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EVALUATION OF TAXIWAY CENTERLINE LIGHTING FOR RUNWAY EXITS AND TAXIWAY INTERSECTIONS

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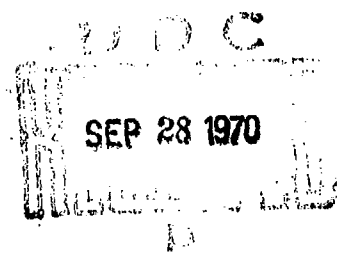

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16. Abstract

An evaluation was conducted on green taxiway centerline lighting to determine the feasibility of its continuance across runways to maintain continuity of taxiway guidance and use in runways on short radius curves leading into taxiways for reducing runway occupancy time. It was determined that green taxiway centerline lighting can be used in the surface of runways to provide (1) exit guidance on short radius curves and (2) continuity of taxiway guidance across runways. By color coding green the three runway centerline lights opposite the "throat" of a taxiway used for exit purposes, a method of providing visual aids for reducing runway occupancy time resulted. Other findings concerned the need for wide beam fixtures adjacent to intersections consisting of straight sections of centerline lighting, a method of determining the minimum number of fixtures on short straight sections, and a hold bar of three yellow lights spaced 5 feet apart as a minimum adequate configuration for providing an imminence of intersection signal--also applicable for holding aircraft clear of intersecting runways and taxiways. Low-profile green reflectors were found effective as a low cost means of marking curved exits from the runway centerlines into the "throats" of taxiways for night operations.

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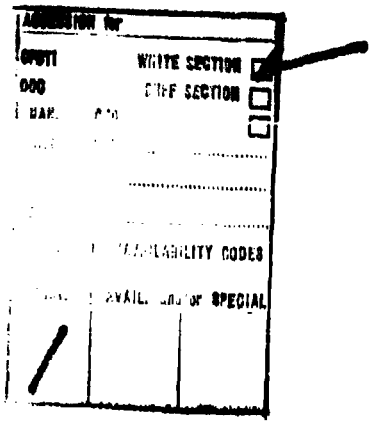

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The National Aviation Facilities Experimental Center maintains laboratories, facilities, skills and services to support FAA research, development and implementation programs through analysis, experimentation and evaluation of aviation concepts, procedures, systems and equipment.

PREFACE

The author of this report acknowledges the substantial contribution made by Mr. John Ryan, Project Pilot, and Messrs. Robert F. Gates, Robert O. Martin, and Warren J. Smith in obtaining the data used in preparing this report.

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INTRODUCTION

Purpose

The purpose of this project was to evaluate the taxiway centerline system regarding (1) the feasibility of continuing taxiway centerline lighting across runways to maintain continuity of taxi guidance, (2) the use of taxiway centerline lighting and low-profile retro-reflective markers extended on short-radius exits from the "throat" of the taxiway out to the runway centerline to decrease runway occupancy time, (3) a means of indicating imminence of intersection, and (4) the requirement for wide beam L-852 fixtures in the system to supplement the basic L-842 fixture.

Background

The basic taxiway centerline lighting system was evaluated at NAFEC and a Final Report No. RD-64-46 was issued in March 1964 titled, "Evaluation of Taxiway Centerline Lighting." The installation did not permit trials on all aspects of the taxi guidance problem but certain fundamentals were established such as spacing, color, effectiveness, etc. It was determined that fixture improvements were required and it was assumed that the lights would be installed on curves at taxiway intersection--such installation being made possible by the addition of fillets as required to provide adequate full-strength pavement to support the aircraft.

Selection Order 1010.40 was issued on Taxiway Centerline Lighting 11 August 1967. The Selection Order was based on the findings of Final Report No. RD-64-46. In planning an installation for a major international airport, it was determined that long-body aircraft would require very extensive and costly fillets if the system were installed on curves at intersections. A request was made that the FAA investigate the feasibility of pilots maneuvering aircraft at intersections using taxiway guidance obtained from lights installed on straight sections at intersections. Also, additional operating requirements needed attention since it had not been possible to evaluate the use of taxiway lights on normal curves for runway exit purposes and continuity of taxiway guidance was lost by the requirement to discontinue taxiway centerline lighting at the edges of the runway.

The matter of installing green taxiway centerline lights or retro-reflectors in the surface of runways was related to the probability of confusion with green threshold and end lighting. Test results obtained on this aspect of the problem have been reported on previously and the following conclusions and recommendations were made.

It was concluded that:

1. Red end lighting can be effective and its use eliminates the possibility of confusing end lighting with taxiway lights or reflectors used either as exit lighting or to continue (uninterrupted) taxiway centerline lighting across runways.

2. The use of yellow edge lights along the final portion of the runway should be discontinued and all-white edge lighting should be provided if red end lights are adopted.

3. Additional end lighting fixtures may be advisable at airports having a large number of obstruction lights in the near vicinity of the runway end. The number of additional fixtures required at individual airports should be determined following an analysis of the extent of the problem at each airport.

It was recommended that:

1. Red end lighting be adopted as a standard component of the National Airspace System.

2. The use of yellow edge lights along the final portion of the runway be discontinued to provide improved contrast between the edge and red end lights.

3. Provisions be made to provide additional red end lights at airports having a heavy concentration of obstruction lights in the near vicinity of the runway end.

It was evident that a wide-angle fixture was needed in addition to the narrow-angle fixture developed for taxiway centerline lighting systems. Such a fixture was developed under contract with the FAA and was available for the installations made at NAFEC.

The results in this report were obtained on (1) a short installation of taxiway centerline lighting on Taxiway J at NAFEC, which was extended on a normal radius to the runway centerline for exit purposes, (2) a more complete taxiway centerline lighting installation at NAFEC on three main taxiways commissioned December 1968, and (3) an installation of retro-reflectors for runway exit purposes at Washington National Airport.

Equipment and Installation Descriptions

The Wide-Angle Taxiway Fixture: A fixture was developed to satisfy the need for an inset light with a wider horizontal beam. The resulting fixture was 8 inches in diameter, the periphery depth was 1-1/2 inch and the top surface of the light assembly sloped upward from the periphery so as to form a maximum protrusion of three-eighths inch above the adjacent paved surface when installed in the pavement. The maximum upward slope of any portion of the top surface did not exceed 10°. The lamp used was a tungsten halogen, prefocused, 6.6-ampere series lamp, with a nominal rating of 60 watts and a rated life of 1,000 hours. The lamp holder securely and accurately positions the lamp. It also provides a means of attaching a color filter as required and has a film disc cutout which immediately closes an auxiliary circuit around the lamp on failure of the lamp. Thus other fixtures in series with the failed lamp will continue to operate. The light beam has a minimum intensity of 100 candelas from -30° to +30° in the horizontal and from 0° to 10° in the vertical direction. This fixture was designated as the L-852 type of inset light. Figure 1 shows an assembled view and Figure 2 shows an exploded view of the original L-852 fixture.

The L-852 inset fixture as originally designed was similar to the L-842 type with the exception of the photometric characteristics. The company that developed the L-852 fixture as shown in Figure 1 determined that their L-842 fixture could be redesigned to give similar photometric characteristics. The redesigned L-842 fixture is shown in Figures 3 and 4. The light channel of the L-842 base was made wider, a central rib added and these changes were incorporated into the mold to produce the L-852 base that is now in use. These progressive changes are shown in Figure 5.

