MODIFICATIONS OF THE SLOPE LINE APPROACH LIGHT SYSTEM

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MODIFICATIONS OF THE SLOPE LINE APPROACH LIGHT SYSTEM

SUMMARY

This report describes the results of certain modifications in the design and arrangement of the basic slope line approach light system These modifications include changes in horizontal and vertical settings of the lamps, changes in lamp wattage, the addition of horizontal bars, and changes in the threshold light pattern. The purpose was to improve lateral coverage, to provide more effective lead-in guidance, to reduce glare, to improve roll guidance and threshold marking, and to provide distance marking

Service testing demonstrates that effective distance marking is provided, and that material improvement is achieved in lateral coverage, lead-in guidance, roll guidance, and threshold marking Reduction in glare is indicated but not yet proved.

INTRODUCTION

The slope line approach light system was described in an earlier report[1] It consists basically of a pattern of linear light units, or bars, set in two planes which intersect on the desired path of flight of an airplane coming in for a landing See Fig 1 The system extends 3,000 feet from the threshold into the approach zone

This approach light system was installed at the Landing Aids Experiment Station, Arcata, California, where it was given exhaustive service testing under very severe weather conditions[2,3] It also has been installed at several major airports where it is being used in regular service

Service experience and extensive service testing have demonstrated the effectiveness of the pattern, but they also have indicated what features might be improved These improvements would require the system to

1 Provide more lateral coverage for pilots approaching off course
2. Provide more conspicuous indication for a pilot using the lights as lead-in lights during good visibility conditions
3. Reduce possible glare from bars at threshold end
4. Provide improved roll guidance.
5. Provide distance indication
6 Provide improved threshold marking.

The first three of these guidance elements and the modifications proposed to improve them were described and discussed in an earlier analytical study.[4]

These modifications are possible because of the design of the individual slope line fixture This fixture was developed as a bar 14 feet long on which are mounted ten evenly spaced lamps Experience at the Landing Aids Experiment Station showed that with alternate lamps omitted from the slope line bars the distinctive linear appearance was still retained, and effectiveness was only slightly reduced[5] Analysis of the effective brightness[6] indicates that the omission of alternate lamps results in a reduction of visual range of the units from 780 meters to 740 meters under 1/4-mile day visibility. This is not serious, and the reduction would become less as the weather gets worse Consequently, it is practical and feasible to omit alternate lamps or to use them with a different setting to provide supplementary indications or wider coverage.

[1] H. J Cory Pearson, "The Slope Line Approach Light System," CAA Technical Development Report No 104, Indianapolis, March 1950

[2] "Airfield Lighting," Progress Report, 1948 Test Season, Air Force-Navy-Civil Landing Aids Experiment Station, Arcata, Calif

[3] "Airfield Lighting," Landing Aids Experiment Station, Final Reports, Air Force-Navy-Civil Landing Aids Experiment Station, Arcata, Calif , 1949

[4] Marcus S Gilbert and H. J. Cory Pearson, "A Study of the Visibility and Glare Ranges of Slope Line Approach Lights," CAA Technical Development Report No. 150, Indianapolis, November 1951

[5] "Airfield Lighting," Progress Report, 1948, Fig 31.

