# AN ANALYSIS OF THE CANDLEPOWER DISTRIBUTION REQUIREMENTS OF RUNWAY LIGHTS

By
Marcus S Gilbert and H. J Cory Pearson
Airport Division

Technical Development Report No 178

CIVIL AERONAUTICS ADMINISTRATION
TECHNICAL DEVELOPMENT AND
EVALUATION CENTER
INDIANAPOLIS, INDIANA
June 1952

## U S DEPARTMENT OF COMMERCE

Charles Sawyer, Secretary

## CIVIL AERONAUTICS ADMINISTRATION

C F Horne, Administrator

D M Stuart, Director, Technical Development and Evaluation Center



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

TABLE OF CONTENTS


| | Page |
|---|---|
| Summary | 1 |
| Introduction | 1 |
| Airplane Paths During Approach, Landing, and Take-off Operations | 1 |
| Assumptions and Calculations | 4 |
| Discussion | 8 |
| Conclusions | 13 |

Manuscript received April 1952

# AN ANALYSIS OF THE CANDLEPOWER DISTRIBUTION REQUIREMENTS OF RUNWAY LIGHTS


## SUMMARY

This report discusses the runway light candlepower distribution based on the functional requirements for adequate guidance of various types of commercial aircraft during circling, approaching, landing, taxiing, and take-off operations conducted in accordance with Civil Air Regulations

Individual aircraft characteristics were considered in establishing positional limits between which different types of aircraft might be expected to operate during various maneuvers After consultation with a number of pilots, assumptions were made concerning which lights a pilot should be able to see for guidance during each operation. The directions and distances between the lights and the successive aircraft positions were then calculated and tabulated

Critical atmospheric transmissivities were assumed in conformity with existing regulations governing operations under various weather minimums, and the corresponding candlepower requirements were then determined These candlepower requirements were then evaluated in order to determine their practicability and in order to determine whether intensities needed for some airplane positions in space would cause glare at other positions

Finally, acceptable candlepower (cp) values were plotted as isocandle curves which can serve as a basis for performance specifications for improved runway lights


## INTRODUCTION

The need for runway lights to outline runways as an aid to air navigation was recognized many years ago Many types of lights embodying the ideas of different designers have been developed Those in the high-intensity category are generally classified on the basis of their candlepower distribution as wide beam, narrow beam, or movable beam units, and considerable uncertainty and confusion exist concerning their relative effectiveness and proper application

The essential function of the runway lights is to mark the position and limits of the runway In order to be useful these lights must be made visible to the prospective user at various stages of landing and take-off operations It would appear then that a logical approach to the problem of runway lighting would be to study aircraft operations with a view to establishing approximately the paths described by aircraft during various maneuvers and to calculate the candlepower distribution required, in order that pilots can see the necessary lights from aircraft following those paths.

Since operations and procedures are more or less standard, being governed by regulations as well as by aircraft characteristics and limitations, it is not an impossible task to determine the general direction and distance from any runway light to an airplane during the course of any specific operational procedure The required candlepower of the light in the direction of the pilot can then be determined mathematically.

In this study use was made of the characteristics of typical commercial airplanes whose maneuvering paths lie farther out from the runway, whose turning radii are greater, and whose demands on the lights are therefore more critical than those of smaller aircraft Any lights designed for commercial airplanes should be satisfactory for most of their military counterparts and for smaller aircraft

The authors wish to emphasize that this analysis has involved consideration of certain intangible factors which cannot be defined exactly In dealing with such factors an attempt was made to arrive at reasonable assumptions through discussion with qualified persons The study is intended to serve as a guide in the development and design of new lighting units

## AIRPLANE PATHS DURING APPROACH, LANDING, AND TAKE-OFF OPERATIONS

Runway lights are used during approaches and landings to provide visual guidance to a pilot for a period which begins after he has started his approach and ends as he leaves the runway after completing his landing. The area within which guidance is required depends largely upon the type of approach he is making The runway light intensity required depends upon the distance from which the lights must be seen and upon the visibility condition prevailing Runway lights are also used during take-offs while the airplane is on or above the runway

The types of approaches that may be made under certain limiting visibility conditions are governed by Civil Air Regulations. Minimum operating conditions vary somewhat at different airports chiefly because of

TABLE I

MINIMUMS GOVERNING APPROACHES AND TAKE-OFFS AT INDIANAPOLIS INDIANA*

| Class of Operator | Type of Aircraft | Landing Minimums Day or Night | | | | Take-Off Minimums Day or Night | | | Alternate Landing Minimums |
|---|---|---|---|---|---|---|---|---|---|
| | | Circling Approach** | | Straight-in Approach** | | | | | |
| | | Radio Range or Automatic Direction Finder | ILS | Radio Range (Runway 9) or Automatic Direction Finder (Runway 4) | ILS Runway 4 | Radio Range or Automatic Direction Finder | ILS Runways 4 or 22 | ILS Other Runways | |
| Scheduled Air Carrier | DC-3 or Smaller | 400-1*** | 400-1 | 400-1 | 200-1/2 | 300-1 | 200-1/2 | 300-1 | 800-2 |
| | CV-240 M-202 | 500-1 1/2 | 500-1 1/2 | 400-1 | 200-1/2 | 300-1 | 200-1/2 | 300-1 | 800-2 |
| | DC-6 DC-4 L-49 | 500-1 1/2 | 500-1 1/2 | 400-1 | 200-1/2 | Runways 4 or 22 200-1/2 Others 300-1 | 200-1/2 | 300-1 | 800-2 |
| All Others Except Military and Users to Whom the CAA has Specifically Authorized Lower Minimums | Aircraft Having Stall Speeds Above 75 mph | 500-1 1/2 | 500-1 1/2 | 500-1 | 400-3/4 | 300-1 | 300-3/4 | 300-1 | 1000-3 |
| | Aircraft Having Stall Speeds Below 75 mph | 400-1 | 400-1 | 500-1 | 400-3/4 | 300-1 | 300-3/4 | 300-1 | 1000-3 |

NOTES ON TABLE I

*While minimums in this chart apply specifically to operations at Weir Cook Municipal Airport Indianapolis Indiana they are applicable to most other airports where the same terrain and obstruction conditions prevail

**Circling approach minimums (known as regular landing minimums) are authorized when it is necessary to circle or maneuver the aircraft during an approach for landing Straight-in landing minimums are authorized only when landing can be accomplished straight in from the navigational facility being used to the near end of the runway without exceeding 500 feet per minute rate of descent and without change of direction of more than 30°

***In columns 3 to 10, numbers indicated thus 400-1 means a ceiling of 400 feet and visibility of 1 mile

Sources of information CAA Flight Information Manual, Vol 5 No 2 June 1951

differences in obstructions Representative minimums are summarized in Table I which shows those in effect at Weir Cook Airport, Indianapolis, Indiana

It can be seen from Table I that circling approach minimums applicable to commercial aircraft generally vary from 400-and-1 to 500-and-1 1/2 This means from a 400-foot ceiling and 1-mile visibility to a 500-foot ceiling and 1 1/2-mile visibility Daylight visibilities are reported on the basis of the observed visual range for large solid objects Night visibilities are based on observations of a 25-candlepower lamp The most commonly applied minimums for straight-in ILS approaches and landings are 300-and-3/4, although at one specially equipped airport qualified commercial pilots have been permitted to make instrument approaches and landings with minimums of 100-and-1/4 Straight-in approaches from a radio facility are generally permitted at 400-and-1 Both circling and straight-in approaches are also made under unrestricted visibility conditions Take-off minimums vary generally from 200-and-1/2 to 300-and-1

The several types of approaches mentioned in the regulations do not make identical demands upon the lights For the circling approach, which may be started from any direction, guidance over a wide area is required from the lights For the straight-in approach from a radio facility, the horizontal path limits are narrowed since straight-in approaches are permitted

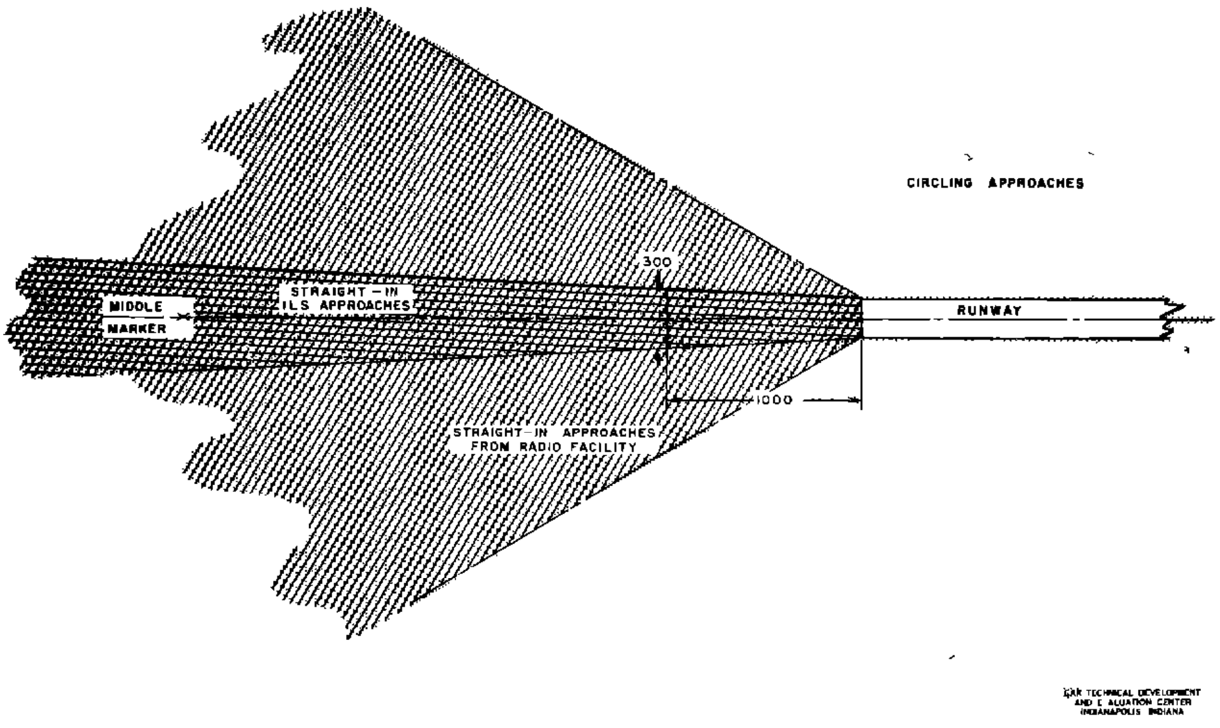


Fig. 1 Plan View of Runway and Approach Showing Directional Guidance Areas Required from Runway Marker Lights

only when the angular difference between the runway direction and a course from the navigation aid to the approach end of the runway is 30° or less For the straight-in ILS approach the limits are further narrowed to a region relatively close to the localizer course which the pilot is following in his let-down For this type of approach there are approach lights to guide him before he reaches the area where the limited coverage of the runway lights will be visible The directional guidance areas to be served by runway lights are shown in Fig 1.