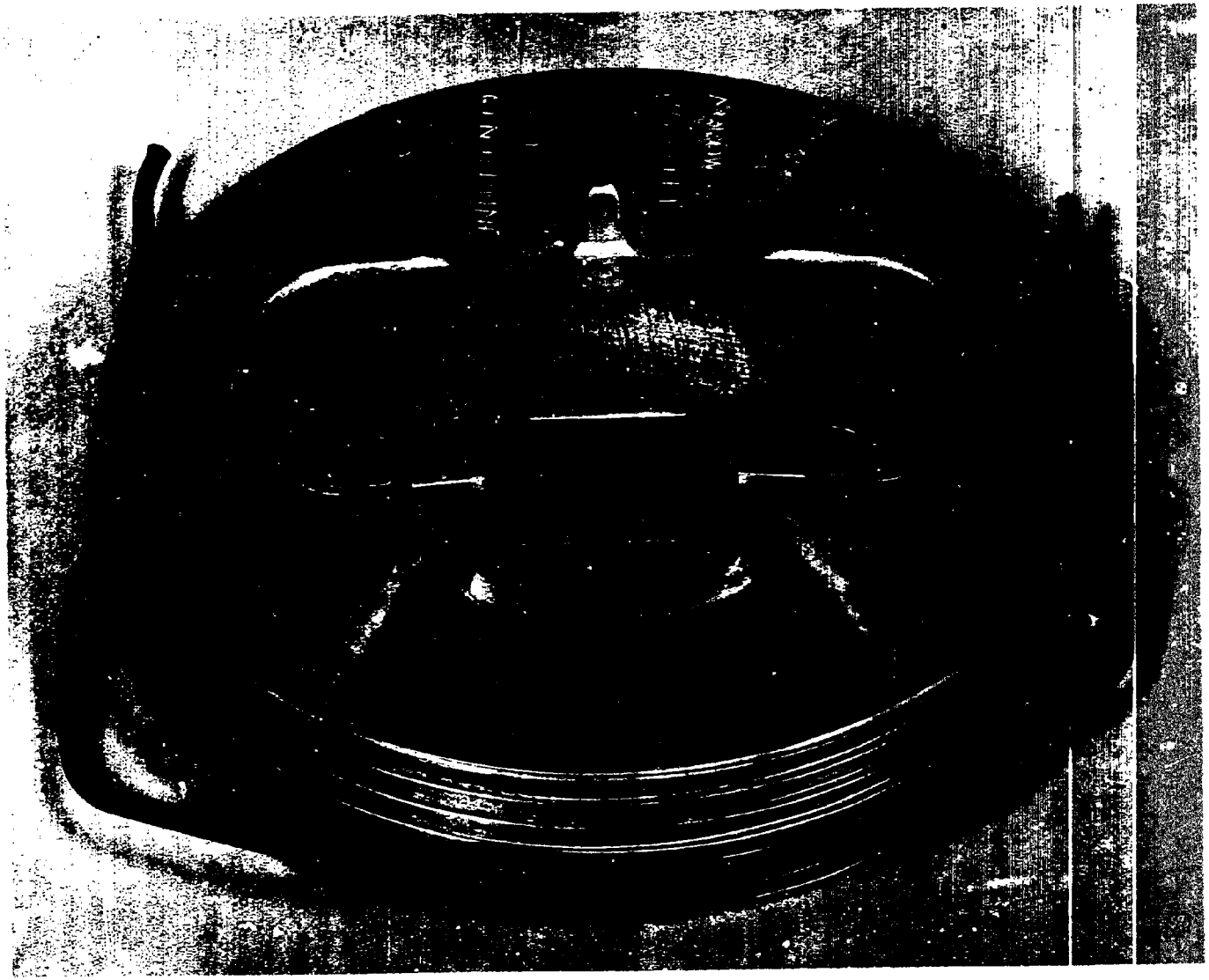

FIG. 1 L-852 INSET FIXTURE - ASSEMBLED VIEW

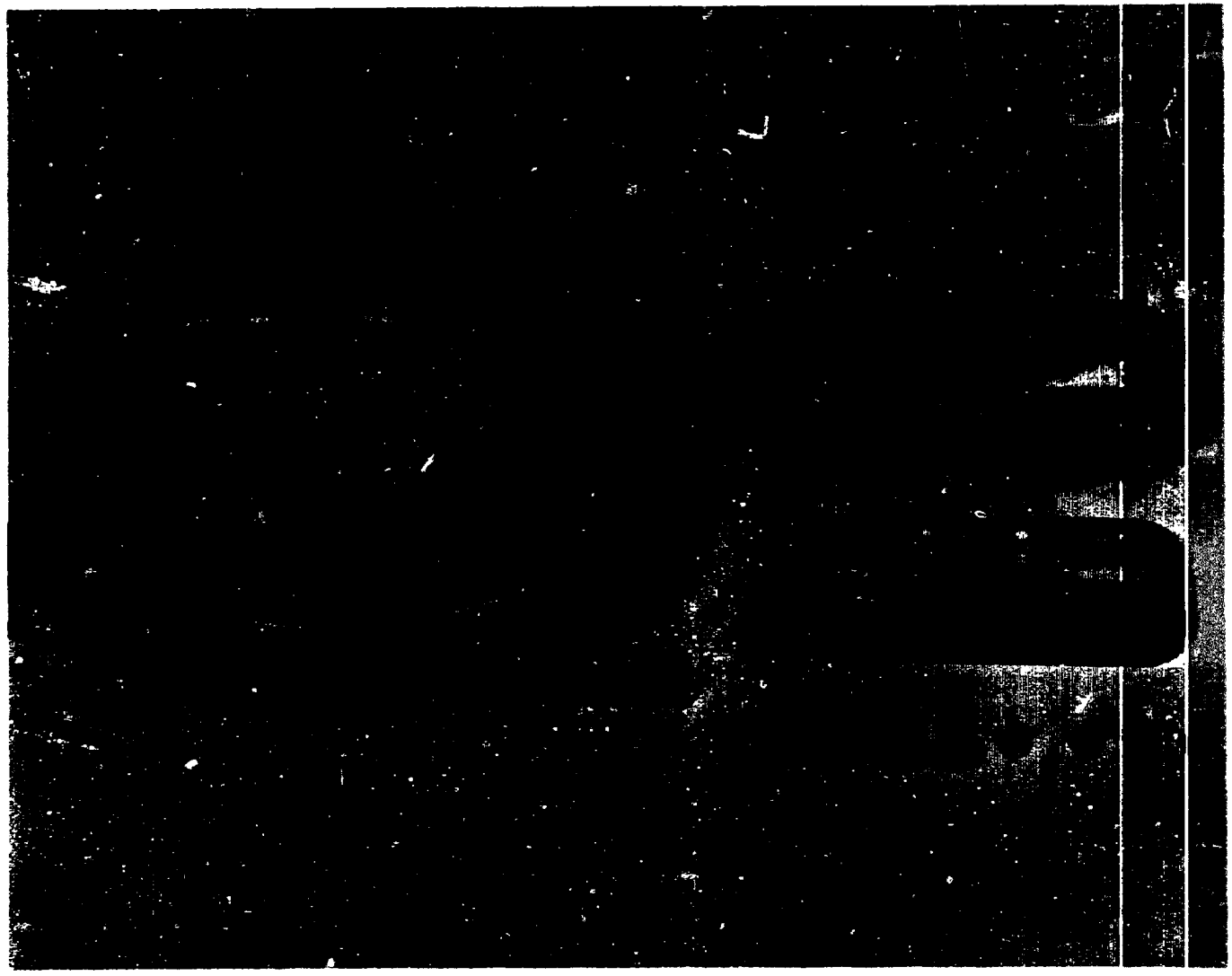

FIG. 2 L-852 INSET FIXTURE - EXPLODED VIEW

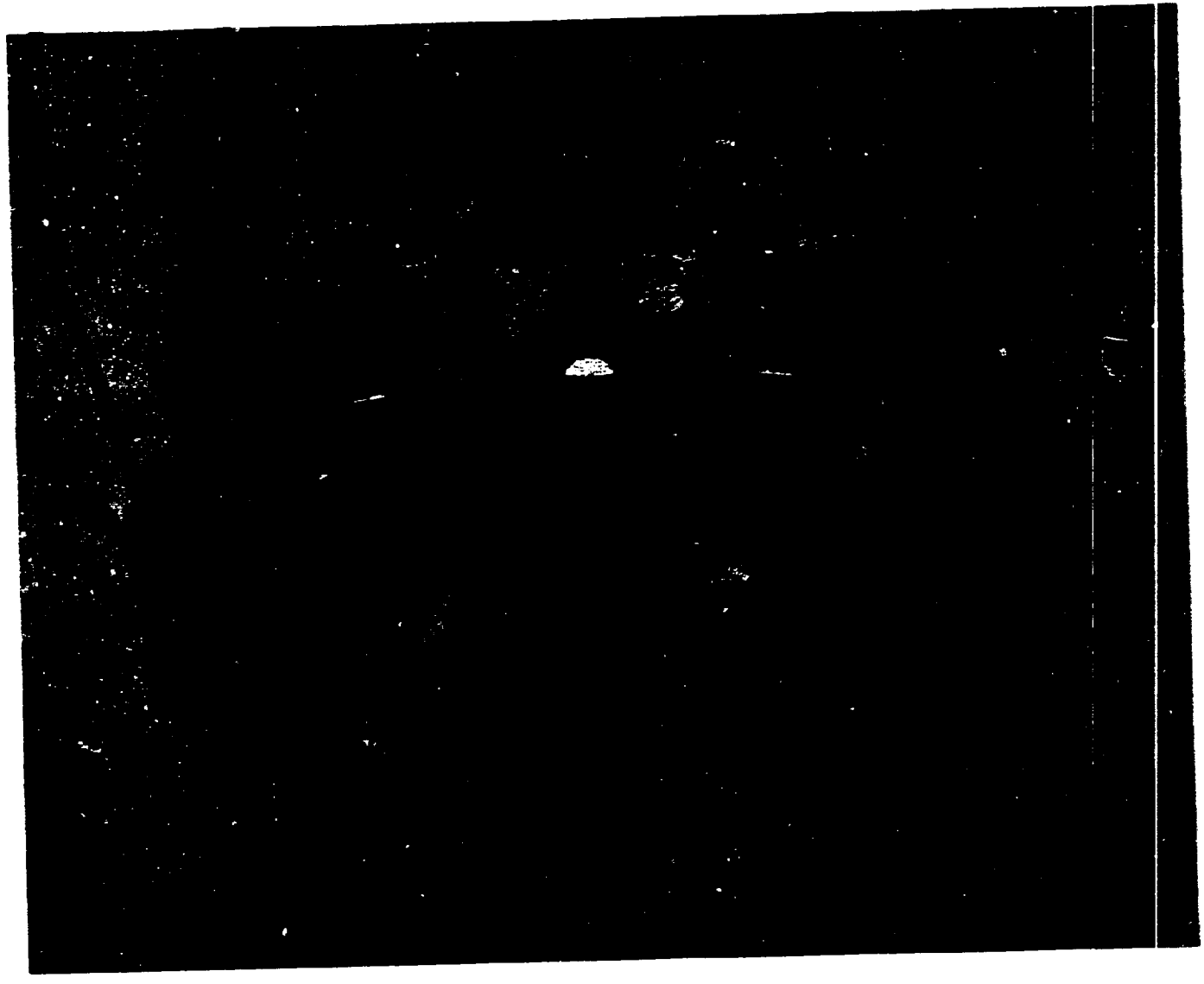

FIG. 3 THE REDESIGNED L-842 FIXTURE - ASSEMBLED VIEW

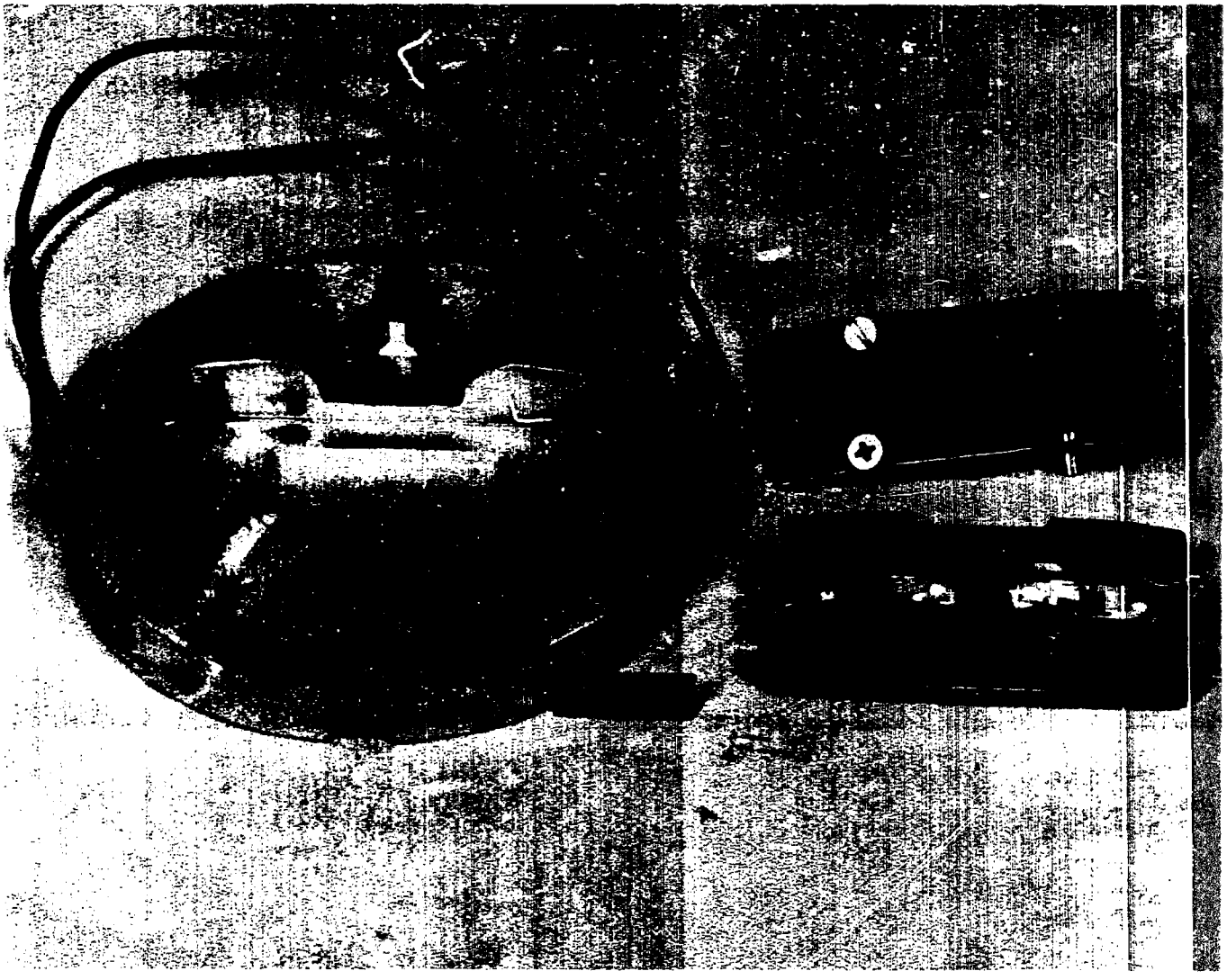

FIG. 4 THE REDESIGNED L-842 FIXTURE
WITH OPTICAL ASSEMBLY REMOVED

FIG. 5 CHANGES IN THE L-842 BASE

The redesigned optical assembly is similar to that for the L-842, except it has a wider lens to accommodate the wider light channel of the base. Either a 45-watt or a 60-watt tungsten halogen, prefocused, 6.6-ampere series lamp can be used in these assemblies. The optical assemblies for the L-842 and the L-852 inset bases are interchangeable. The resulting L-852 is shown in Figures 6 and 7.

Taxiway J Installation at NAFEC: An installation of wide-angle L-852 fixtures was made on Taxiway J at the Atlantic City Airport, NAFEC. This installation intersected the centerline of Taxiway B at 90° and curved into Runway 13-31 along a radius of 175 feet. Green filters were used and various spacings were simulated in the test program. The fixtures on the curve were installed with the center of the beams tangent to the radii. A cross bar was provided at the centerline of the straight portion consisting of five L-852 fixtures spaced 3 feet apart. The cross bar was installed perpendicular to the centerline at a distance of 120 feet from the runway edge. The bar was tested as a hold-bar for assuring clearance of aircraft holding clear of runways and intersecting taxiways as well as an imminence of intersection signal. Both green and yellow filters were tested in the hold-bar pattern at various spacings with an inoperative fixture simulated as a test condition. The installation on Taxiway J is shown in Figure 8.

Taxiway A, B, and I Installations at NAFEC: The full lengths of Taxiways A, B and I were provided with centerline lighting using L-842 fixtures, (See Figure 9.) L-852 fixtures were installed at intersections of other taxiways also having taxiway centerline lighting. The L-852 fixtures were installed at a distance of 300 feet on each side of the three intersections of A and B, B and I, and B and J. L-852 fixtures also were provided within the three intersections listed above. This installation provided a system for evaluating the problem of continuing taxiway lighting across runways as well as evaluating the requirement for wide-beam guidance at intersections of taxiways.