[6] See Appendix

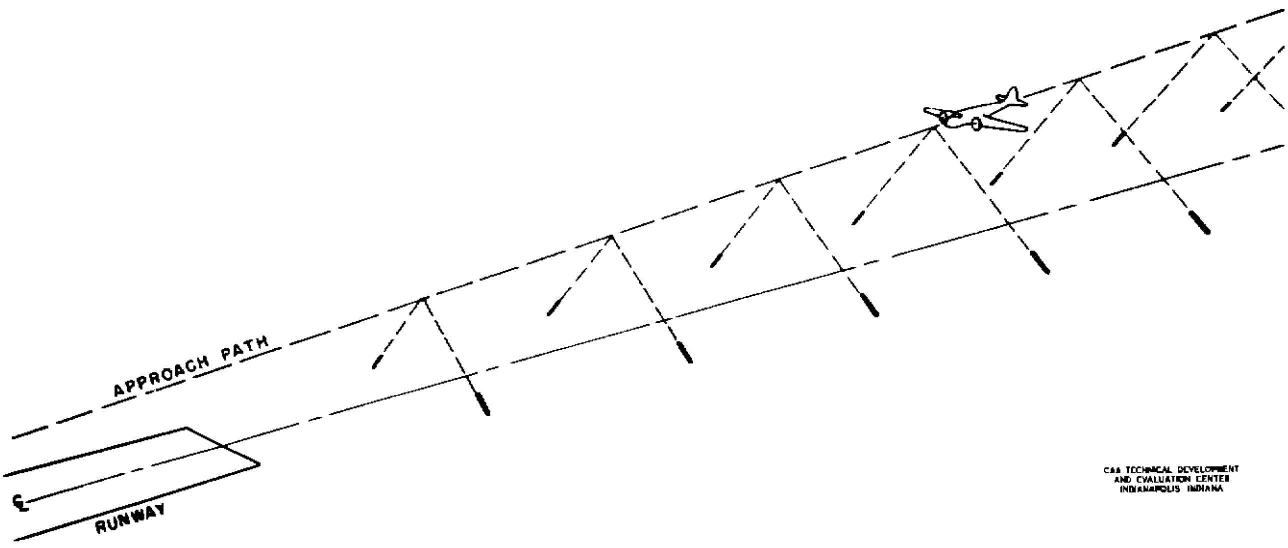

Fig. 1 Arrangement of Slope Line Approach Lights

The approach light installation at Weir Cook Airport, Indianapolis, was used for service testing the modifications proposed on the basis of the analytical study Other modifications were designed to improve roll guidance and threshold marking and to provide distance indication The various changes are shown in Fig 2. Due to site limitations at Indianapolis, the outer section of the installation is somewhat shorter than the standard system.

MODIFICATIONS

Increased Lateral Coverage.

The limitations of lateral coverage with the standard lamp arrangement for the slope line installation were previously discussed.[7] These limitations become progressively more important as the visibility conditions become poorer and are of serious import when visual ranges drop below 1/8 mile Fig 3A outlines the areas of horizontal visibility covered by representative units under 1/16-mile visibility conditions The boundary of the area from which both rows of lights will be visible is also shown

The modification consists of directing the beam of every alternate lamp 30 degrees inward toward the approach axis, leaving the other half of the lamps directed in planes parallel to the approach axis This increases the area from which the units are visible, as shown in Fig 3B This modification was applied only to the outer one-third of the entire approach pattern for two reasons First, it normally will be the outer one-third of the pattern that is first picked up by the pilot in approaches under low visibility, and his maximum lateral deviation from the indicated path normally will occur at the point where he first glimpses the lights Second, if he has not corrected approximately to an on-course path by the time he reaches the end of the outer one-third of the pattern, it will be too late to make a successful landing Once a pilot has seen both lines, he has no trouble in finding and maintaining his course

Lead-In Indication

Often pilots approaching an airport under conditions of good visibility make use of the approach lights as lead-in lights For this purpose the pilot picks up the lights from several miles out and guides himself in to the final approach by their aid The vertical coverage of these lights is relatively narrow, as shown in Fig 4, and as the aircraft is normally well below the area from which the lights are most readily visible, the pilot calls to have the lights increased to maximum intensity As the pilot continues his approach, he intersects the area covered by the maximum intensity of the beams and is suddenly exposed to excessive brightness and glare Before he can call and have the brightness reduced, he will have passed beyond the lights A modification of the lamp settings to prevent this