The Circling Approach

In order to determine distances through which the light must travel to reach the pilot's eye, consideration must be given to the circling procedure before establishing the limits of the possible paths of an approaching airplane This procedure is required when a pilot first establishes visual contact with the airport from a point not suitable for his final approach It may also be necessitated by traffic conditions.

During the down-wind leg of the approach, the altitude of the airplane will be limited by two factors (1) the minimum clearance that must be maintained above the tallest obstructions in the airport vicinity, and (2) the maximum height from which a pilot can descend in comfort and safety. At most airports the minimum height above ground for circling is established at 500 feet A let-down rate of 500 feet per minute may be considered a maximum for aircraft not pressurized, although this rate could be increased in an emergency On this basis, a height of 2,000 feet may be considered a maximum for normal approaches and might be increased to 4,000 feet for emergency conditions

From a series of actual flight measurements conducted by TDEC engineers, it had been previously determined that during the circling approach the maneuvering speed was approximately 16/9 $V_s$, where $V_s$ = stall speed For the several types of airplanes listed, the values would be approximately those shown in Table II There are many variables which affect these speeds, but for the purposes of this determination the values

TABLE II

SPEED AND VISIBILITY CHARACTERISTICS OF VARIOUS AIRLINERS

| Aircraft | | Characteristic Speed* (mph) | | Typical Circling Approach (15° Bank) | | Minimum Forward Visibility on Ground** (Feet) | |
|---|---|---|---|---|---|---|---|
| Manufacturer | Model | Approach | Stall | Selected Speed (mph) | Corresponding Turn Radius (Feet) | Landing | Taxiing |
| Boeing | 377 | 150 | 100 | 175 | 7600 | 146 | 73 |
| Consolidated-Vultee | Convair 240 | 115 - 130 | 91 | 160 | 6400 | 62 | 59 |
| Douglas | DC-6 | 125 - 135 | 89 | 160 | 6400 | 104 | 98 |
| Douglas | DC-4 | 120 - 135 | 83 | 150 | 5600 | 152 | 98 |
| Douglas | DC-3 | 95 - 110 | 69 | 120 | 3600 | 104 | 331 |
| Lockheed | Constellation | 120 - 135 | 88 | 160 | 6400 | 155 | 123 |
| Martin | 202 | 115 - 130 | 83 | 150 | 5600 | 69 | 66 |

*These figures were supplied by the respective manufacturers They will vary under different conditions of altitude loading winds and reserve fuel carried However for lighting requirements and estimations these values will be satisfactory

**Some of these figures were obtained from manufacturers and the others from actual measurement at this Center

given are sufficiently accurate

At the end of the down-wind leg, the pilot makes a turn of approximately 180° This turn is so executed that at its completion the airplane will be at a height of approximately 500 feet above the runway level and in position to begin a final approach from a point approximately 3,500 feet distant from the runway end During the down-wind leg the pilot maintains the necessary horizontal distance from the runway to permit him to execute the turn properly This distance is about twice the radius of turn, and is dependent upon the degree of bank and the maneuvering speed These factors are interrelated as indicated by the equation

$$R = \frac{V^2}{g \tan \phi} \qquad (1)$$

where

R = radius of turn (feet)
V = maneuvering speed prior to landing (feet per second)
g = acceleration of gravity (32.2 feet per second per second)
$\phi$ = degree of bank For turns made by passenger-carrying aircraft, 15° is a normal and comfortable bank.

Because of their greater speeds the large airplanes require a larger turning radius, and pilots normally execute the down-wind legs at a greater distance from the runway For this reason, Civil Air Regulations require higher minimum visibility conditions for large aircraft

From the data shown in Table II and the application of Equation (1), the theoretical limits of circling paths shown in Fig 2 were determined Figs 3A and 3B show some typical circling approaches plotted from actual field observations under good visibility conditions These are preliminary results from a collision course study now being conducted at this Center as one phase of an investigation concerning the development of cockpit visibility standards The results of this investigation will be published in a subsequent report While there is considerable variation between paths for the same model of airplane, the paths shown are generally consistent with the theoretical computations

## ASSUMPTIONS AND CALCULATIONS

Before an optimum candlepower distribution for runway lights can be determined it is necessary to arrive at a practical assumption concerning the number of feet of runway a pilot should be able to see from various points along his path It is understandable that most pilots might prefer to be able to see all the runway, or all the lights outlining the runway, at all times after starting an approach Such a requirement would not be realistic, however, because it would involve excessive candlepower for low visibility conditions and would produce glare

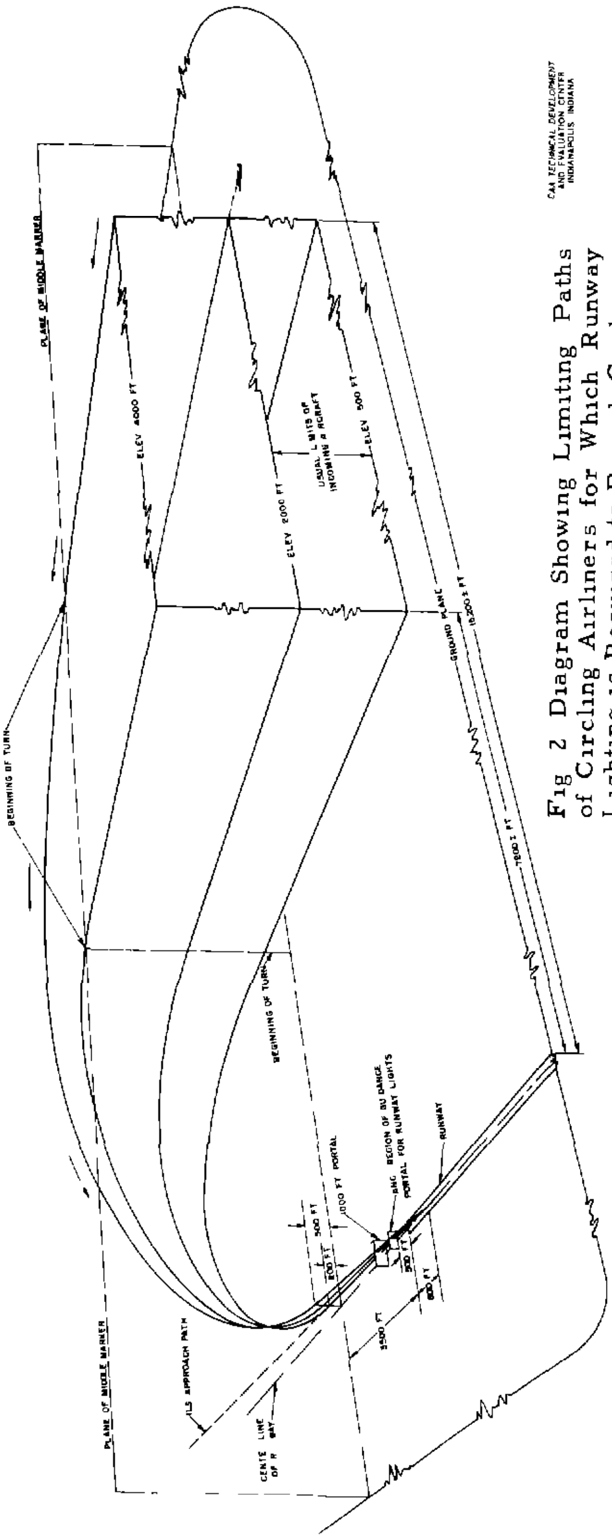


Fig 2 Diagram Showing Limiting Paths of Circling Airliners for Which Runway Lighting is Required to Provide Guidance

during certain phases of the landing operation Experience in low visibility operation has also shown that such an ideal situation is not required for safety A more realistic requirement must be based on a study of the actual needs for each part of the approach rather than on what might be considered desirable

In arriving at a tentative decision on this point, discussions were held with a group of pilots who were asked to state their opinions about the minimum length of runway necessary to be seen during each part of the approach The consensus is listed in Table III The pilots stated that for all operations it is desirable to see the lights on both sides of the runway in order that the runway may be more readily recognized

It will be noted that for operations under circling minimums, where navigation after the break-through is by visual means, the pilots desired to see a relatively large portion of the runway For the very restricted visibility operations, such as straight-in ILS approaches, the requirements were reduced to 1,000 feet because the pilot is guided by electronic equipment almost to the point of final touchdown For the landing roll, taxiing, and take-off operations it is unnecessary to see large portions of the runway This is because the airplane already is oriented along a definite ground course or is proceeding more slowly than in the approach

Having assumed which lights it is desirable for a pilot to see in order to keep himself properly oriented during the different operations, the next step was to calculate the distances and angles from these lights to the various airplane positions In making the calculations it was assumed that the glide angle is 2 65°, the touchdown point is 800 feet from the runway end, and the runway width (when necessary to be considered) is 200 feet

Transmissivities along the slanting paths between the aircraft and the lights were assumed to correspond to the horizontal visibilities given in Table III For circling approaches, the visibility condition for operation of a given airplane was taken from Table I No consideration was given to the effect of ceiling height, since circling approaches are permitted only when an aircraft is below the ceiling

After the calculations of angle and distance were made, the candlepower values required to make the lights visible from the maneuvering path were read from nomographs

