


Fig. 7 Per Cent of Light Output Versus Lamp Voltage

Lines and also by Lake Central Air Lines at the completion of their Instrument Landing System (ILS) approaches. Both crews stated that the experimental lights were seen before the approach lights became visible. They also said that the first one-third (experimental portion) of the runway looked very good.

Further investigation revealed that the regulators supplying voltage to the experimental system had time-delay relays in their circuits which permitted the lights to be operated at full intensity for only short durations regardless of the switch position. When the relay operated, the system was automatically returned to step 4 to conserve lamp life. This relay was by-passed for all further test operations.

June 8, 1956, 11 30 a.m., Indianapolis. Weather ceiling 12,000 feet overcast, visibility 4 miles in smoke. An ILS approach to runway 4 was flown in TDC aircraft N-182, and the control tower was requested to switch the experimental lights to 100 per cent brightness for a routine maintenance check. The runway surface became visible before the lights could be seen. After landing, it became apparent that only the lights on the right-hand side of the runway were operating. Investigation revealed that the electrical cable supplying the left-hand side had been severed by mowing equipment. Further analysis of the situation revealed that the reason the surface was seen before the point-source lights came into view was because, at the requested intensity, the resulting toe-in angle of 11.8° caused the light beams to intersect the runway centerline about 360 feet ahead of their respective fixtures. Under the existing weather conditions, the runway surface could be seen from a distance of four miles which was much farther out the extended centerline than the light-beam focal point.

June 19, 1956, 9 35 a.m., Indianapolis. Weather ceiling 600 feet overcast, visibility 1 1/2 miles in fog and smoke. Circling approaches were attempted in TDC aircraft N-181 to simulate minimum conditions, but traffic congestion prohibited further evaluation. The system appeared to be operating normally.

June 20, 1956, 9 10 p.m., Indianapolis. Weather CAVU. A simulated ILS approach was made to observe the operation of the lights. All lights were operating properly. However, as a result of a rewiring program being initiated in the control tower, the brightness switch had been temporarily disconnected. This left only position 5 available. As was previously observed, glare prohibits the use of this system when operated at full intensity during night operations in unrestricted weather.

The following approaches were made at General Mitchell Field, Milwaukee, Wisconsin, on November 2, 1956, after 8 p m It was necessary to view the system from several different angles, since the primary interest in the fixture was based on the amount of guidance it presented to a pilot making circling approaches. Since these approaches were conducted in instrument weather, the test procedure was as follows Airport Surveillance Radar (ASR) operators gave range and azimuth information to the pilot in the form of Plan Position Indicator (PPI) approaches to runways 7-25 and 13-31 Vector service to the outer locator was given for ILS approaches. An east-west pass over the center of the field was included also. At the visual threshold on each approach, the pilot notified the radar operator who, in turn, supplied the necessary distance-to-runway information. Using the runway mid-point as a center, one-mile radius circles were flown around the field at minimum circling altitude (600 feet) to observe the over-all picture of guidance and evenness. During the following approaches, the ceiling varied from about 3,000 feet down to 600 feet, and the air-to-ground visibility was 2 miles on the first approach and was reported as 1 mile on the remainder of the approaches

Approach No. 1 - Visibility 2 miles, lights operated at 110 volts (maximum). A straight-in approach was made using the ILS The lights were first sighted when the airplane was over the ILS outer marker (4.7 miles), centered on the localizer and on the glide path. The approach end of the runway was much brighter than the remainder A landing was not accomplished out of this approach because of glare discomfort.

Approach No 2 - Visibility 1 mile, lights at 110 volts. A PPI approach was made on a 70° course toward the field The lights became visible at a distance of 3 2 miles at an altitude of 600 feet

Approach No. 3 - Visibility 1 mile, lights at 110 volts. A PPI approach was made on a course of 310°. The lights were first seen at 3.2 miles and at an altitude of 1,000 feet.

Approach No 4 - Visibility 1 mile, lights at 110 volts. The airplane was flown to the center of the airport on a 90° course as directed by ASR. The runway lights appeared at a distance of 2 miles and at an altitude of 600 feet. A line of lights mistaken for the experimental system was seen prior to this when the airplane was 3 miles from the field, but as the flight continued on its 90° course and the actual runway lights came into view, it was evident that those observed at the 3-mile point were beyond the field.