[7] Gilbert and Pearson, op cit

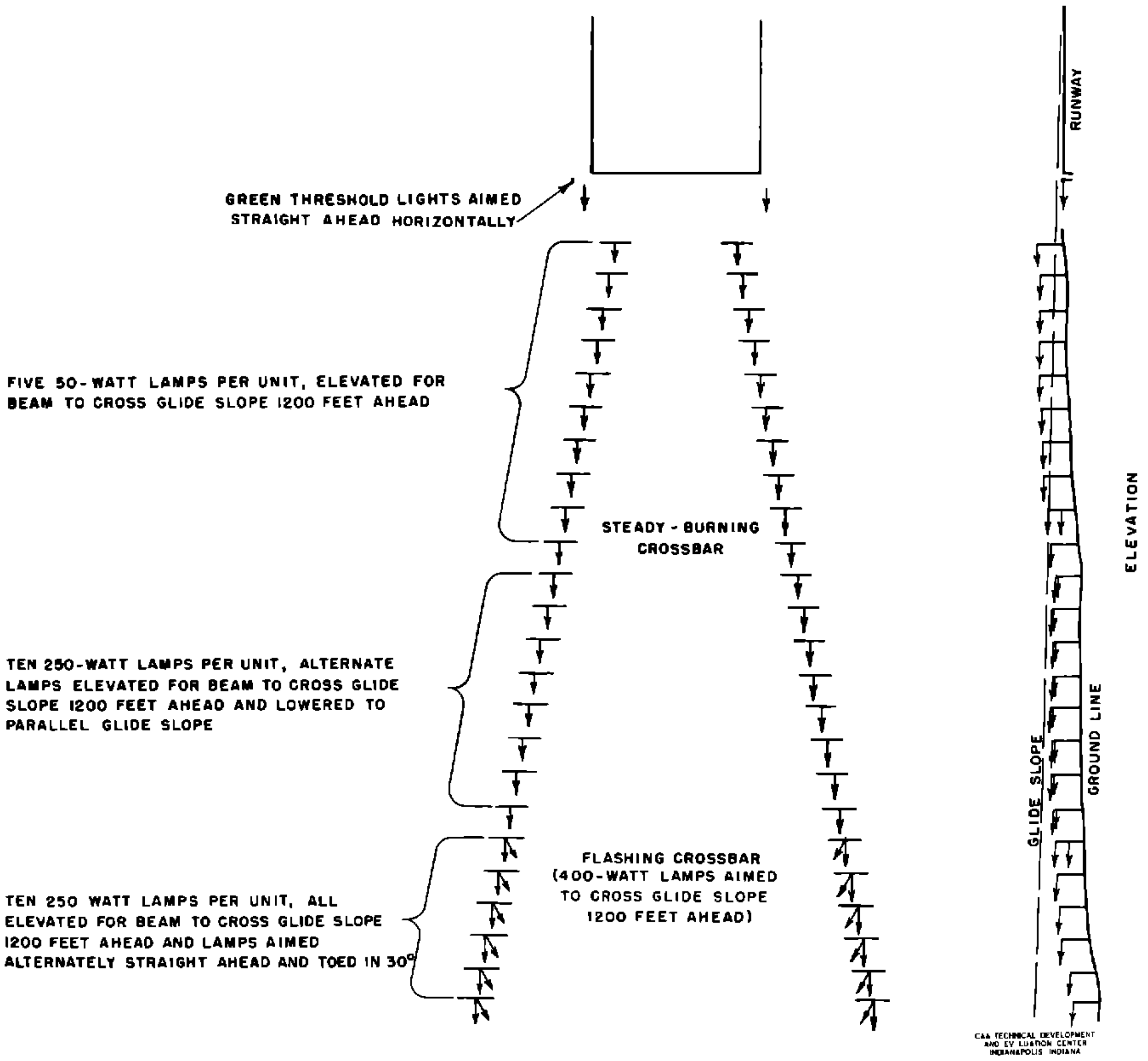

Fig 2 Plan of Experimental Slope Line Approach Light System

sudden glare and to improve the guidance afforded by the approach lights for lead-in purposes was discussed and analyzed in a previous report under the heading "Vertical Angular Settings of Lamps for Good Visibility Conditions "[8]

This modification consists of lowering the vertical angular setting of alternate lamps in one section of the pattern to a setting where the axes of the beams are parallel with the indicated approach plane See Fig 5 As the vertical spread of the lamps is about 5 1/2 degrees for 20,000 candles, this spread will cover approximately the entire space from the approach plane down to the horizontal, and the pilot will never be below the beams. The remaining lamps are set so that the axes of their beams intersect the glide slope 1,200 feet in advance to make the units visible to a pilot on the approach path under critical visibility conditions

This modification is applied to the middle one-third of the pattern The outer one-third is modified to spread the visibility