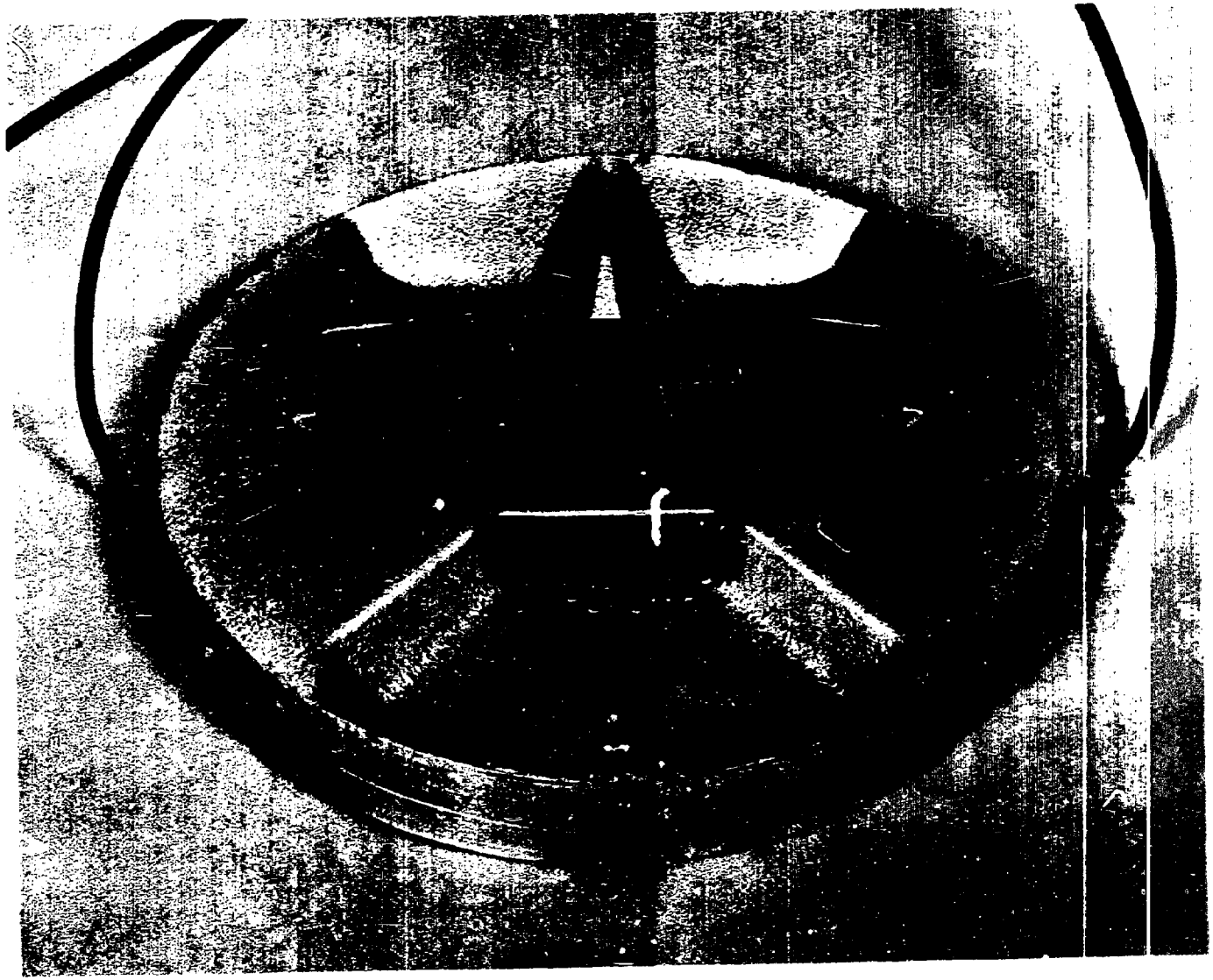

FIG. 6 THE L-852 FIXTURE - ASSEMBLED VIEW

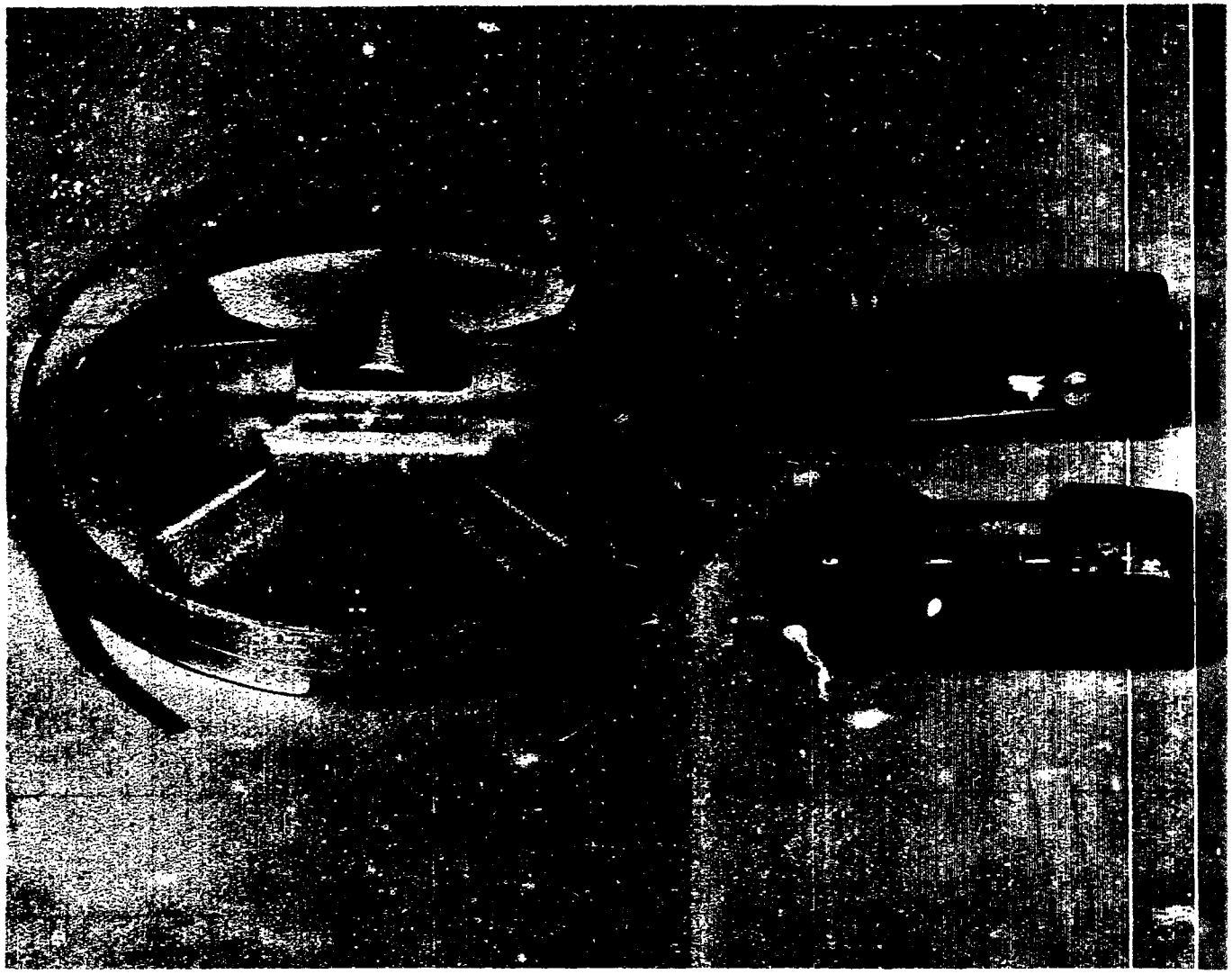

FIG. 7 THE L-852 FIXTURE
WITH OPTICAL ASSEMBLY REMOVED

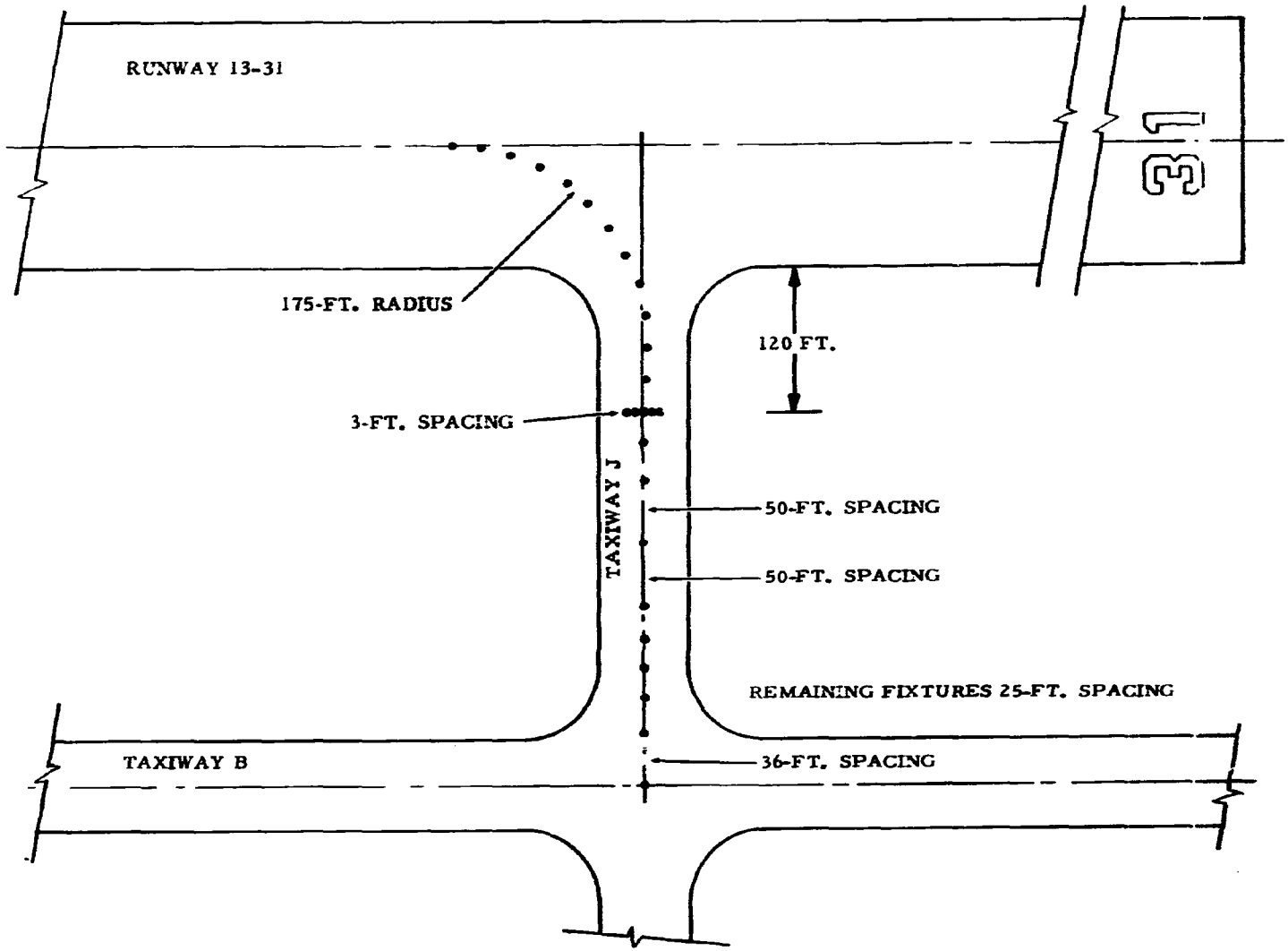

FIG. 8 LOCATION OF LIGHTS ON TAXIWAY J AT NAFEC

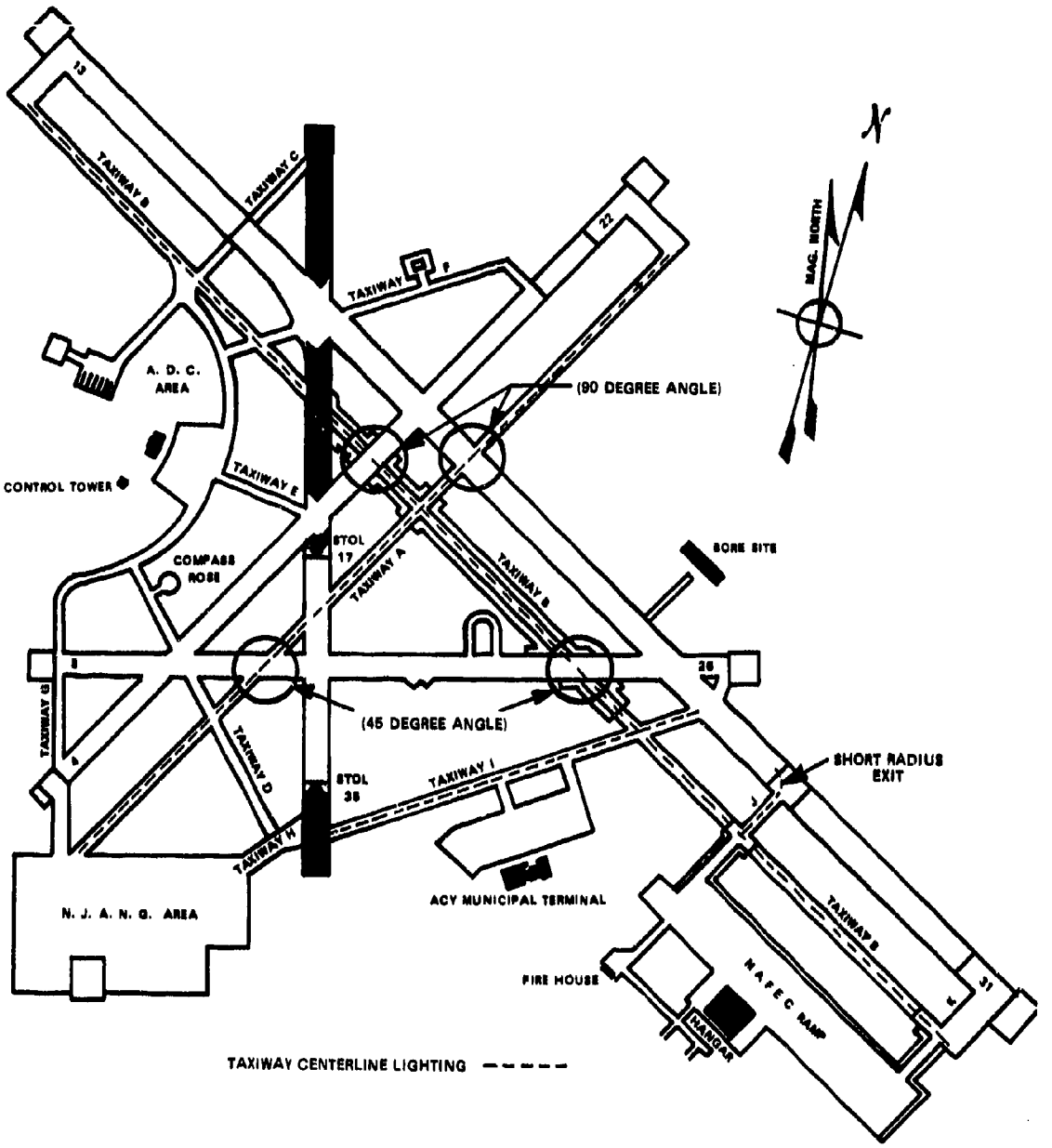

FIG. 9 LOCATION OF CENTERLINE LIGHTS ON TAXIWAYS A, B, I AND J AT NAFEC

Taxiway G and I Installations at Washington National Airport: Unidirectional green retro-reflectors were installed November 1968 on two exits for Runway 36 at Washington National Airport (Figure 10). The installations were made on a radius of 577 feet for Taxiway G--650 feet for Taxiway I from the "throat" of the taxiways to the point of tangency with the runway centerline. The height of the retro-reflectors was approximately three-fourths inch allowing one-sixteenth inch for the thickness of the adhesive pad used to attach the markers to the pavement. They were spaced 25 feet apart and the center of the axis of the reflected beam was "toed-in" so as to intersect the center-line at a point 200 feet ahead of the markers measured along the chord of the curve.