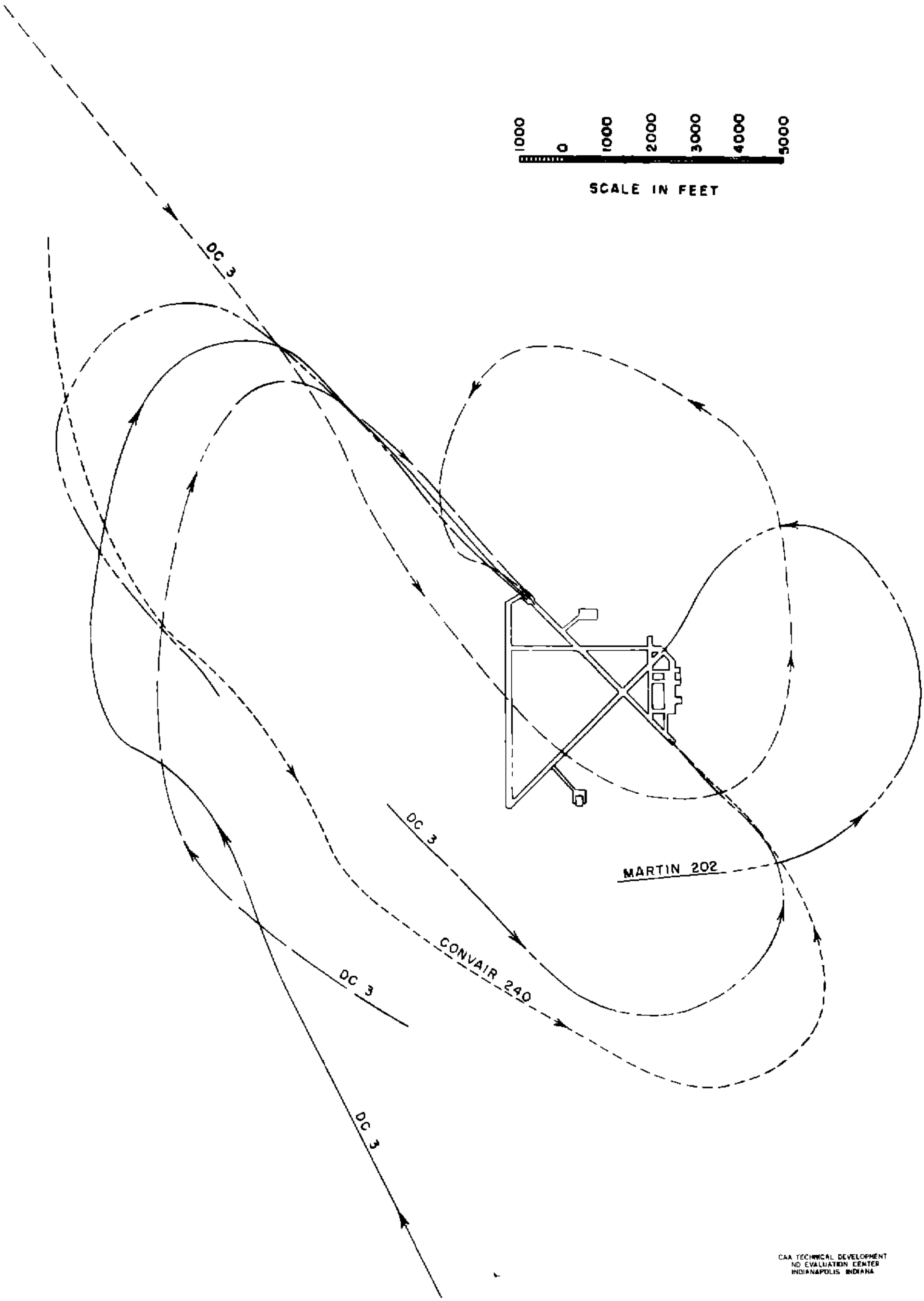


Fig 3A Plan View of Circling Approach Patterns Followed by Various Airliners

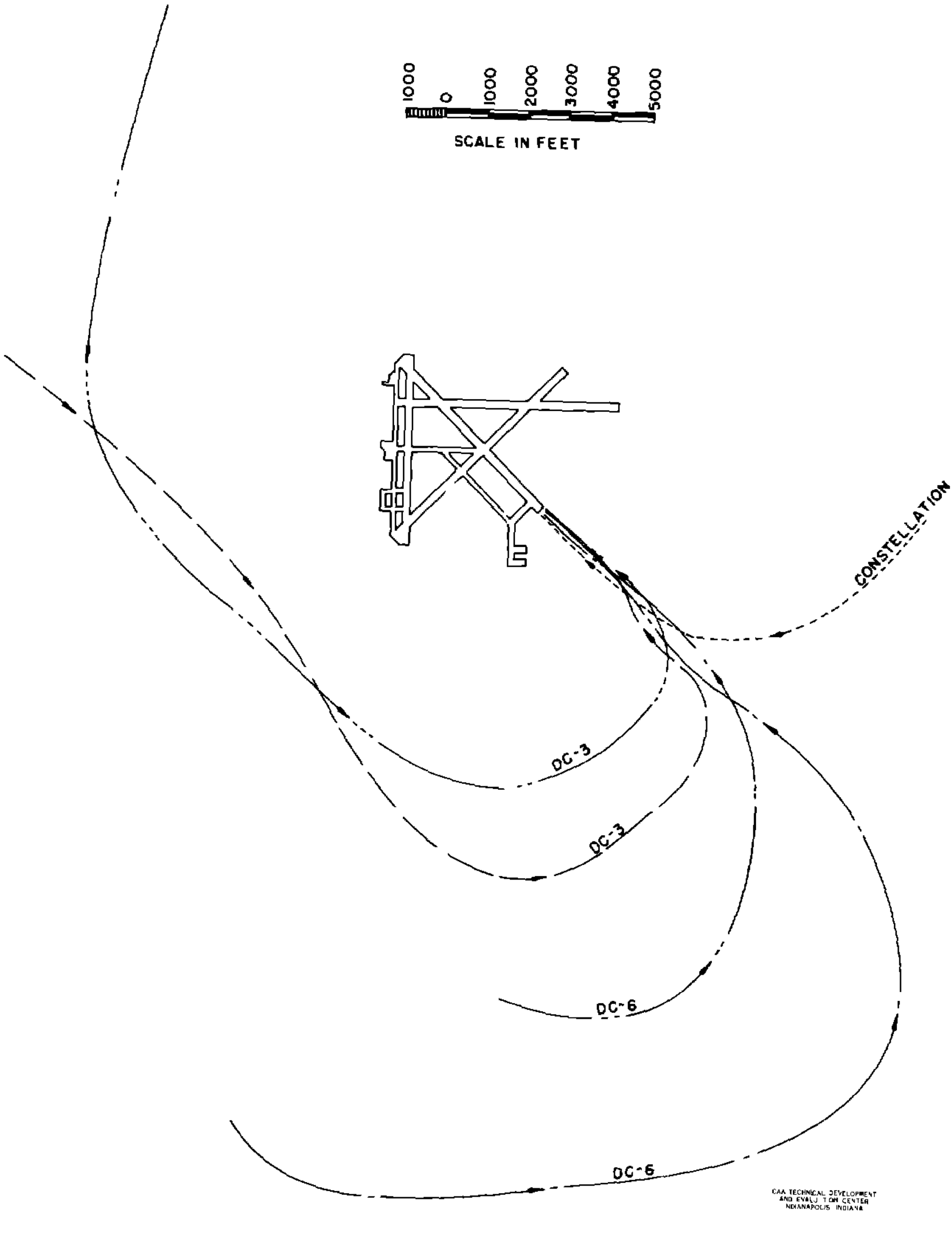


Fig 3B Plan View of Circling Approach Patterns Followed by Various Airliners

TABLE III

LENGTH OF RUNWAY DESIRABLE FOR PILOTS TO SEE DURING AIRPLANE OPERATIONS UNDER RESTRICTED VISIBILITY

| Visibility | Operation | Position of Airplane | Height Above Runway Level (Feet) | Minimum Length of Runway to be Seen (Feet) |
|---|---|---|---|---|
| Down to 1 Mile (Night) | Circling on Path as Near as Possible to Runway | On Down-Wind Leg | 500 to 4000 | 5000 |
| | | At 90 Point on 180 Turn | 350 to 2000 | 1000 |
| | Crossing Runway | Above Runway | 500 to 4000 | 3000 In Either Direction |
| | | 1/4-Mile From Either Side of Runway | | |
| | | 1/2-Mile From Either Side of Runway | | |
| | Straight-in Approach From Radio Facility | 8000 Feet to 10000 Feet Beyond Runway End | 400 to 525 | 200 |
| | | 3500 Feet Beyond Runway End | 200 to 600 | Entire Runway (5000-8000) |
| Down to 1/4 or 1/2-Mile (Day or Night) | Straight-in ILS Approach | 3500 Feet Out – Not More than 300 Feet Off Course | On Glide Path<br>Above Glide Path<br>Below Glide Path | 1000 |
| | | 1000 Feet Out – Not More than 150 Feet Off Course | On Glide Path<br>Above Glide Path | 1000 |
| | | 500 Feet Out – Not More than 125 Feet Off Course | On Glide Path<br>Above Glide Path | 1000 |
| Down to 1/4-Mile (Day or Night) | Touchdown Take-Off | | On Runway | 1000 |
| | Taxiing | | | 500 |

published previously[1] These values, listed in Tables IVa and IVb, were used to plot isocandle curves The isocandle curves shown in Fig 4 cover the requirements for circling approaches Figs 5 and 6 show the candlepower requirements for straight-in approaches under selected conditions

Intensities which are only high enough for threshold visibility from one point in the maneuvering space may be glaring to the same pilot or to other pilots when viewed from some other point in the same direction but at a shorter distance For example, a light which was barely visible to the pilot on the down-wind leg of his approach might be glaring during the landing roll While it is possible to vary the intensity of lights to some extent for varying weather conditions, it is not practicable to vary it for different stages of an approach, because several pilots at different points may be using the lights simultaneously

[1] M 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, November 1950, pp 6-7

Calculations of glare ranges for various values of light intensity were based on the assumption that glare can be produced by candlepower values approximately 1,000 times those producing threshold illumination at a given distance[2] Glare diagrams shown in Figs 7 and 8 are based on intensities required for seeing 1,000 feet of runway from the middle marker and from the 1,000-foot portal during a 1/4-mile night visibility condition The glare diagrams in Figs 9 and 10 are based on intensities required for seeing 1,000 feet of runway from the 1,000-foot portal during 1/4- and 1/2-mile day visibility conditions As a result of field tests, all candlepower values of 200 or less were considered to be non-glaring for short-range viewing regardless of the visibility condition