[8]Gilbert and Pearson, op cit., p 27

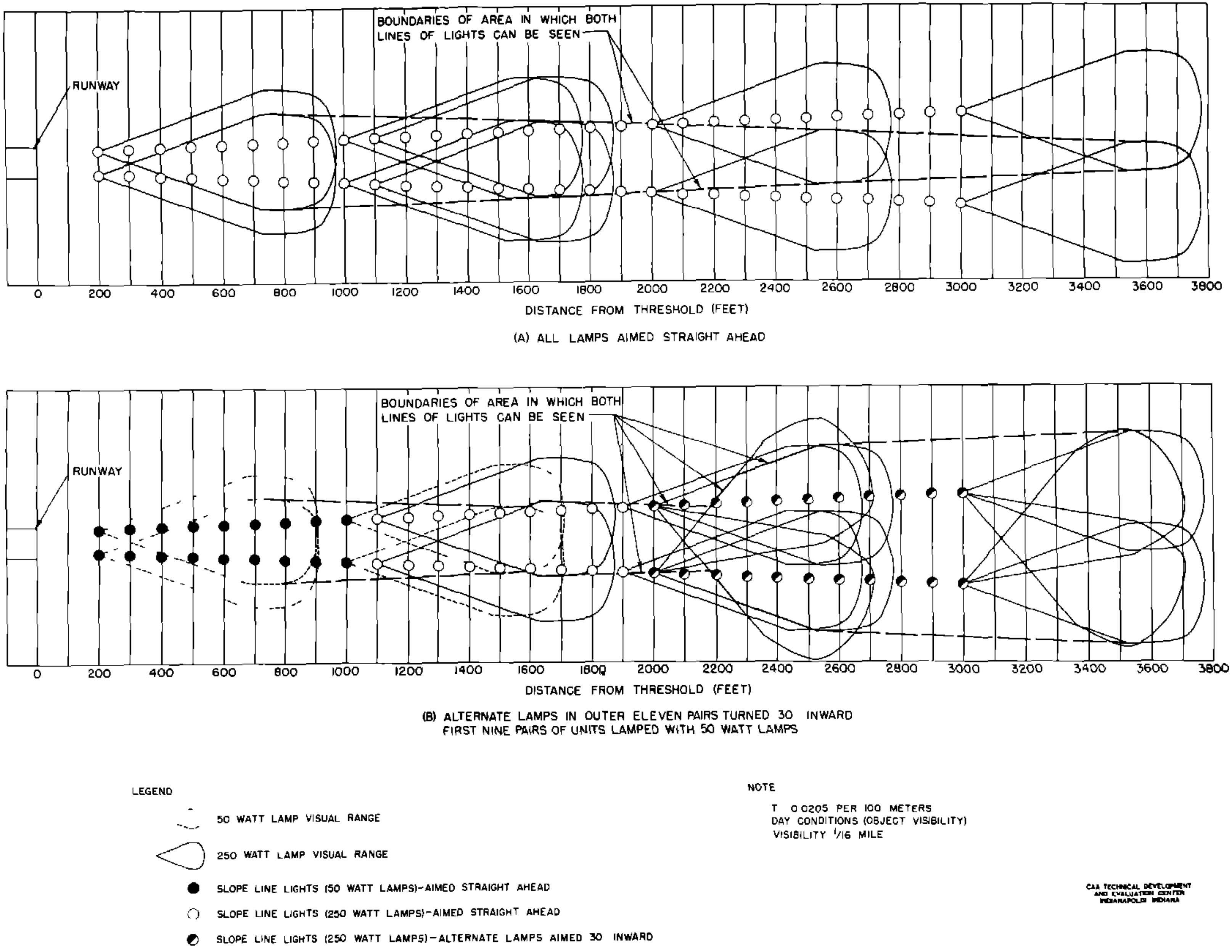

Fig 3 Effect of Modified Horizontal Setting on Visibility Area

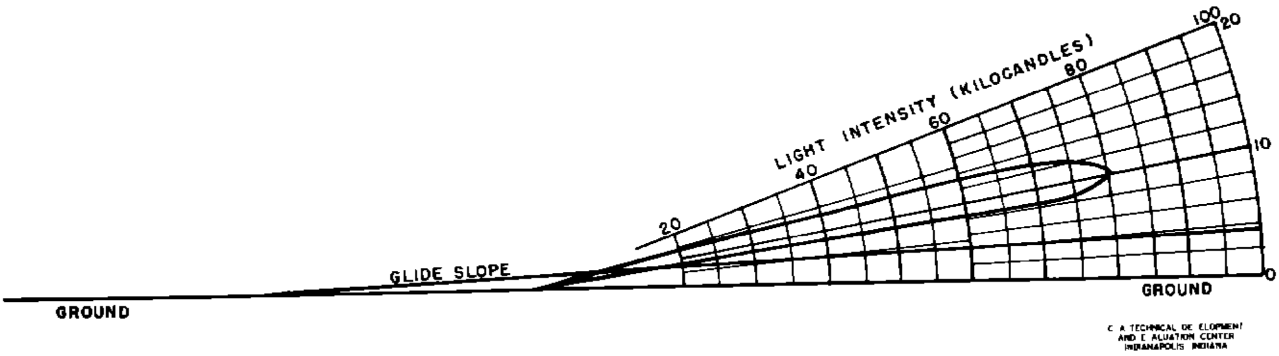

Fig 4 Vertical Setting and Light Distribution of Approach Light Lamp

horizontally, because it is the critical part of the pattern with reference to first sight. On the other hand, the vertical modification being used in clear weather can be equally effective from any part of the pattern.

Reduction of Glare

The earlier analysis of glare conditions shows that there is little or no likelihood of glare to a pilot who is on the correct glide slope so long as the brightness is reasonably matched to the weather, at least until he enters the last one-third of the system See Fig 6 This analysis indicates that uncomfortable