One-Mile Orbit - Visibility 1 mile, lights at 110 volts. A 1-mile radius circle was flown around the field at an altitude of 600 feet It was evident from all angles that the first 800 feet of the runway, which was equipped with two fixtures at each station and 100 feet longitudinal separation, was much brighter than the rest of the system. In addition to the lights on the ILS runway (1-19), the conventional lights on runway 13-31 were lighted for comparison. The system on runway 1-19 was visible throughout the entire circle while the lights on 13-31 were visible only as the aircraft passed through an arc within plus or minus 10° of the extended runway centerline

With regard to the experimental system, it was noticed that there were portions of the circle where only the lights on the near side of the runway could be seen This situation would occur when the pilot was on the downwind leg of his circling approach pattern The portion of light which would be directed inward toward the runway from each lamp was eliminated by the fixture to reduce glare at high intensities. This cutoff also had the effect of eliminating one entire line of lights, as mentioned above If a pilot's attention was diverted too long from contact flying back to the cockpit, it is conceivable (as happened once during this test) that, upon resumption of contact flying, the lights could be mistaken for something other than runway lights Since several factors have to exist at precisely the right time to effect this illusion, this was not deemed a serious defect in the system.

Approach No. 5 - Visibility 1 mile, lights reduced to 75 volts A PPI approach was made on a course of 250°. The lights were first sighted at 2 6 miles at an altitude of 700 feet.

Approach No. 6 - Visibility 1 mile, lights at 75 volts. A PPI approach was made on a 130° course. The lights appeared at a range of 1 2 miles at an altitude of 500 feet The ceiling was ragged on this pass and probably accounted for the apparent reduction in visual range.

Approach No 7 - Visibility 1 mile, lights at 75 volts. With ASR guidance, the airplane was flown toward the center of the field on a 270° course The lights were seen at 2 6 miles at an altitude of 700 feet. The lights appeared to be uneven, with the amber lights on each end of the runway appearing much brighter than the other lights throughout the center of the installation This could have been caused by patches of ground fog which had started to form.

Approach No. 8 - Visibility 1 mile (air to ground), lights at 75 volts. A straight-in ILS approach was made from the outer marker. The lights were sighted at 3.7 miles, with the airplane centered on the localizer and glide-path beams The double lights at the approach end of the runway appeared much brighter than the remainder of the system. Two probable reasons were the wider beam as a result of the dual installation alignment in the first 1,200 feet, and the presence of ground fog. After the touchdown on the runway was completed, the cutoff appeared to be very sharp and there was hardly sufficient light output to enable the pilot to keep the aircraft on the runway during roll-out even though higher intensity would not have been desirable during the approach. A thin layer of heavy ground fog reduced the surface visibility to less than 400 feet.

Table II summarizes the results of the Milwaukee tests. Azimuth refers to the orientation of the pattern as set forth in the photometric analysis Since the output curves of this fixture were symmetrical about a line normal to the runway, it was not necessary to explore reciprocal courses at both voltage settings.

TABLE II

FLIGHT TEST RESULTS

Approach	Mag. Course (degrees)	Azimuth (degrees)	Vertical Angle (degrees)	Visual Threshold Distance (sta mi.)	Visibility (sta. mi.)	Intensity (c p.)	Lamp Voltage	Brightness (per cent)
1	006	90	2.8	4.7	2	5265	110	83
2	070	154	2.5	3.2	1	2015	110	83
3	310	146	4 1	3.2	1	2475	110	83
4	090	174	3.9	2.0	1	1475	110	83
5	250	154	3.5	2.6	1	1170	75	23
6	130	146	5 7	1.2	1	605	75	23
7	270	174	3 5	2 6	1	775	75	23
8	006	90	2.8	3 7	1	10395	75	23

DISCUSSION OF RESULTS

After flight-test and photometric data had been collected and compiled, it became apparent that, with regard to circling approach guidance, the experimental fixture had light output characteristics which were superior to those of any other fixture observed during this evaluation Table II shows that the visual threshold of the fixture, when operated at 110 volts, was at least twice the meteorological visibility At 75 volts, the threshold still was greater in each case than the visibility.

Data reduction revealed that the combination of a narrow beam and a large-angle traverse was a weakness of this fixture. These factors had little effect on circling guidance, but became critical during restricted weather straight-in approaches, landings, and roll-out control.