## DISCUSSION

A study of the tabulated candlepower data, isocandle curves, and glare diagrams indicates that the candlepower values required to satisfy the various conditions outlined in Table III are within practical limits

[2] Ibid , pp 5 and 8

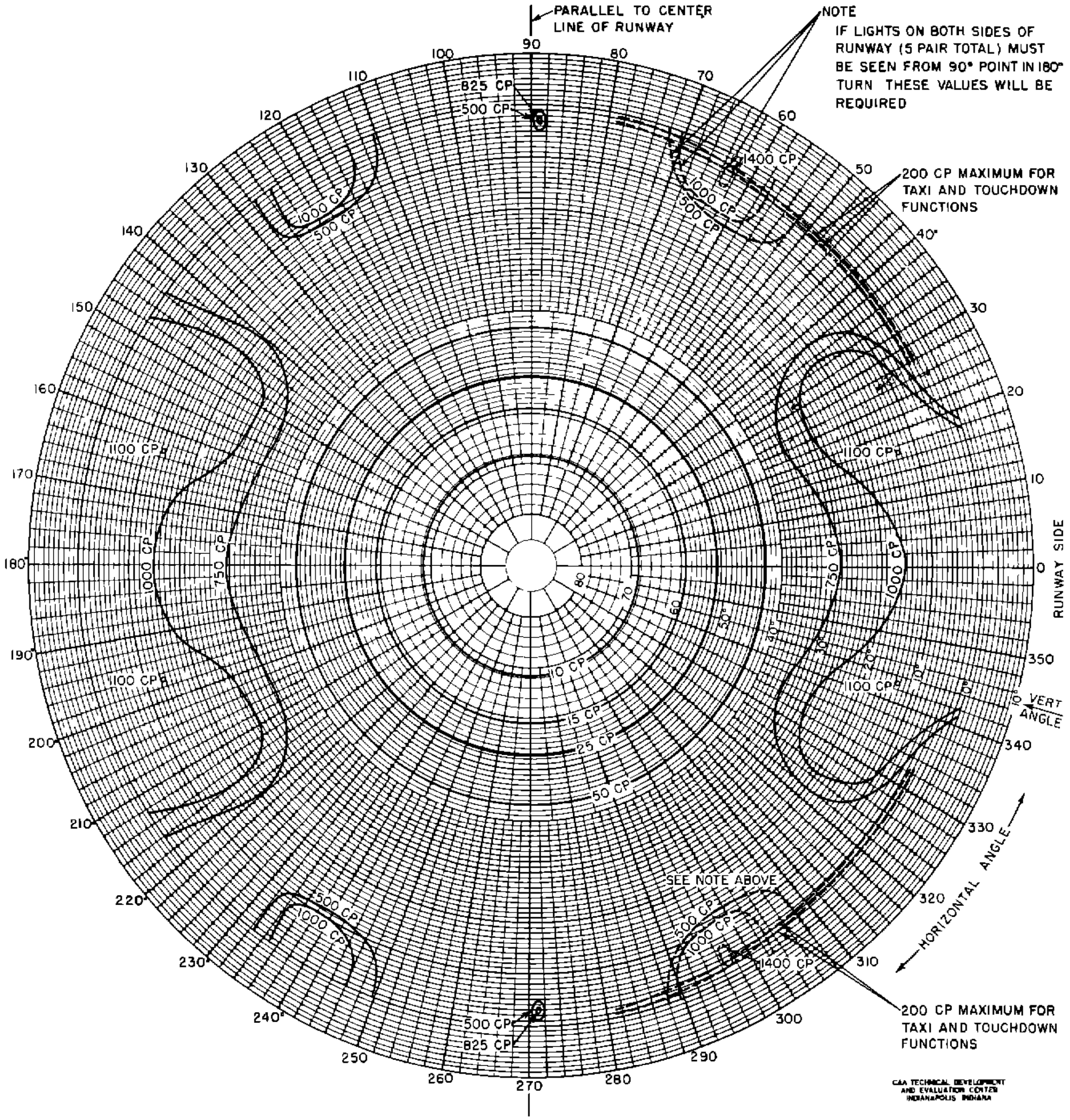


Fig 4 Isocandle Curves Showing Minimum Candlepower Requirements of Runway Lights for Night Operations Under Circling Minimums

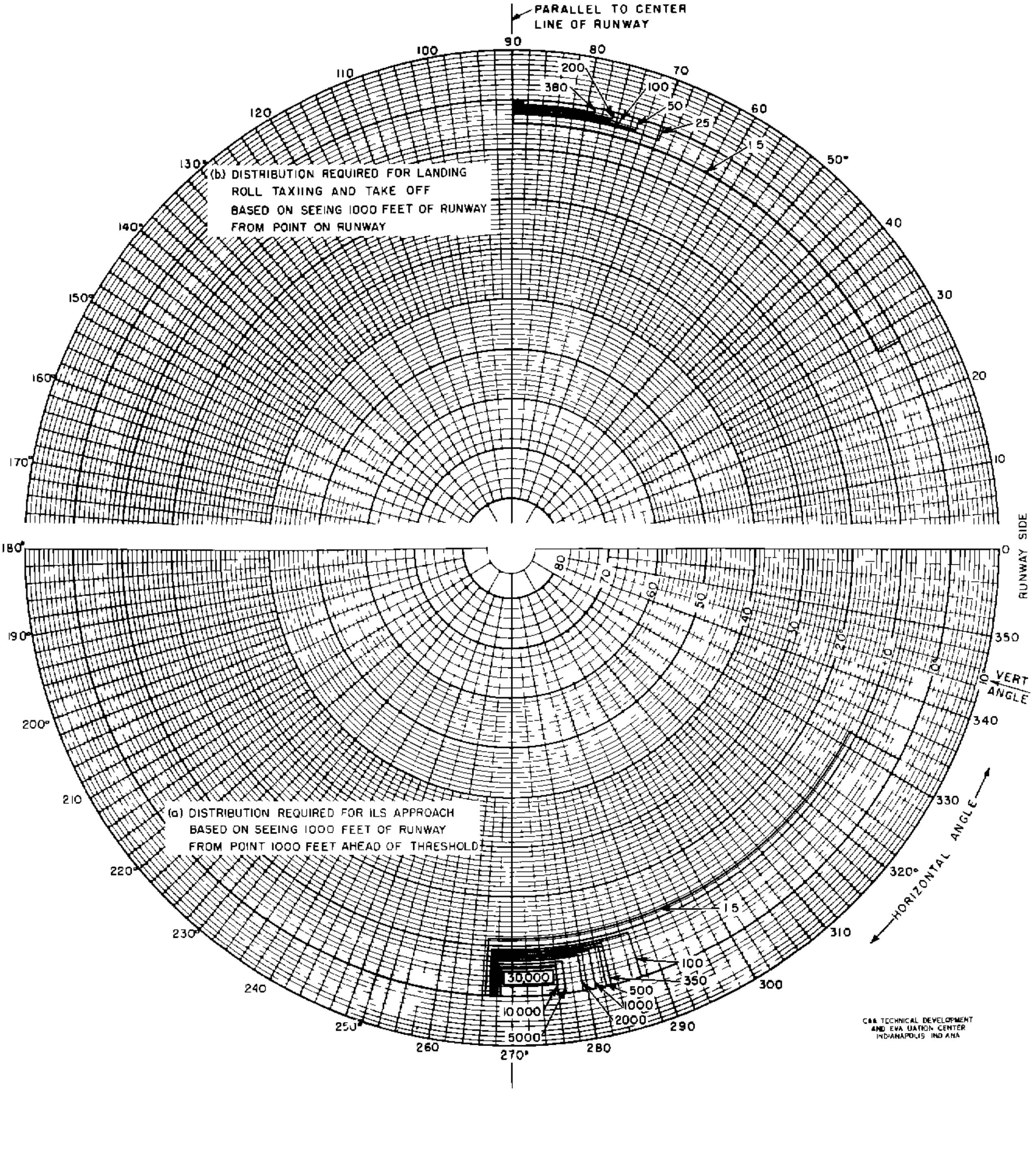


Fig 5 Isocandle Curves Showing Minimum Candlepower Requirements for Day Operations During 1/4-Mile Visibility Condition