glare is more likely to occur in the section of the approach system adjacent to the threshold, where the pilot is low over the lights. It was also shown that smaller lamps should produce adequate visibility in this section and reduce glare This section of the approach system was therefore equipped with only five 50-watt lamps in each unit

Improved Roll Guidance and Distance Indication.

Operational experience at the Landing Aids Experiment Station and elsewhere indicated that the addition of crossbars would improve the effectiveness of the slope line pattern These crossbars serve two functions They serve as a horizon reference to

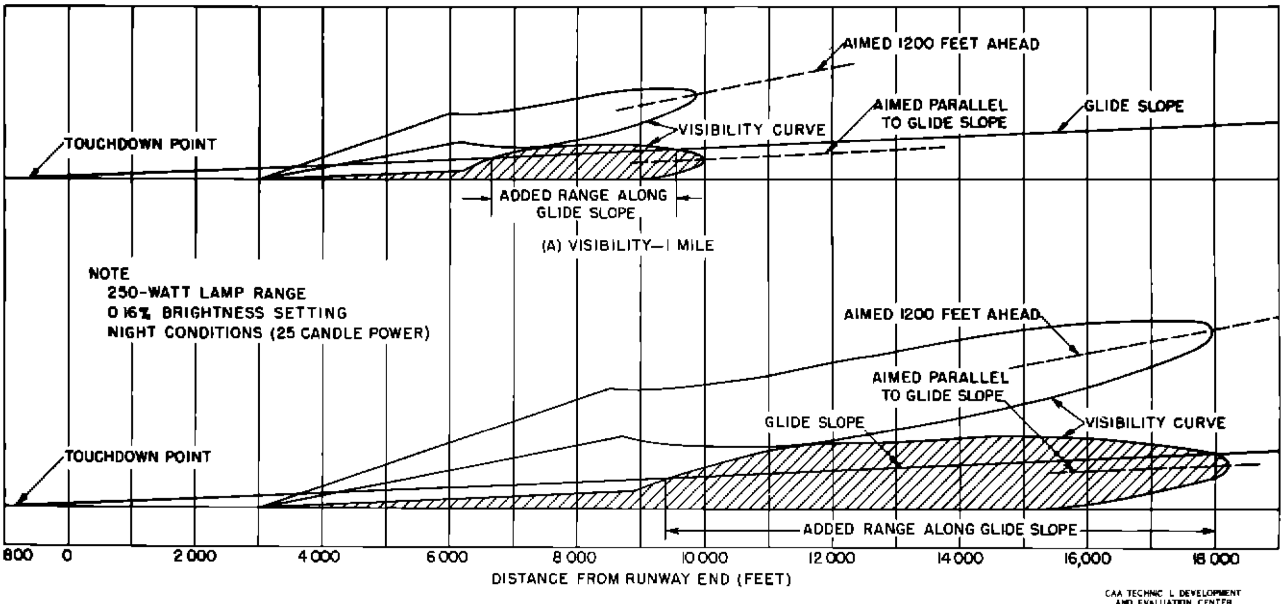

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Fig 5 Effect of Modification of Vertical Setting on Visibility