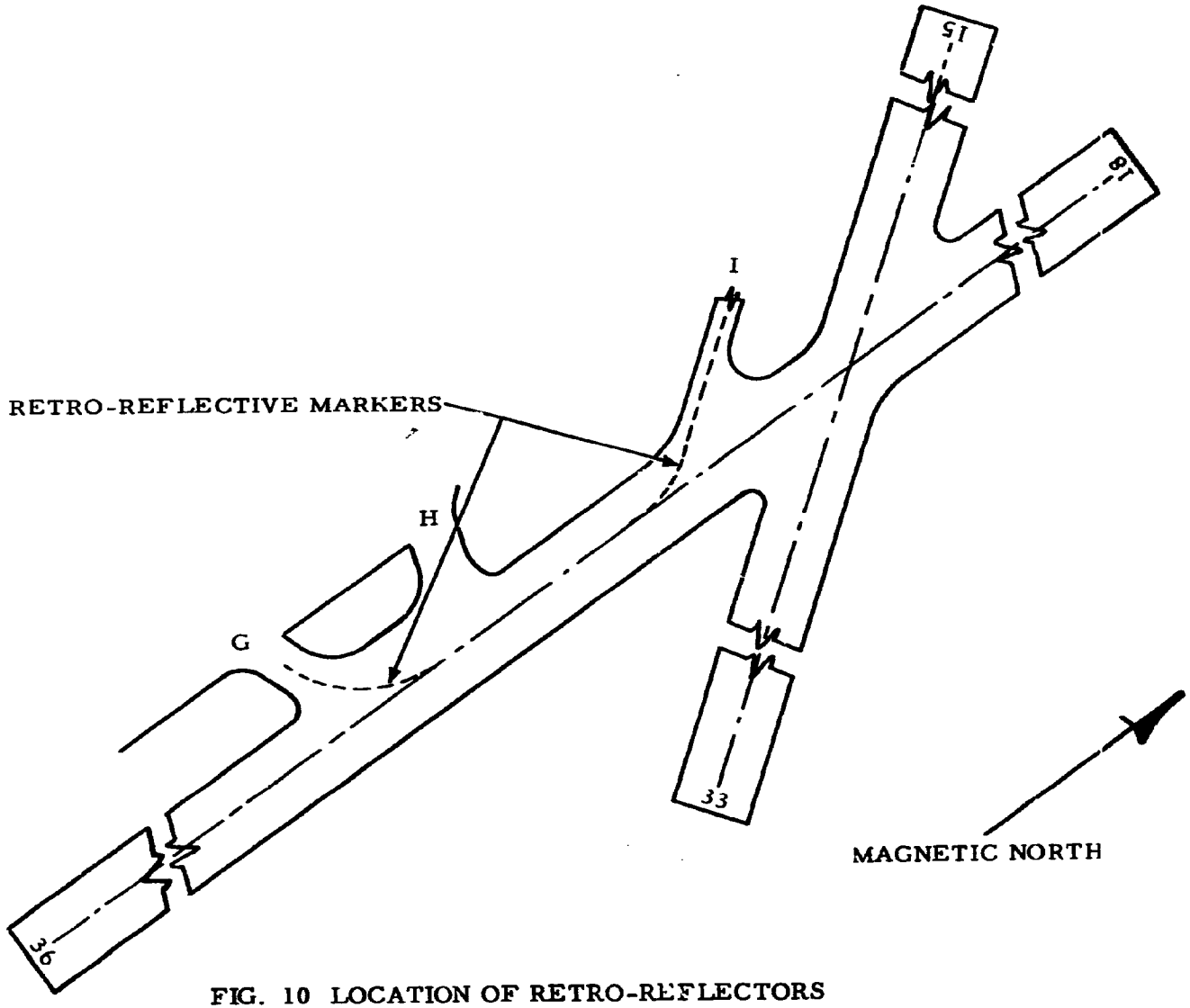

FIG. 10 LOCATION OF RETRO-REFLECTORS
AT WASHINGTON NATIONAL AIRPORT

DISCUSSION

Test Procedures

Laboratory Tests: The "Contract" L-852, the redesigned L-842 and the L-852 types of wide-angle fixtures were each tested in the Photometric Laboratory to determine their horizontal and vertical beam characteristics.

The fixtures also were installed on a test pad at NAFEC to permit operational tests and observations to be made.

Taxiway J at NAFEC: A test plan together with a questionnaire was designed to be used by the subject pilots. These are given in Appendix A.

Pattern A had a 25-foot spacing except for three 50-foot spaces near the hold bar. There were five lights in the hold bar with a spacing of 3 feet between centers. All fixtures had aviation green filters. Pattern A is shown in Figure 11.

Two runs were made on each pattern. On the second run lamp failures were simulated to study the safety factor necessary for each pattern as the system deteriorated.

Pattern B had a spacing of 50 feet with three lights in the hold bar spaced 6 feet between centers. Figure 12 shows the arrangement for Pattern B.