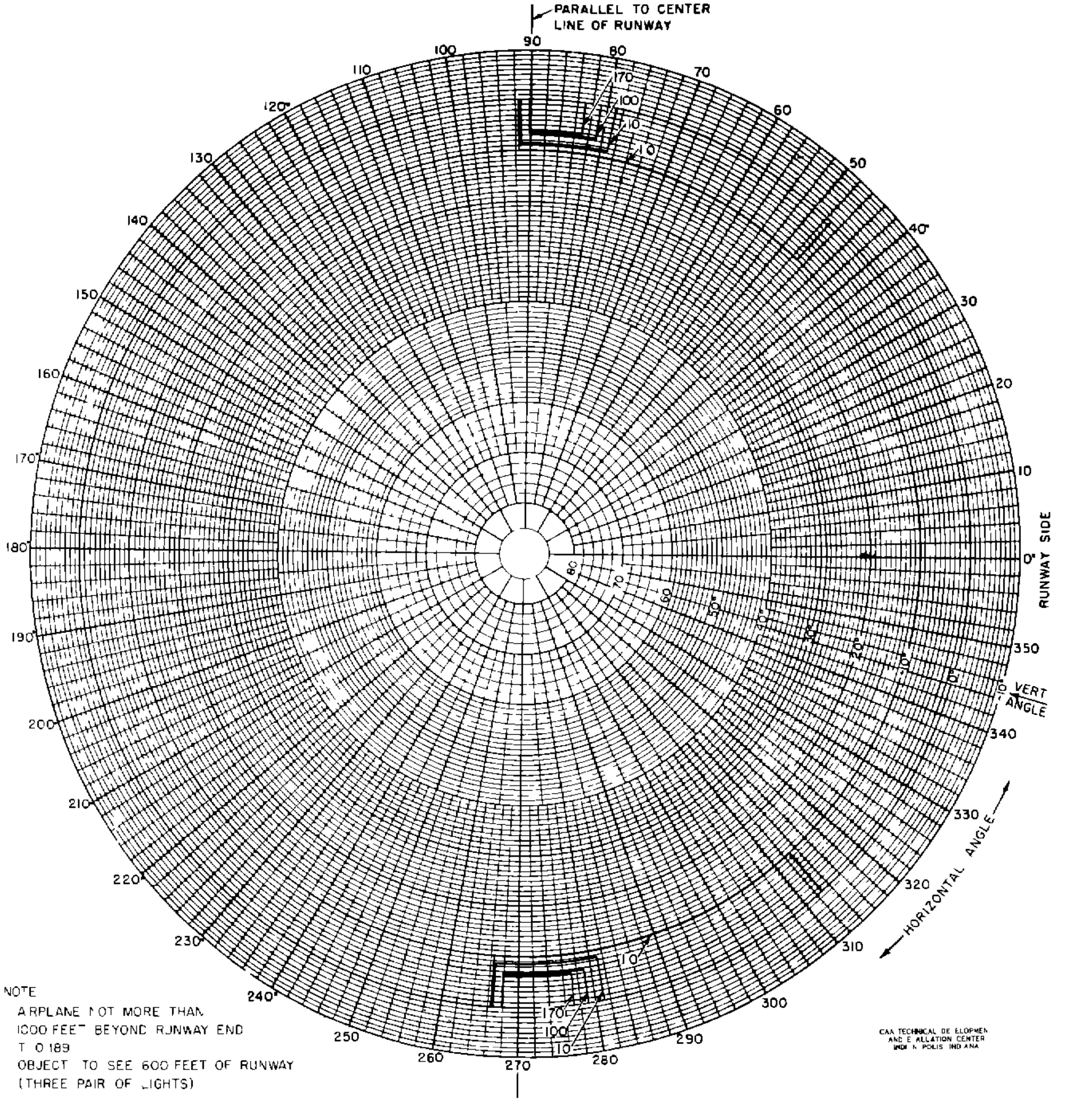


Fig 6 Isocandle Curves Showing Minimum Candlepower Requirements for Night Operations During 1/4-Mile Visibility Condition

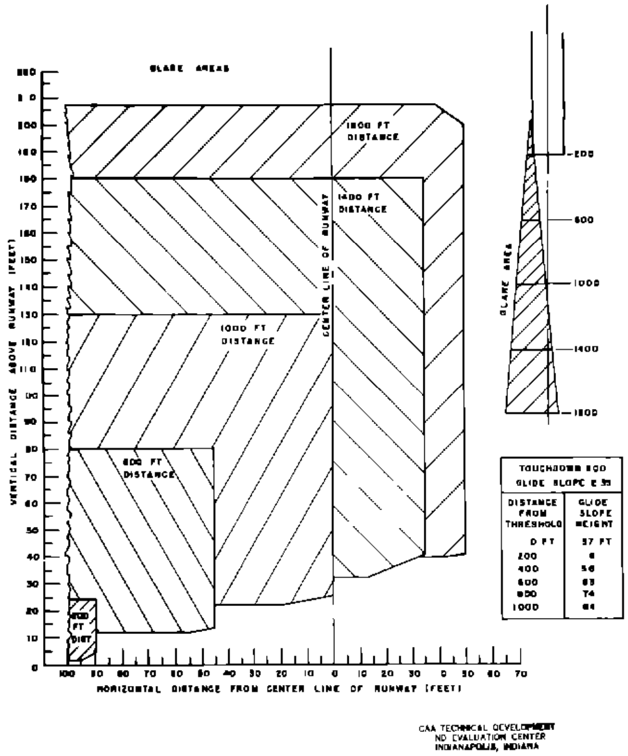


Fig 7 Outlines of Glare Area, at Designated Distances from Airplane, of a Runway Light Based on Candlepower Required to See 1,000 Feet of Runway from Middle Marker
Visibility 1/4-Mile, Night (25 cp)

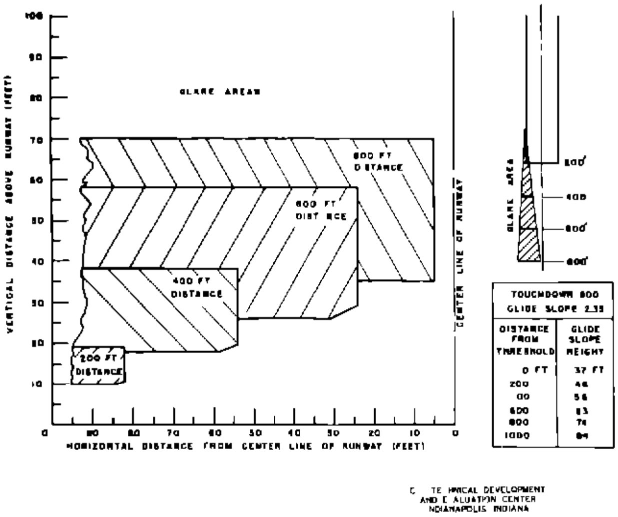


Fig 8 Outlines of Glare Area, at Designated Distances from Airplane, of a Runway Light Based on Candlepower Required to See 1,000 Feet of Runway from the 1,000-Foot Portal.
Visibility 1/4-Mile, Night (25 cp)

with the following exceptions

a To make 8,000 feet of runway visible from the middle marker (3,500 feet out from the runway end) for night visibilities below 1 1/2 miles would require impractical candlepower values which would also produce glare areas

b To make 1,000 feet of runway visible from the middle marker during 1/2-mile day visibility would also require excessively high candlepower values To make the same length of runway visible from the same point during 1/2-mile night visibility would involve glare at other positions, although the candlepowers would be relatively low and easy to obtain

c To make 1,000 feet of runway visible from a point 1,000 feet beyond the threshold during 1/4-mile night visibility would also result in glare Reducing to 600 feet the length of runway to be seen would correct this condition

The requirement that the lights on both sides of the runway should be visible from a given point gives rise to some points of conflict The difficulty is particularly apparent in the case of the candlepower distribution required by a pilot on the down-wind leg of a circling approach These values are much too high for a taxiing pilot who sees the lights at the same angles If the requirement were modified to make only the lights on the near side of the runway visible to the pilot on the down-wind leg, this difficulty would be eliminated

In order to cover various situations and visibility conditions, it appears that several candlepower distribution patterns will be required from the runway lights A distribution throughout a 360° horizontal range and with no high intensity beams, as shown in Fig 4, will be needed on all runways during night visibility conditions of one mile or more in order to provide guidance during (1) circling approaches, (2) approaches from a radio facility, (3) deceleration after touchdown, (4) taxiing, and (5) take-off

For straight-in ILS approaches there will be required from lights in the touchdown area a different pattern consisting of a high intensity beam through relatively narrow limits In order to maintain a margin of safety for a landing airplane which might be somewhat off course prior to crossing the threshold, the beam spread should be sufficient to cover a portal 300 feet wide at a distance 1,000 feet out from the runway end The isocandle diagram Fig 5a, illustrates the minimum candlepower needed for the 1/4-mile visibility condition, the most restricted condition considered in this study

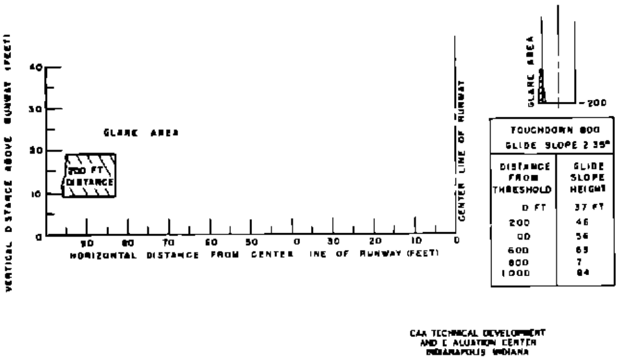


Fig 9 Outlines of Glare Area, at Designated Distances from Airplane, of a Runway Light Based on Candlepower Required to See 1,000 Feet of Runway from the 1,000-Foot Portal
Visibility 1/4-Mile, Day

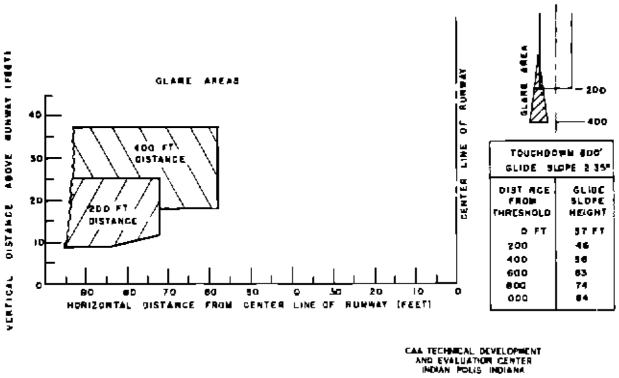


Fig 10 Outlines of Glare Area, at Designated Distances from Airplane, of a Runway Light Based on Candlepower Required to See 1,000 Feet of Runway from the 1,000-Foot Portal.
Visibility 1/2-Mile, Day.