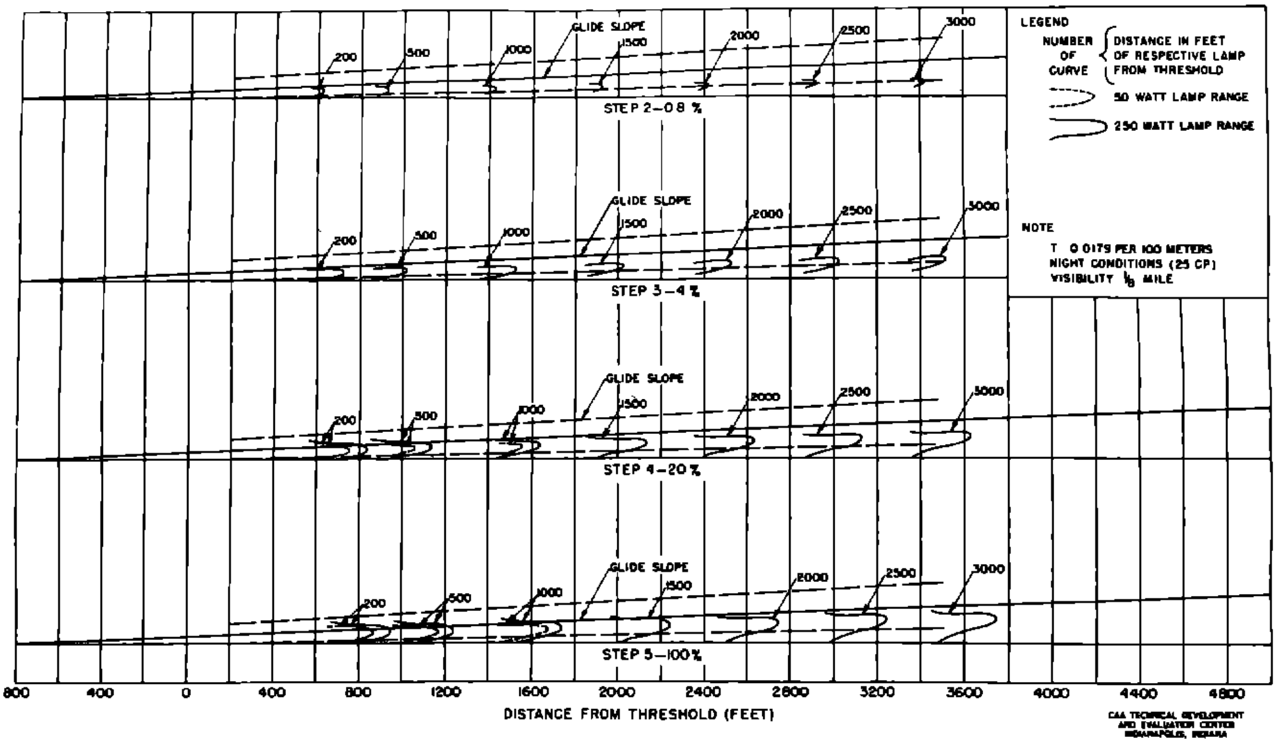

Fig. 6 Glare Range Diagrams With 1/8-Mile Visual Range

improve roll guidance, and they serve as distance markers.

A number of crossbar patterns have been developed, all incorporating two essential elements horizontal bars, and fixed distances One pattern, employing split lines, was installed at the Landing Aids Experiment Station A simple pattern, consisting of two solid lines traversing the width of the system, was installed at Indianapolis

These lines both consist of individual light units set on five-foot centers and are operated and controlled with the approach lights. The inner row is 1,000 feet from the threshold, and the outer row is 2,000 feet from the threshold The inner row is steady burning, and the outer row is flashed as a means of distinguishing one bar from the other. This cycle is about three seconds, which is the minimum to which the 250-watt lamp will respond All lamps are equipped with red filters

Threshold Guidance

The principal problem in threshold lighting is to provide adequate conspicuity without excessive glare The possibility of glare is particularly important due to the fact that the pilot passes over the lights at a very low altitude when making a landing

The experimental pattern used at Indianapolis consists of lamps similar to those used in the approach light system, set five feet on centers to form two horizontal bars, each 30 feet long, and separated by a gap 80 feet wide This pattern is symmetrical about the extended axis of the runway See Fig. 1. The lamps are equipped with green filters, and can be adjusted individually. This threshold marking is operated on the approach light brightness control

The threshold lamps were set initially with the axes of the lamps directed upward to intersect the glide plane 1,200 feet in advance. During the period that the approach lights were operated without red filters no criticisms were heard from pilots on threshold brightness, which was somewhat less than that of the approach lights As soon as filters were installed on the approach lights, the pilots commenced complaining about glare from the threshold lights In order to reduce this glare, the lamps were reset with the axes of the beams horizontal.