There seems to be little need for having the center of the beam move outward past a position parallel to the runway. In the fully toed-out position the intensity is so low that

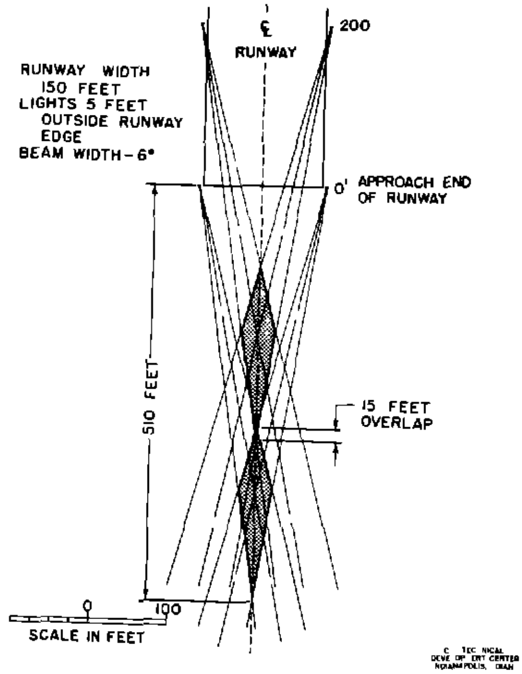


Fig 8 Experimental Fixture Main Beam Intersection Pattern at Centerline When Fully Toed-In (11 8°) and Spaced 200 Feet Longitudinally

glare ceases to be a problem regardless of the minimum azimuth position. In the fixtures tested, the beam traversed an arc of 12.5°, ranging from a toe-out, or minimum setting, of 0.7° to a toe-in of 11.8°

Given a 150-foot wide runway with a lateral spacing between lights of approximately 160 feet, the axis of each beam at 100 per cent intensity intersects the runway centerline at a point approximately 380 feet from the fixtures toward the approaching aircraft Considering a 6° beam width (down to 10 per cent of maximum intensity), a pilot on the runway centerline would be within a pair of light beams only for an interval of 215 feet, i e., from 515 feet to 300 feet ahead of the fixtures. Since this interval is only 15 feet greater than the normal longitudinal spacing of the lights on a runway, it would be impossible to be in the beams of more than two pairs of fixtures at any instant, and the pilot would have to be accurately centered on the runway to achieve this Figure 8 shows the main beam intersection pattern under the described conditions, and Fig 9 shows how the situation could be relieved somewhat by decreasing the longitudinal spacing between the fixtures to 100 feet. Note, however, that the requirement of accurate alignment with the runway centerline still exists. Since a different approach to runway lighting probably will be needed when the visibility becomes less than 1/4 mile, it seems fruitless to attempt to give a pilot conventional guidance in a 300-foot visual range situation.

If the beam width was increased to 12° and the traverse reduced to 5°, covering a 0° to 5° toe-in range, the beam at full intensity would intersect the centerline 920 feet ahead of its source, and the coverage would extend from 410 feet ahead of the fixture to the visibility limits, as shown in Fig. 10. A pilot would be able to see as many pairs of lights as the atmospheric conditions permitted while being restricted laterally only to the confines of the runway. Light patterns would be limited as a result of visual range rather than by limitations imposed by the optical system.

Obviously, the maximum intensity of the beam would be reduced by distributing light from the same source over a greater area, but this does not seem to be of consequence when a 500-watt lamp is used It should be noted also that reduction in the beam traverse would benefit the thermal actuating mechanism by permitting a more favorable linkage, and, therefore, more positive action The combination of a more stable shifting mechanism and a greater beam width should greatly reduce unevenness in the system Reduction of the traverse angle appears desirable even if the narrow-beam feature is retained.

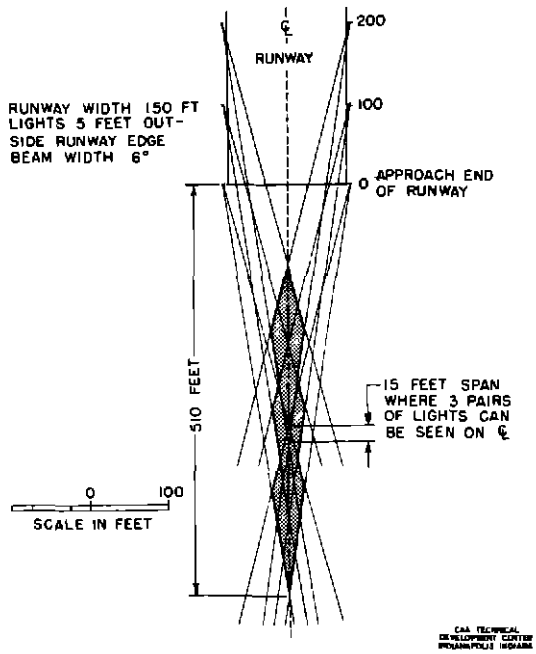


Fig. 9 Experimental Fixture Main Beam Intersection Pattern at Centerline When Fully Toed-In (11 8°) and Spaced 100 Feet Longitudinally