Pattern C had a spacing of 100 feet except the first light in front of the bar which had a spacing of 50 feet. The hold bar had two lights spaced 6 feet on centers. Each light was located 3 feet from the taxiway centerline. This pattern is shown in Figure 13

Pattern D had a 100-foot spacing with no hold bar. This pattern is shown in Figure 14.

Pattern E had a spacing of 25 feet except for two 100-foot spaces beyond the hold bar. The hold bar had five lights spaced 3 feet apart. This pattern is shown in Figure 15.

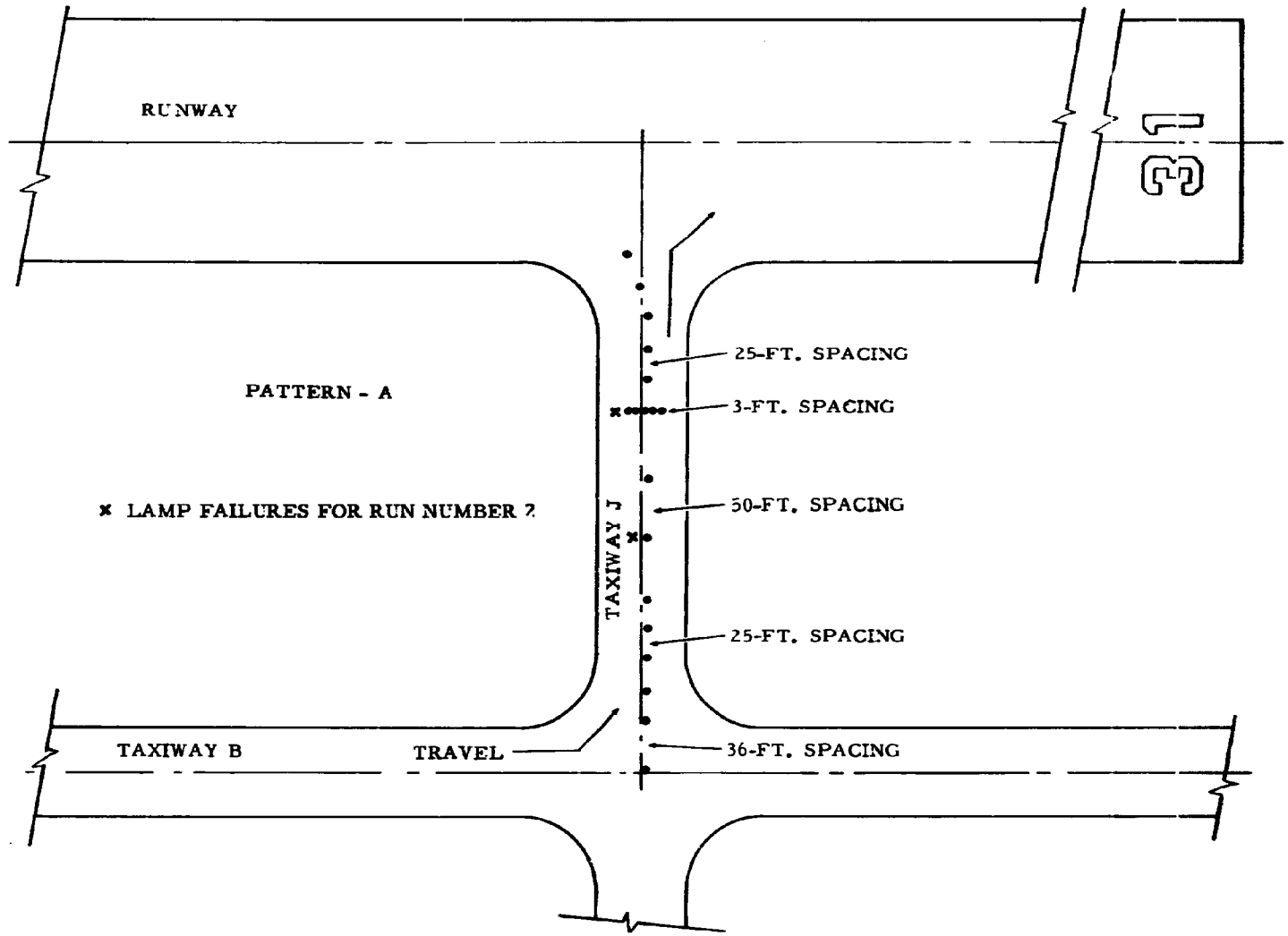

FIG. 11 TAXIWAY CENTERLINE LIGHTING
PATTERN A FOR RUNS NO. 1-2

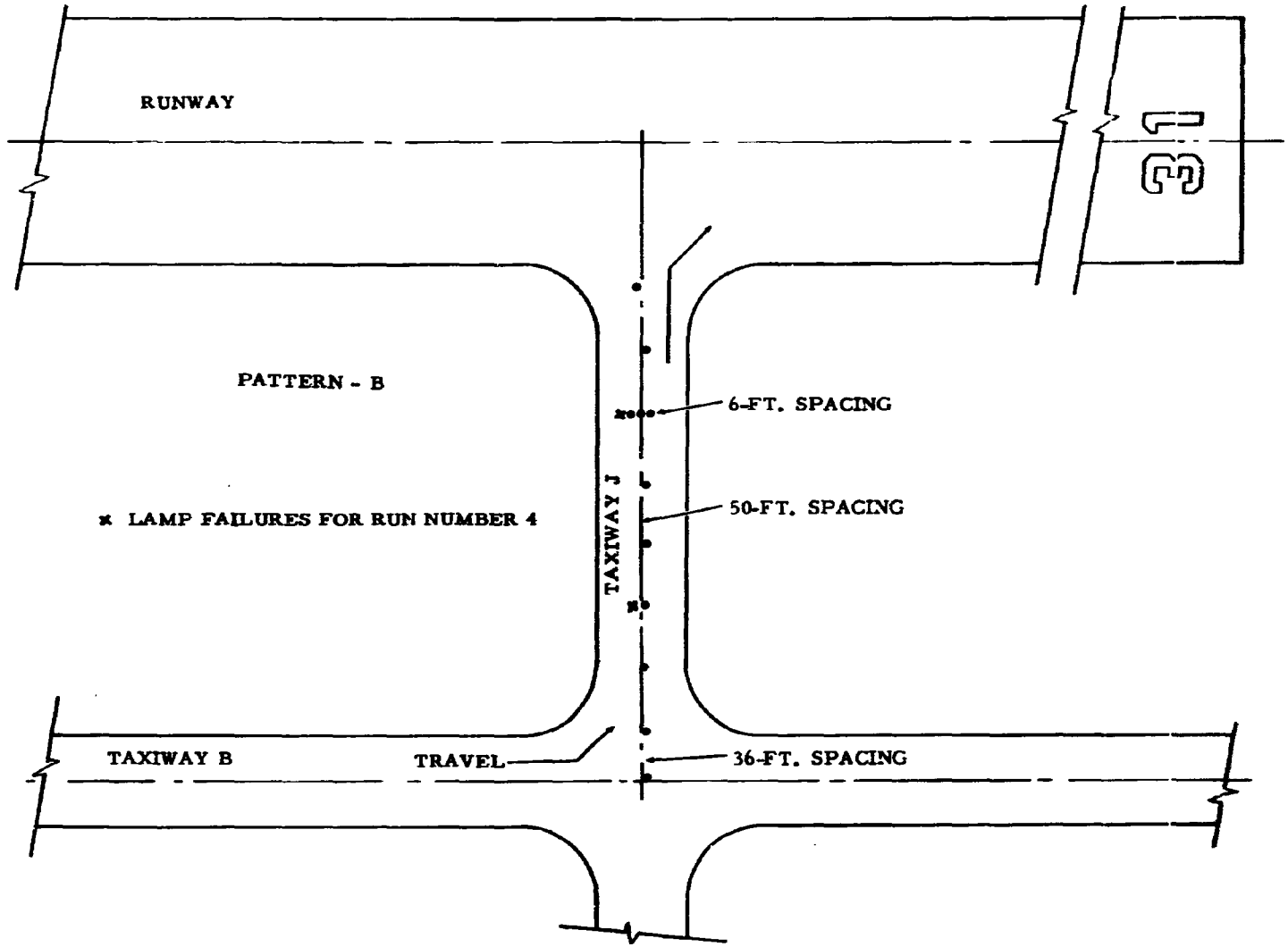

FIG. 12 TAXIWAY CENTERLINE LIGHTING
PATTERN B FOR RUNS NO. 3-4

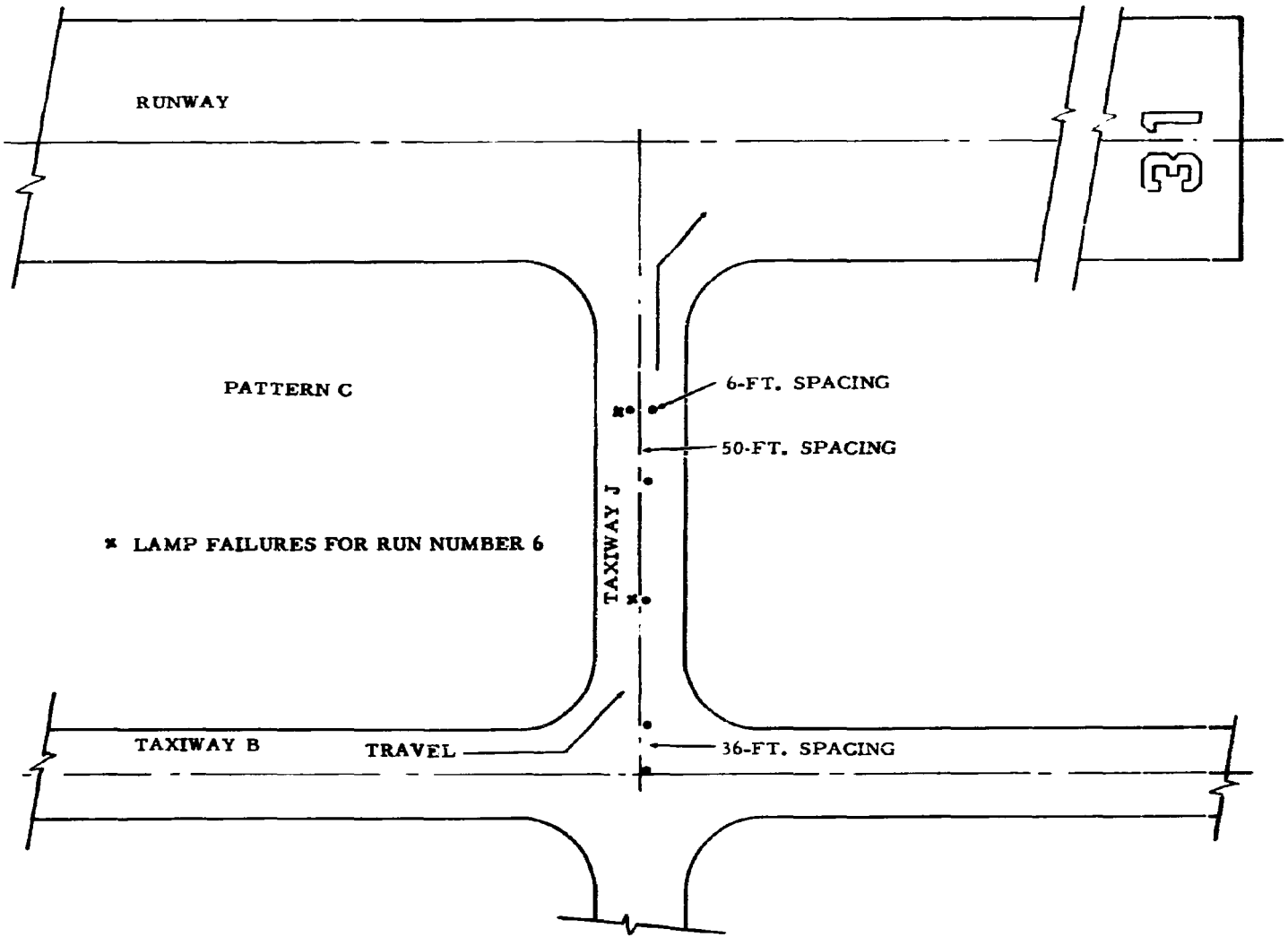

FIG. 13 TAXIWAY CENTERLINE LIGHTING
PATTERN C FOR RUNS NO. 5-6

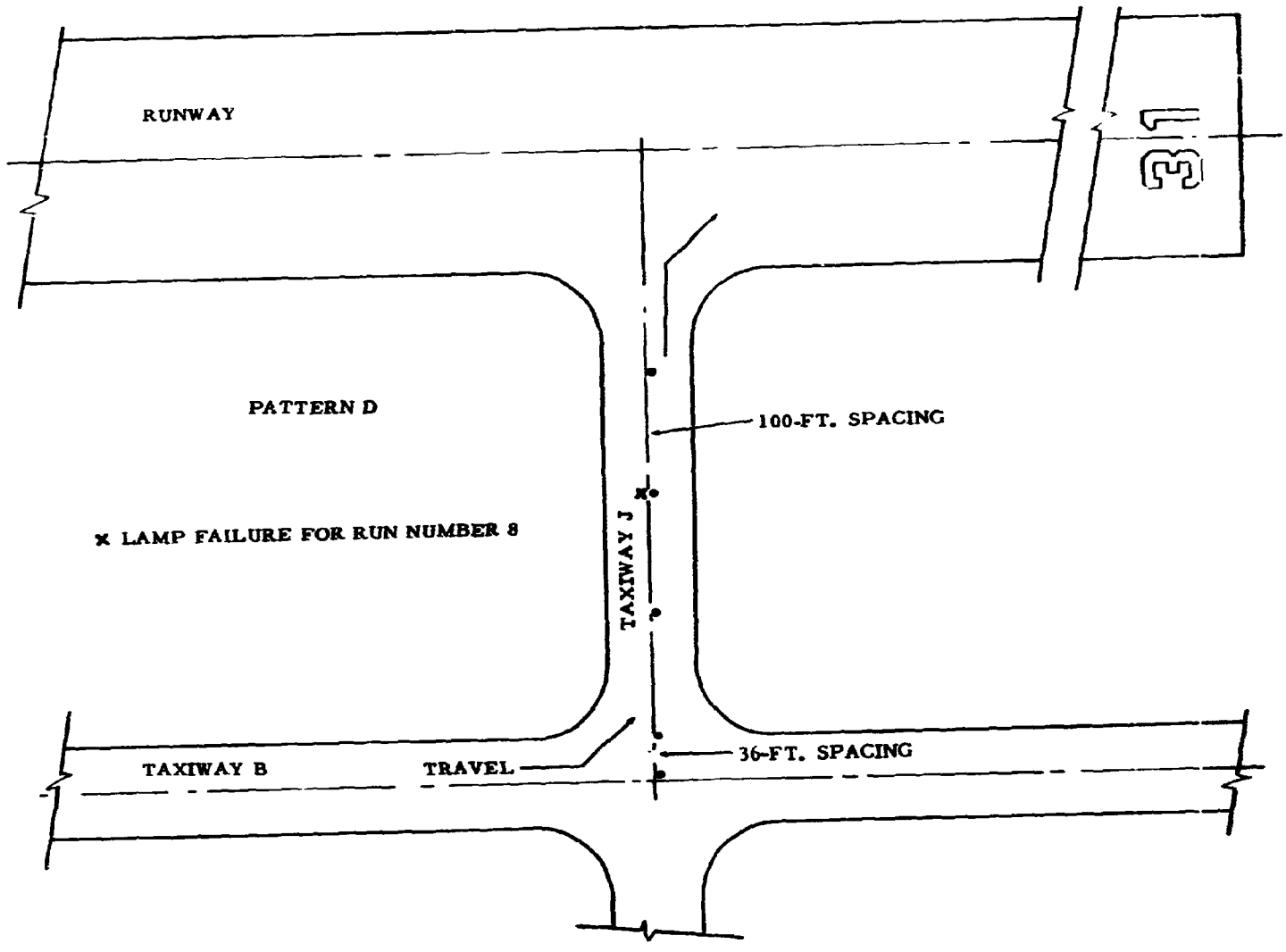

FIG. 14 TAXIWAY CENTERLINE LIGHTING
PATTERN D FOR RUNS NO. 7-8

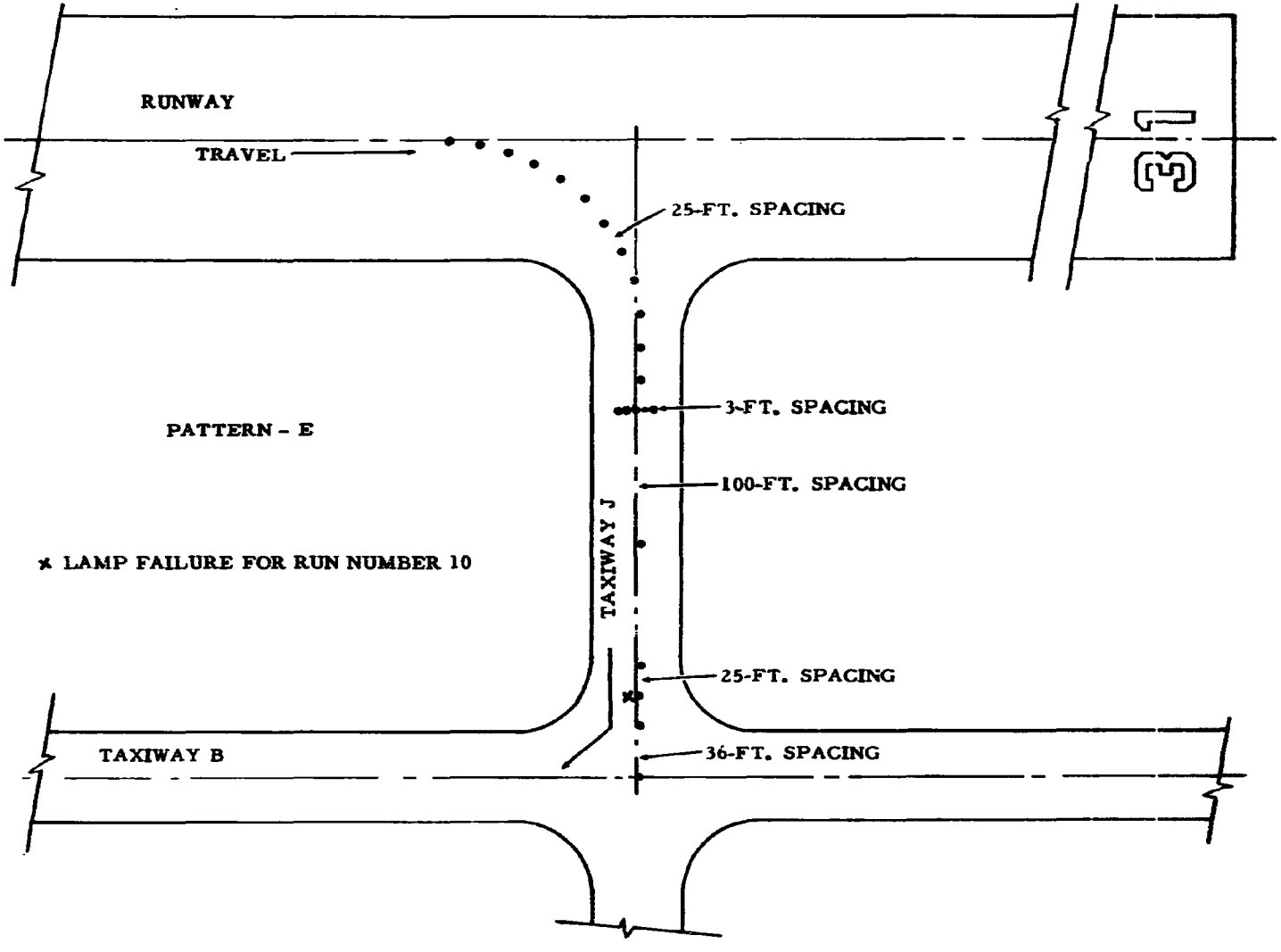

FIG. 15 TAXIWAY CENTERLINE LIGHTING
PATTERN E FOR RUNS NO. 9-10

The elevated blue taxiway edge lights were bagged and blue reflective markers were installed with similar spacings as the taxiway edge lights to indicate the edge of the taxiway pavement. Taxi travel was in the direction as indicated by the box marked Travel and its accompanying arrow.

Additional runs were made to compare the effectiveness of aviation green filters and aviation yellow filters on the hold bar. A five-light bar was compared with a three-light bar. A three-light bar with close spacing (3 feet) and one with wide spacing (6 feet) were investigated.