This high intensity beam of 30,000 cp is based on the assumption of a need for seeing 1,000 feet of runway from a point on the 1,000-foot portal

A narrower beam of lower intensity will suffice for the landing roll, taxiing, and take-off during visibility conditions below one mile See Fig 5b The peak of 380 cp in this low intensity beam is based on a requirement for seeing only the 1,000 feet of runway immediately ahead of the pilot after the airplane touches the runway Should it be considered necessary to extend this latter range of visibility, higher beam candlepower values obviously will be needed The maximum may be as high as 30,000 cp should it be necessary for a pilot to see 2,000 feet of runway from the touchdown point

In the event that it is undesirable or impractical to design a high-intensity lighting unit of sufficient beam width for use in the touchdown zone, narrow beam units with the same maximum candlepower can be used in groups of two or three along the touchdown zones so that the total width of the combined beams will be sufficient to cover the portal

The intensity requirements will be considerably lower for operations at night, when the background brightness is low See Fig 6 Lights should be designed on the basis of the intensities required for the most exacting combination of transmissivity and background brightness expected to occur at representative airports Lower intensities for less exacting conditions may be obtained through intensity control, either manual or automatic Since intensities up to 200 cp can be tolerated from the glare standpoint under the best night visibility conditions, it is not necessary to use values less than this even though minimum requirements indicate use of lower intensities

It may be possible to develop a single type of runway light to combine the distributions required for all or several functions In any event, there is little doubt that combination or multiple units can be used to achieve the desired distributions Combining units to meet the candlepower requirements may also help in mitigating glare under certain conditions through use of the most suitable unit of the combination for any specific visibility condition

## CONCLUSIONS

1 On the basis of the assumptions set forth in this report the theoretical candlepower distributions needed to meet various requirements and conditions have been established The following conditions cannot be met with reasonable candlepower requirements without producing glare

a To see 8,000 feet of runway from the middle marker in visibility conditions less than the 1 1/2-mile night condition

b To see 1,000 feet of runway from the middle marker during the 1/2-mile day or night condition

c To see 1,000 feet of runway from the 1,000-foot portal during 1/4-mile night visibility To see 600 feet of runway without glare would be theoretically possible

2 It is not practical to see lights along both sides of the runway during the down-wind leg of a circling approach under some visibility conditions, because this will introduce

glare to pilots of other aircraft already on the runway

3 Three types of candlepower distribution are required for runway lights The first will cover the requirements for circling and other approaches under visibility conditions down to one mile by day or night The second will be required for the touchdown zone for straight-in ILS approaches The third will be required for the runway beyond the touchdown zone when the visibility is below one mile It may be necessary to use multiple fixtures in order to meet all conditions

4 Since the distributions developed in this report are based entirely on theoretical analysis, it is recommended that they be given adequate service testing before they are used as a basis for specification requirements

TABLE IVa

MINIMUM CANDLEPOWER REQUIREMENTS OF RUNWAY LIGHTS FOR NIGHT OPERATIONS UNDER CIRCLING MINIMUMS

Aircraft Position Circling on Downwind Leg
Requirement To See 2500 Feet of Runway From the Path Indicated

| Path – Horizontal Distance Between Runway Edge and Down-Wind Leg (Feet) | Altitude (Feet) | Vertical Angle (Degrees) | Horizontal Angle | | Candlepower | |
|---|---|---|---|---|---|---|
| | | | Runway Side (Degrees) | Off Runway Side (Degrees) | 1 1/2-Mile Visibility T = 0 881 | 1-Mile Visibility T = 0 7854 |
| 15200 | 500 | 1 9 | 0 | 180 | 1035 | |
| | 2000 | 7 5 | 0 | 180 | 1050 | |
| | 4000 | 14 7 | 0 | 180 | 1075 | |
| | 500 | 1 9 | 8 6 351 4 | 171 4 188 6 | 1055 | |
| | 2000 | 7 5 | 8 6 351 4 | 171 4 188 6 | 1055 | |
| | 4000 | 14 6 | 8 6 351 4 | 171 4 188 6 | 1075 | |
| 12000 | 500 | 2 39 | 0 | 180 | 250 | |
| | 2000 | 9 46 | 0 | 180 | 250 | |
| | 4000 | 18 4 | 0 | 180 | 375 | |
| | 500 | 2 35 | 10 85 349 15 | 169 15 190 85 | 250 | |
| | 2000 | 9 29 | 10 85 349 15 | 169 15 190 85 | 260 | |
| | 4000 | 18 2 | 10 85 349 15 | 169 15 190 85 | 400 | |
| 7200 | 500 | 3 99 | 0 | 180 | | 280 |
| | 2000 | 15 54 | 0 | 180 | | 300 |
| | 4000 | 29 1 | 0 | 180 | | 750 |
| | 500 | 3 79 | 17 75 342 25 | 162 25 197 75 | | 325 |
| | 2000 | 14 84 | 17 75 342 25 | 162 25 197 75 | | 400 |
| | 4000 | 27 9 | 17 75 342 25 | 162 25 197 75 | | 925 |
| Requirement To See an Additional 2500 Feet of Runway – (5000 Feet Total) | | | | | | |
| 15200 | 500 | 1 8 | 16 8 343 2 | 163 2 196 8 | 1080 | |
| 15200 | 2000 | 7 2 | 16 8 343 2 | 163 2 196 8 | 1090 | |
| 15200 | 4000 | 14 1 | 16 8 343 2 | 163 2 196 8 | 1100 | |
| 12000 | 500 | 2 24 | 20 94 339 06 | 159 06 200 94 | 375 | |
| 12000 | 2000 | 8 81 | 20 94 339 06 | 159 06 200 94 | 420 | |
| 12000 | 4000 | 17 3 | 20 94 339 06 | 159 06 200 94 | 760 | |
| 7190 | 500 | 3 35 | 32 61 327 39 | 147 39 212 61 | | 1000 |
| 7190 | 2000 | 13 20 | 32 61 327 39 | 147 39 212 61 | | 1030 |
| 7190 | 4000 | 25 1 | 32 61 327 39 | 147 39 212 61 | | 1050 |

T = Transmissivity

TABLE IVa (Continued)

MINIMUM CANDLEPOWER REQUIREMENTS OF RUNWAY LIGHTS
FOR NIGHT OPERATIONS UNDER CIRCLING MINIMUMS

Aircraft Position Requirement — At 90 Point on 180 Turn To See Pair of Lights Listed

| Path | Altitude (Feet) | Threshold To Pair Of Lights (Feet) | Vertical Angle (Degrees) | Horizontal Angle: Runway Side (Degrees) | Horizontal Angle: Off Runway Side (Degrees) | Candlepower: 1 1/2-Mile Visibility T = 0 881 | Candlepower: 1-Mile Visibility T = 0 7854 |
|---|---|---|---|---|---|---|---|
| 15200 | 350 | 200 | 1 5 | | 123 8 236 2 | 925 | |
| | 1000 | | 4 2 | | 123 8 236 2 | 925 | |
| | 2000 | | 8 4 | | 123 8 236 2 | 930 | |
| | 350 | 400 | 1 5 | | 123 3 236 7 | 930 | |
| | 1000 | | 4 2 | | 123 3 236 7 | 950 | |
| | 2000 | | 8 3 | | 123 3 236 7 | 1000 | |
| | 350 | 800 | 1 4 | | 122 5 237 5 | 1050 | |
| | 1000 | | 4 1 | | 122 5 237 5 | 1050 | |
| | 2000 | | 8 1 | | 122 5 237 5 | 1100 | |
| | 350 | 200 | 1 5 | 55 5 304 5 | | 930 | |
| | 1000 | | 4 2 | 55 5 304 5 | | 930 | |
| | 2000 | | 8 4 | 55 5 304 5 | | 930 | |
| | 350 | 400 | 1 5 | 56 0 304 0 | | 935 | |
| | 1000 | | 4 2 | 56 0 304 0 | | 935 | |
| | 2000 | | 8 3 | 56.0 304 0 | | 935 | |
| | 350 | 800 | 1 4 | 56 9 303 1 | | 1050 | |
| | 1000 | | 4 1 | 56 9 303 1 | | 1050 | |
| | 2000 | | 8 1 | 56 9 303 1 | | 1050 | |
| 12000 | 350 | 200 | 1 6 | | 128 7 231 3 | 330 | |
| | 1000 | | 4 7 | | 128 7 231 3 | 335 | |
| | 350 | 400 | 1 6 | | 128 1 231 9 | 375 | |
| | 1000 | | 4 6 | | 128 1 231 9 | 380 | |
| | 350 | 800 | 1 6 | | 126 9 233 1 | 560 | |
| | 1000 | | 4 5 | | 126 9 233 1 | 570 | |
| | 350 | 200 | 1 6 | 50 6 309 4 | | 375 | |
| | 1000 | | 4 6 | 50 6 309 4 | | 380 | |
| | 350 | 400 | 1 6 | 51 2 308 8 | | 390 | |
| | 1000 | | 4 6 | 51 2 308 8 | | 400 | |
| | 350 | 800 | 1 6 | 52 3 307 7 | | 580 | |
| | 1000 | | 4 5 | 52 3 307 7 | | 600 | |
| 7200 | 350 | 200 | 2 5 | | 117 0 243 0 | | 700 |
| | 1000 | | 7 1 | | 117 0 243 0 | | 700 |
| | 350 | 400 | 2 4 | | 116 4 243 6 | | 920 |
| | 1000 | | 6 9 | | 116 4 243 6 | | 925 |
| | 350 | 800 | 2 3 | | 115 2 244 8 | | 1225 |
| | 1000 | | 6 7 | | 115 2 244 8 | | 1250 |
| | 350 | 200 | 2 5 | 61 7 298 3 | | | 700 |
| | 1000 | | 7 1 | 61 7 298 3 | | | 700 |
| | 350 | 400 | 2 4 | 62 3 297 7 | | | 925 |
| | 1000 | | 6 9 | 62 3 297 7 | | | 930 |
| | 350 | 800 | 2 3 | 63 6 296 4 | | | 1400 |
| | 1000 | | 6 6 | 63 6 296 4 | | | 1400 |

TABLE IVa (Continued)