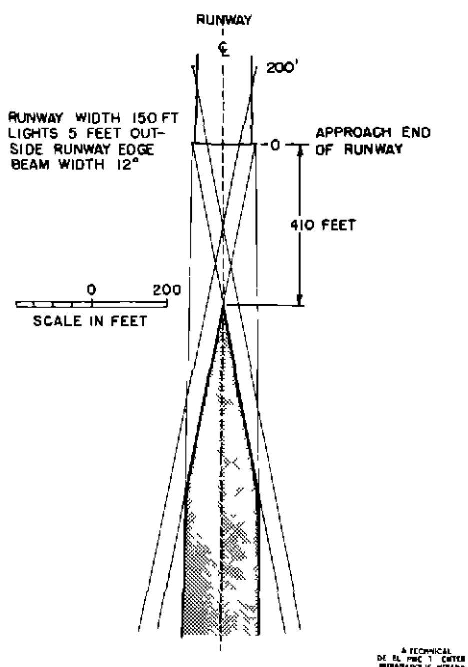


Fig 10 Suggested Fixture Main Beam Pattern Permitting View of All Pairs of Lights Within Runway Visual Range When Fully Toed-In (5°) and Spaced 200 Feet Longitudinally

Some consideration should be given to optimum use of this fixture on runways wider than 150 feet. For example, on a 200-foot runway a maximum toe-in angle of 6.5° would be required to achieve the same intersection point of light beam and runway centerline as was suggested for the 150-foot installation. Similarly, a 9.5° maximum angle would be required for a 300-foot runway. Table III lists the proposed toe-in angles and resulting cutoff points at the runway centerline when using a fixture with a 12° beam

TABLE III

TOE-IN AND CUTOFF ANGLES FOR 12° BEAM

Runway Width	150'	200'	300'
Proposed Beam Toe-In Angles	5°	6.5°	9.5°
Innermost Cutoff	410'	470'	560'
Main Beam Intersection Point	920'	920'	920'
Outermost Cutoff	None	None	2500'

In view of these facts, it appears desirable to provide a different beam-traversing linkage for each standard runway width, thereby adding flexibility and utility to the fixture.

CONCLUSIONS

1. Flight observations revealed that some nonuniformity existed in the system, especially on straight-in approaches. Laboratory examinations disclosed that the combination of a 6° beam and a 12° beam swinging mechanism, which had a tendency to stick occasionally in intermediate positions, invited a certain amount of unevenness in the light pattern
2. The first 1,200 feet of the Milwaukee installation, where a second unit, toed slightly outward, was included at each position to increase the effective beam width, proved the superiority of a wider beam angle and gave very satisfactory guidance.
3 A fixed relationship between beam toe-in and brightness is at best only a compromise because of the many meteorological parameters involved.
4. On one straight-in approach at Milwaukee with the lights at 75 volts and a thin layer of heavy ground fog existing, adequate guidance was realized almost to the point of touchdown, where the restricted visibility combined with the sharp beam cutoff left hardly sufficient light output to enable the pilot to complete successfully a full-stop landing.
5. Laboratory and flight tests revealed that the beam width should be greater and the beam traverse should be reduced. Such modifications would reduce unevenness and greatly increase the area of guidance. Consideration also should be given to the implementation of runways wider than 150 feet where different beam traverse ranges would be necessary.
6. Glare does not seem to be a problem as long as the intensity is controlled according to the visibility conditions
7. Circling guidance was satisfactory as long as the pilot realized how the runway-side cutoff affected the horizontal light pattern. The fact that the lights on both sides of the runway were not equally visible at all times (for example, on the downwind leg) made it possible for the pilot to lose orientation temporarily, if his attention was diverted from contact flying for too long a period of time This phenomenon exists with most runway lighting systems and is not considered to be a serious operational disadvantage.
8. All factors considered, the experimental system as installed at Milwaukee provided better circling guidance than any other system observed during this evaluation.