OBSERVATIONS AND CONCLUSIONS

Observation flights were made on the approach light system after the various modifications were made, and service flights use the system regularly Based on this experience, the following conclusions appear justified

1 Observation of the modified setting of the lamps in the outer one-third of the system indicates that the effective spread of the coverage has been broadened to about the degree anticipated, and the appearance of the system from on-course has not been appreciably impaired

2 The lead-in function of the pattern has been greatly improved From a distance of eight or ten miles the middle section of the pattern shows up clearly, while the outer and inner sections are dim or even invisible. As the pilot approaches and comes into the area covered by the direct beams from the first section of the pattern, the lights in this section appear to increase in brightness to match that of the middle section, which has been conspicuous for the entire approach

This modification appears to fulfill its design function perfectly, and there is no tendency to call for increases in brightness over that required for the weather condition prevailing If the lights have been set at an excessive brightness, the pilot has ample warning from the section whose beams are directly toward him and can call for a reduction of brightness in sufficient time to avoid dangerous glare or discomfort.

3 The modification of the inner one-third of the system to reduce glare was accomplished, but there has been no weather severe enough to permit flight testing under critical conditions. The flight testing that was done has indicated that the visual range still is adequate when the system brightness is set to correspond with the weather conditions, and indications are that the anticipated glare reduction will be realized

The use of only five lamps on 34-inch centers in this section and the reduction of wattage of the lamps result in a material saving of power With the 50-watt lamps, which were used in this installation, this saving amounts to more than 45 kilowatts

4 The crossbar pattern appears to be fully as effective as the split crossbar pattern used at the Landing Aids Experiment Station No difficulty has been experienced in differentiating between the steady-burning and the flashing bars

5 The threshold pattern appears to be a marked improvement over the usual arrangement The comments of the Technical Development and Evaluation Center pilots (and the comments of transport pilots, as reported by the control tower) were all favorable to the pattern

The objections voiced with respect to glare from these lamps, however, emphasize that the brightness and distribution of the units used for this purpose are critical, and more study is needed to develop a distribution which will give sufficient conspicuity without uncomfortable glare and without excessive waste It is recommended that more comprehensive study be given the requirements for threshold lights and that a practical compromise be effected between visibility distance requirements and tolerable glare

APPENDIX

ANALYSIS OF RELATIVE VISIBILITY

Using the row factor developed by de Boer,[9] it is possible to determine the relative visual range of slope line bar units with ten lamps set parallel and with alternate lamps set to a different angle. This is done by assuming in one case that all ten lamps are effective and in the other case that every alternate lamp is not effective. Inasmuch as there exists a considerable quantity of spill light from the five lamps considered ineffective, the actual difference will be somewhat less than that calculated

To compare the visibility of the ten-lamp fixture with that of the five-lamp fixture, with the lamps at double spacing, the row factors of the two fixtures are derived. This row factor represents the illumination required of each lamp of the row divided by that required of a single lamp to produce the same visibility

The row factor is based on the diameter of the light source divided by the spacing, and de Boer provides a chart from which the numerical value of the row factor can be determined from the diameter-to-spacing ratio For the ten-lamp fixture, this ratio is 0 411 and the row factor is 0 28 For the five-lamp fixture, the ratio is 0 206 and the row factor is 0 42

The effective visual range is given by

$$I = E_o D^2 T^{-D}$$

where

I = Intensity of light source in candles

E_o = Threshold brightness in hectometer candles = 2.0 for daylight background

D = Distance in hectometers

T = Transmission of atmosphere per hectometer, which for 1/4-mile visibility can be taken as 0 141

By modifying the value E_o by the row factors, the following visual ranges for 1/4-mile daylight visibility are derived

1. For a ten-lamp bar, 780 meters
2. For a five-lamp bar, 740 meters.

[9] J. B de Boer, "Visibility of Approach and Runway Lights," Reprint R 168, Philips Research Laboratories, Eindhoven, Netherlands, June 1951

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