MINIMUM CANDLEPOWER REQUIREMENTS OF RUNWAY LIGHTS
FOR NIGHT OPERATIONS UNDER CIRCLING MINIMUMS

Aircraft Position Requirement: Crossing Runway To See 3000 Feet of Runway in Either Direction from Various Altitudes

| Position of Aircraft with Respect to Runway | Altitude (Feet) | Vertical Angle (Degrees) | Horizontal Angle | | Candlepower | |
|---|---|---|---|---|---|---|
| | | | Runway Side (Degrees) | Off Runway Side (Degrees) | 1 1/2-Mile Visibility T = 0 681 | 1-Mile Visibility T = 0 7854 |
| Over | 500 | 78 7 | 0 | | 1 0 | 1 0 |
| | 2000 | 87 1 | 0 | | 1 0 | 1 0 |
| | 4000 | 88 6 | 0 | | 1 25 | 6 5 |
| | 500 | 78 6 | 84 3 | | 1 0 | 1 0 |
| | 2000 | 87 1 | 84 3 | | 1 0 | 1 0 |
| | 4000 | 88 6 | 84 3 | | 1 25 | 6 5 |
| | 500 | 14 0 | 87 1 | | 1 0 | 1 0 |
| | 2000 | 45 0 | 87 1 | | 1 0 | 1 25 |
| | 4000 | 63 4 | 87 1 | | 3 0 | 10 0 |
| | 500 | 9 5 | 88 1 | | 1 0 | 1 5 |
| | 2000 | 33 7 | 88 1 | | 1 0 | 3 5 |
| | 4000 | 53 1 | 88 1 | | 4 0 | 23 0 |
| 1/4-Mile Distant | 500 | 20 8 | | 180 | 1 0 | 1 0 |
| | 2000 | 56 6 | | 180 | 1 0 | 1 0 |
| | 4000 | 71 7 | | 180 | 2 0 | 9 0 |
| | 500 | 18 2 | 0 | | 1 0 | 1 0 |
| | 2000 | 52 8 | 0 | | 1 0 | 1 0 |
| | 4000 | 69 2 | 0 | | 2 0 | 10 0 |
| | 500 | 16 8 | | 142 9 217 1 | 1 0 | 1 0 |
| | 2000 | 50 4 | | 142 9 217 1 | 1 0 | 1 0 |
| | 4000 | 67 5 | | 142 9 217 1 | 2 0 | 10 0 |
| | 500 | 15 4 | 33 3 326 7 | | 1 0 | 1 0 |
| | 2000 | 47 7 | 33 3 326 7 | | 1 0 | 1 0 |
| | 4000 | 64 5 | 33 3 326 7 | | 2 0 | 10 0 |
| | 500 | 11 8 | | 123 4 236 6 | 1 0 | 1 0 |
| | 2000 | 39 8 | | 123 4 236 6 | 1 0 | 2 0 |
| | 4000 | 59 1 | | 123 4 236 6 | 2 5 | 15 0 |
| | 500 | 11 3 | 52 8 307 2 | | 1 0 | 1 0 |
| | 2000 | 38 5 | 52 8 307 2 | | 1 0 | 2 0 |
| | 4000 | 57 8 | 52 8 307 2 | | 2 5 | 15 0 |
| | 500 | 8 6 | | 113 7 246 3 | 1 0 | 2 5 |
| | 2000 | 31 5 | | 113 7 246 3 | 1 5 | 5 0 |
| | 4000 | 50 8 | | 113 7 246 3 | 5 0 | 30 0 |
| | 500 | 8 5 | 63 1 296 9 | | 1 0 | 3 0 |
| | 2000 | 30 8 | 63 1 296 9 | | 1 5 | 5 0 |
| | 4000 | 50 0 | 63 1 296 9 | | 5 0 | 30 0 |
| 1/2-Mile Distant | 500 | 10 7 | | 180 | 1 0 | 1 0 |
| | 2000 | 37 1 | | 180 | 1 0 | 2 5 |
| | 4000 | 56 5 | | 180 | 2 5 | 15 0 |
| | 500 | 10 0 | 0 | | 1 0 | 1 0 |
| | 2000 | 35 2 | 0 | | 1 0 | 3 0 |
| | 4000 | 54 7 | 0 | | 3 0 | 17 0 |
| | 500 | 10 1 | | 159 3 200 7 | 1 0 | 1 5 |
| | 2000 | 35 3 | | 159 3 200 7 | 1 0 | 3 0 |
| | 4000 | 54 8 | | 159 3 200 7 | 3 0 | 20 0 |
| | 500 | 9 4 | 19 4 340 6 | | 1 0 | 2 0 |
| | 2000 | 33 6 | 19 4 340 6 | | 1 0 | 4 0 |
| | 4000 | 53 0 | 19 4 340 6 | | 3 5 | 25 0 |
| | 500 | 8 6 | | 142 9 217 1 | 1 0 | 2 7 |
| | 2000 | 31 2 | | 142 9 217 1 | 1 0 | 5 0 |
| | 4000 | 50 4 | | 142 9 217 1 | 4 5 | 35 0 |
| | 500 | 8 2 | 35 2 324 8 | | 1 0 | 3 0 |
| | 2000 | 29 9 | 35 2 324 8 | | 1 5 | 6 5 |
| | 4000 | 49 0 | 35 2 324 8 | | 5 0 | 35 0 |
| | 500 | 7 1 | | 131 3 228 7 | 2 0 | 7 0 |
| | 2000 | 26 6 | | 131 3 228 7 | 2 5 | 10 0 |
| | 4000 | 45 0 | | 131 3 228 7 | 6 0 | 45 0 |

TABLE IVa (Continued)

MINIMUM CANDLEPOWER REQUIREMENTS OF RUNWAY LIGHTS
FOR NIGHT OPERATIONS UNDER CIRCLING MINIMUMS

| Distance Out (Feet) | Altitude (Feet) | Vertical Angle (Degrees) | Horizontal Angle Runway Side (Degrees) | | Candlepower 1 1/2-Mile Visibility T = 0 881 | Candlepower 1-Mile Visibility T = 0 7854 |
|---|---|---|---|---|---|---|
| Aircraft Position On Glide Path; Requirement To See First Pair of Lights | | | | | | |
| 8000 | 409 | 2 9 | 89 2 | 270 8 | - - | 825 |
| 10500 | 526 | 2 8 | 89 4 | 270 6 | 200 | - - |
| Aircraft Position Over Middle Marker – 3500 Feet Out; Requirement To See Pairs of Lights Listed | | | | | | |
| 200 | 200 | 3 1 | 88 45 | 271 55 | 1 0 | 4 0 |
| | 600 | 7 69 | 88 9 | 271 55 | 1 0 | 4 0 |
| 2400 | 200 | 1 9 | 88 9 | 271 1 | 6 5 | 75 0 |
| | 600 | 5 8 | 88 9 | 271 1 | 7 5 | 80 0 |
| 4600 | 200 | 1 4 | 89 2 | 270 8 | 40 0 | 600 0 |
| | 600 | 4 2 | 89 2 | 270 8 | 45 0 | 700 0 |
| 7800 | 200 | 1 0 | 89 4 | 270 6 | 275 0 | 8000 0 |
| | 600 | 3 0 | 89 4 | 270 6 | 280 0 | 8500 0 |
| Aircraft Position At Touchdown (Pilot 20 Feet From Runway Edge); Requirement To See 1000 Feet of Runway | | | | | | |
| 200 | 16 | 3 32 | 46 47 | 313 53 | 1 0 | 1 0 |
| 400 | | 2 07 | 64 60 | 295 40 | 1 0 | 1 0 |
| 600 | (Convair) | 1 45 | 72 43 | 287 57 | 1 0 | 1 0 |
| 800 | | 1 17 | 76 62 | 283 38 | 1 0 | 1 0 |
| 1000 | | 0 9 | 79 25 | 280 75 | 1 0 | 1 0 |
| 200 | 20 8 | 4 32 | 46 47 | 313 53 | 1 0 | 1 0 |
| 400 | | 2 68 | 64 60 | 295 40 | 1 0 | 1 0 |
| 600 | (Constellation) | 1 88 | 72 43 | 287 57 | 1 0 | 1 0 |
| 800 | | 1 45 | 76 62 | 283 38 | 1 0 | 1 0 |
| 1000 | | 1 17 | 79 25 | 280 75 | 1 0 | 1 0 |
| Aircraft Position Taxiing 20 Feet From Runway Edge; Requirement To See 500 Feet of Runway | | | | | | |
| 100 | 12 5 | 3 33 | 27 77 | 332 23 | 1 0 | 1 0 |
| 300 | (Convair) | 2 02 | 57 67 | 302 33 | 1 0 | 1 0 |
| 500 | | 1 33 | 69 20 | 290 80 | 1 0 | 1 0 |
| 100 | 16 2 | 4 32 | 27 77 | 33 23 | 1 0 | 1 0 |
| 300 | (Constellation) | 2 60 | 57 67 | 302 33 | 1 0 | 1 0 |
| 500 | | 1 73 | 69 20 | 290 80 | 1 0 | 1 0 |

## TABLE IVb

### MINIMUM CANDLEPOWER REQUIREMENTS OF RUNWAY LIGHTS FOR NIGHT AND DAY OPERATIONS UNDER ILS MINIMUMS

Aircraft Position Over Middle Marker (3500 From Runway End)
Requirement To See 1000 Feet of Runway

| Distance Threshold to Pair of Lights (Feet) | Vertical Angle (Degrees) On Glide Path Altitude (200 Feet) | Above Glide Path Altitude (500 Feet) | Below Glide Path Altitude (100 Feet) | Horizontal Angle Runway Side (Degrees) | Off Runway Side (Degrees) | Candlepower 1/2-Mile Visibility T = 0 5201 Night | T = 0 612 Day |
|---|---|---|---|---|---|---|---|
| **A On Course** | | | | | | | |
| 200 | 3 1 | 7 7 | 1 5 | 88 3 271 7 | | 360 | 62500 |
| 400 | 2 9 | 7 3 | 1 5 | 88 4 271 6 | | 660 | 100000 |
| 600 | 2 8 | 6 9 | 1 4 | 88 5 271 5 | | 975 | 130000 |
| 800 | 2 7 | 6 6 | 1 3 | 88 5 271 5 | | 1600 | 180000 |
| 1000 | 2 5 | 6 3 | 1 3 | 88 6 271 4 | | 2000 | 300000 |
| **B 300 Feet Off Course** | | | | | | | |
| 200 | 3 1 | 7 7 | 1 5 | 83 8 276 2 | 93 1 266 9 | 360 | 62500 |
| 400 | 2 9 | 7 3 | 1 5 | 84 1 275 9 | 92 9 267 1 | 660 | 100000 |
| 600 | 2 8 | 6 9 | 1 4 | 84 4 275 6 | 92 8 267 2 | 975 | 130000 |
| 800 | 2 7 | 6 6 | 1 3 | 84 7 275 3 | 92 7 267 3 | 1600 | 180000 |
| 1000 | 2 5 | 6 3 | 1 3 | 84 9 275 1 | 92 5 267 5 | 2000 | 300000 |