To obtain additional information on the taxiway exit into Taxiway J, questionnaires for two additional projects operating along Runway 13 included questions on the usefulness of the exit lighting. These questions were as follows:

Would you recommend the use of green taxiway exit lighting as installed from the runway centerline into Taxiway J for use in decreasing runway occupancy time? Yes_____No_____.

Did the exit lighting expedite your exiting the runway? Yes_____No_____.

The exit lighting into Taxiway J was operated routinely for approximately 2 years during night operations with transient aircraft notified through NOTAM's.

The exit lighting into Taxiway J was shortened in a special trial to evaluate the effectiveness of exit lighting that did not extend all the way out to the runway centerline, and the spacing was changed from 25 feet to 50 feet. The system was (1) terminated at the edge of the runway, (2) extended out to a distance of 40 feet from the runway centerline and (3) continued to tangency with the runway centerline. At the completion of this trial, the exit lighting was operated routinely in the third configuration (3 above) at 25-foot spacings and all further trials were conducted with the lights extended to the runway centerline.

A total of 10 subject pilots were used in evaluating the straight portion of Taxiway J. All operations were conducted in good visibility conditions at night using the DC-7, Gulfstream 159, and Convair T-29 aircraft.

Taxiways A, B, and I Installations at NAFEC: Nine subject pilots participated in this phase of the project taxiing Gulfstream 159, Aero Commander 680 and Convair T-29 aircraft. Operations were conducted in both day and night conditions (three by day--all others by night) with three pilots taxiing in clear night visibility conditions and all others taxiing in visibilities at and below 1 mile.