Aircraft Position 1000 Feet From Runway End
Requirement To See 1000 Feet of Runway

| Distance Threshold to Pair of Lights (Feet) | Altitude (Feet) | Vertical Angle (Degrees) | Horizontal Angle Runway Side (Degrees) | Off Runway Side (Degrees) | Candlepower 1/2-Mile Visibility T = 0 5201 Night | T = 0 612 Day | 1/4-Mile Visibility T = 0 189 Night | T = 0 378 Day |
|---|---|---|---|---|---|---|---|---|
| **A On Glide Path and On Course** | | | | | | | | |
| 200 | 84 | 4 0 | 84 8 275 2 | | 1 0 | 160 | 10 | 950 |
| 400 | | 3 4 | 85 5 274 5 | | 1 0 | 280 | 46 | 2200 |
| 600 | | 3 0 | 86 1 273 9 | | 1 3 | 500 | 150 | 5500 |
| 800 | | 2 7 | 86 5 273 5 | | 2 3 | 800 | 520 | 12000 |
| 1000 | | 2 4 | 86 8 273 2 | | 4 0 | 1500 | 2200 | 29000 |
| **B Above Glide Path On Course** | | | | | | | | |
| 200 | 175 | 8 3 | 84 8 275 2 | | 1 0 | 160 | 11 | 950 |
| 400 | | 7 1 | 85 5 274 5 | | 1 0 | 290 | 50 | 2300 |
| 600 | | 6 2 | 86 1 273 9 | | 1 3 | 500 | 160 | 5500 |
| 800 | | 5 6 | 86 5 273 5 | | 2 3 | 800 | 550 | 12000 |
| 1000 | | 5 0 | 86 8 273 2 | | 4 0 | 1500 | 2200 | 29000 |
| **C At Glide Path Level — 150 Feet Off Course** | | | | | | | | |
| 200 | 84 | 4 0 | 80 5 279 5 | | 1 0 | 160 | 12 | 980 |
| 400 | | 3 4 | 81 9 278 1 | | 1 0 | 295 | 53 | 2300 |
| 600 | | 3 0 | 82 9 277 1 | | 1 3 | 500 | 170 | 5500 |
| 800 | | 2 6 | 83 7 276 3 | | 2 3 | 840 | 575 | 12200 |
| 1000 | | 2 4 | 84 3 275 7 | | 4 0 | 1500 | 2300 | 30000 |
| 200 | | 4 0 | | 92 4 267 6 | 1 0 | 150 | 11 | 940 |
| 400 | | 3 4 | | 92 0 268 0 | 1 0 | 275 | 45 | 2250 |
| 600 | | 3 0 | | 91 8 268 2 | 1 3 | 495 | 158 | 5500 |
| 800 | | 2 7 | | 91 6 268 4 | 2 3 | 800 | 575 | 12000 |
| 1000 | | 2 4 | | 91 4 268 6 | 4 0 | 1500 | 2200 | 29000 |
| **D Above Glide Path — 150 Feet Off Course** | | | | | | | | |
| 200 | 175 | 8 2 | 80 5 279 5 | | 1 0 | 170 | 13 | 1000 |
| 400 | | 7 0 | 81 9 278 1 | | 1 0 | 298 | 55 | 2500 |
| 600 | | 6 2 | 82 9 277 1 | | 1 3 | 500 | 170 | 5500 |
| 800 | | 5 5 | 83 7 276 3 | | 2 3 | 840 | 585 | 12200 |
| 1000 | | 5 0 | 84 3 275 7 | | 4 0 | 1500 | 2300 | 30000 |
| 200 | | 8 3 | | 92 4 267 6 | 1 0 | 160 | 12 | 975 |
| 400 | | 7 1 | | 92 0 268 0 | 1 0 | 293 | 50 | 2300 |
| 600 | | 6 2 | | 91 8 268 2 | 1 3 | 500 | 170 | 5500 |
| 800 | | 5 5 | | 91 6 268 4 | 2 3 | 820 | 575 | 12100 |
| 1000 | | 5 0 | | 91 4 268 6 | 4 0 | 1500 | 2300 | 30000 |

## TABLE IVb (Continued)

### MINIMUM CANDLEPOWER REQUIREMENTS OF RUNWAY LIGHTS FOR NIGHT AND DAY OPERATIONS UNDER ILS MINIMUMS

| Distance Threshold to Pair of Lights (Feet) | Altitude (Feet) | Vertical Angle (Degrees) | Horizontal Angle: Runway Side (Degrees) | Horizontal Angle: Off Runway Side (Degrees) | Candlepower: 1/2-Mile Visibility, T = 0 5201, Night | Candlepower: 1/2-Mile Visibility, T = 0 612, Day | Candlepower: 1/4-Mile Visibility, T = 0 189, Night | Candlepower: 1/4-Mile Visibility, T = 0 378, Day |
|---|---|---|---|---|---|---|---|---|
| Aircraft Position Requirement: At 500 Foot Portal, To See 1000 Feet of Runway | | | | | | | | |
| A On Glide Path and On Course | | | | | | | | |
| 200 | 60 | 4 8 | 81 1  278 9 | | 1 0 | 23 | 1 0 | 65 |
| 400 | | 3 8 | 83 0  277 0 | | 1 0 | 54 | 1 5 | 200 |
| 600 | | 3 1 | 84 3  275 7 | | 1 0 | 100 | 5 0 | 500 |
| 800 | | 2 6 | 85 2  274 8 | | 1 0 | 199 | 25 0 | 1300 |
| 1000 | | 2 3 | 85 8  274 2 | | 1 0 | 370 | 100 0 | 3600 |
| B Above Glide Path On Course | | | | | | | | |
| 200 | 125 | 10 0 | 81 1  278 9 | | 1 0 | 25 | 1 0 | 70 |
| 400 | | 7 9 | 83 0  277 0 | | 1 0 | 58 | 1 5 | 205 |
| 600 | | 6 5 | 84 3  275 7 | | 1 0 | 120 | 6 0 | 530 |
| 800 | | 5 5 | 85 2  274 8 | | 1 0 | 220 | 25 0 | 1400 |
| 1000 | | 4 8 | 85 8  274 2 | | 1 0 | 400 | 100 0 | 3800 |
| C At Glide Path Level – 125 Feet Off Course | | | | | | | | |
| 200 | 60 | 4 7 | 71 4  288 6 | | 1 0 | 27 | 1 0 | 80 |
| 400 | | 3 7 | 75 4  284 6 | | 1 0 | 56 | 2 0 | 230 |
| 600 | | 3 0 | 78 0  282 0 | | 1 0 | 120 | 7 0 | 600 |
| 800 | | 2 6 | 79 8  280 2 | | 1 0 | 220 | 27 0 | 1500 |
| 1000 | | 2 3 | 81 1  278 9 | | 1 0 | 385 | 102 0 | 3750 |
| 200 | | 4 9 | | 91 2  268 8 | 1 0 | 23 | 1 0 | 67 |
| 400 | | 3 8 | | 91 0  269 0 | 1 0 | 52 | 1 5 | 200 |
| 600 | | 3 1 | | 90 8  269 2 | 1 0 | 100 | 6 0 | 500 |
| 800 | | 2 6 | | 90 7  269 3 | 1 0 | 200 | 25 0 | 1350 |
| 1000 | | 2 3 | | 90 6  269 4 | 1 0 | 380 | 100 0 | 3650 |
| D Above Glide Path – 125 Feet Off Course | | | | | | | | |
| 200 | 125 | 9 6 | 71 4  288 6 | | 1 0 | 28 | 1 0 | 86 |
| 400 | | 7 6 | 75 4  284 6 | | 1 0 | 60 | 2 0 | 235 |
| 600 | | 6 3 | 78 0  282 0 | | 1 0 | 125 | 7 0 | 620 |
| 800 | | 5 4 | 79 8  280 2 | | 1 0 | 225 | 25 0 | 1560 |
| 1000 | | 4 6 | 81 1  278 9 | | 1 0 | 420 | 110 0 | 4200 |
| 200 | | 10 1 | | 91 2  268 8 | 1 0 | 24 | 1 0 | 70 |
| 400 | | 7 9 | | 91 0  269 0 | 1 0 | 53 | 1 5 | 210 |
| 600 | | 6 5 | | 90 8  269 2 | 1 0 | 110 | 6 0 | 510 |
| 800 | | 5 5 | | 90 7  269 3 | 1 0 | 205 | 25 0 | 1400 |
| 1000 | | 4 8 | | 90 6  269 4 | 1 0 | 390 | 102 0 | 3900 |
| Aircraft Position Requirement: At Touchdown Point – 20 Feet From Runway Edge, To See 1000 Feet of Runway | | | | | | | | |
| 200 | On Runway | 3 32 | 46 47  313 53 | | 1 0 | 2 | 1 0 | 3 |
| 400 | | 2 07 | 64 6  295 4 | | 1 0 | 6 | 1 0 | 13 |
| 600 | | 1 45 | 72 43  287 57 | | 1 0 | 17 | 1 0 | 42 |
| 800 | | 1 17 | 76 62  283 38 | | 1 0 | 37 | 1 0 | 125 |
| 1000 | | 0 9 | 79 25  280 75 | | 1 0 | 85 | 3 5 | 380 |
| 200 | | 4 32 | 46 47  313 53 | | 1 0 | 2 | 1 0 | 3 |
| 400 | | 2 68 | 64 6  295 4 | | 1 0 | 6 | 1 0 | 13 |
| 600 | | 1 88 | 72 43  287 57 | | 1 0 | 17 | 1 0 | 42 |
| 800 | | 1 45 | 76 62  283 38 | | 1 0 | 37 | 1 0 | 125 |
| 1000 | | 1 17 | 79 25  280 75 | | 1 0 | 85 | 3 5 | 380 |
| Aircraft Position Requirement: Taxiing 20 Feet From Runway Edge, To See 500 Feet of Runway | | | | | | | | |
| 100 | | 3 33 | 27 77  332 23 | | 1 0 | 1 5 | 1 0 | 1 5 |
| 300 | | 2 02 | 57 67  302 33 | | 1 0 | 3 5 | 1 0 | 6 0 |
| 500 | | 1 33 | 69 2  290 8 | | 1 0 | 11 0 | 1 0 | 24 0 |
| 100 | | 4 32 | 27 77  332 23 | | 1 0 | 1 5 | 1 0 | 1 5 |
| 300 | | 2 6 | 57 67  302 33 | | 1 0 | 3 5 | 1 0 | 6 0 |
| 500 | | 1 73 | 69 2  290 8 | | 1 0 | 11 0 | 1 0 | 24 0 |

CPO 81 106153