The pilots were requested to watch for taxiway centerline lights as they proceeded along Runway 13, Runway 22, and Runway 8. If visible, the pilots were to decide whether the lights could be confusing or mistaken for threshold or end lights. Also, pilots were to comment on the adequacy of identifying taxiway intersections and guidance provided in turning at the intersections.

Taxiway G and I Installations at Washington National Airport: Pilots operating into Washington National Airport filled out the questionnaire shown in Appendix B. The questionnaires were directed to airline pilots through their flight dispatch offices. Since the turn-offs were located so far from the runway threshold, no effort was made to obtain pilot opinion from other than airline transport pilots.

Test Results

Laboratory Tests: The characteristics obtained in the photometric range are shown in Figures 16 to 20. Figure 17 shows the results of using a narrow-beam optical assembly in the redesigned L-842 base. The horizontal beam was 30° wide with a maximum intensity of nearly 800 candelas. The same general results shown in Figure 19, were obtained when a similar optical assembly was used with the L-852 base. A 45-watt lamp was used in the narrow-beam optical assemblies. These data were taken without aviation green filters being installed in the fixture. The transmission of the color filters to be used with these fixtures is near 20 percent at a color temperature of 2,854° Kelvin. The intensities given in these figures should be reduced to 20 percent to allow for the green filter.

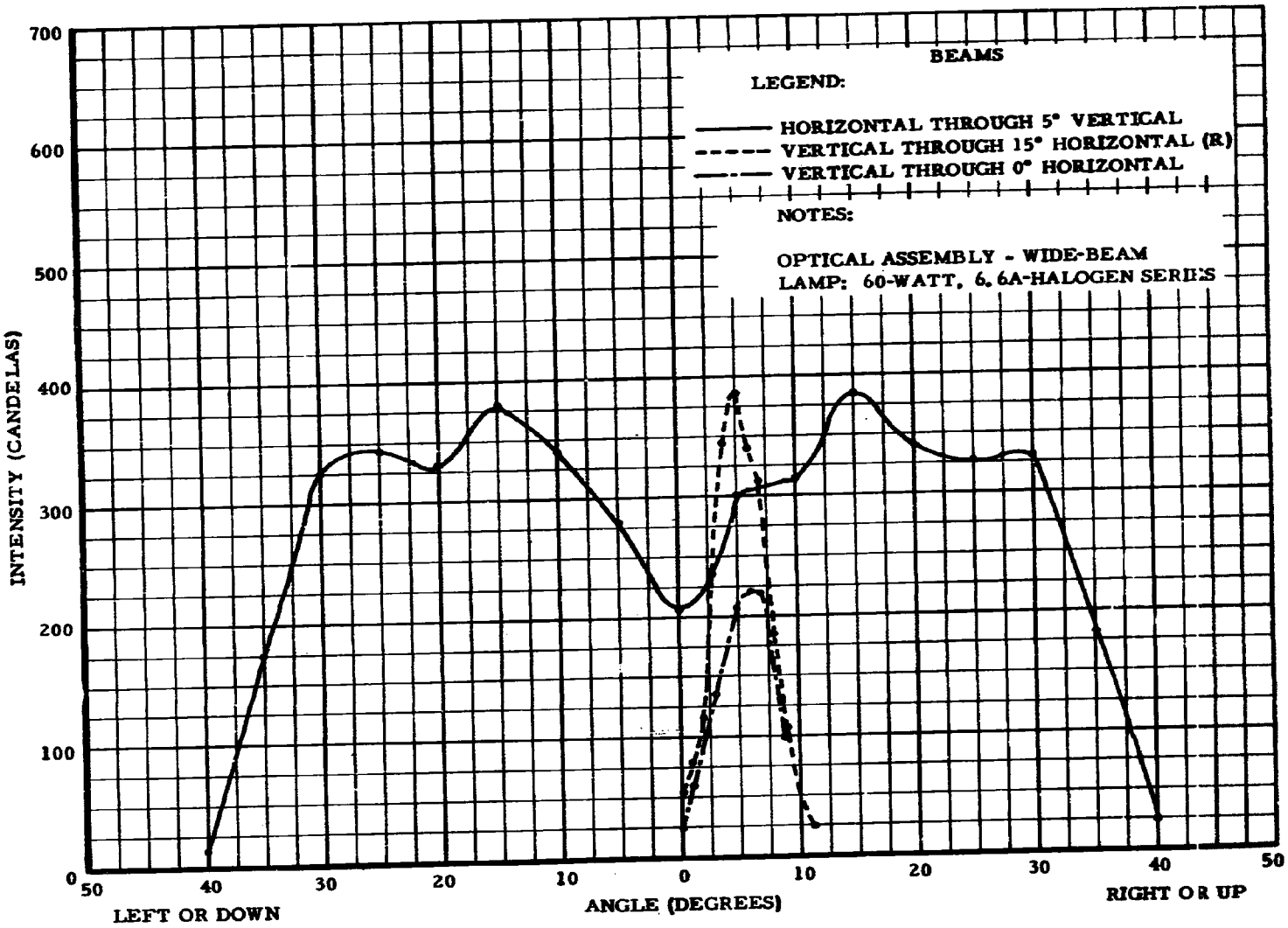

FIG. 16 BEAM CHARACTERISTICS
OF THE L-852 "CONTRACT" FIXTURE

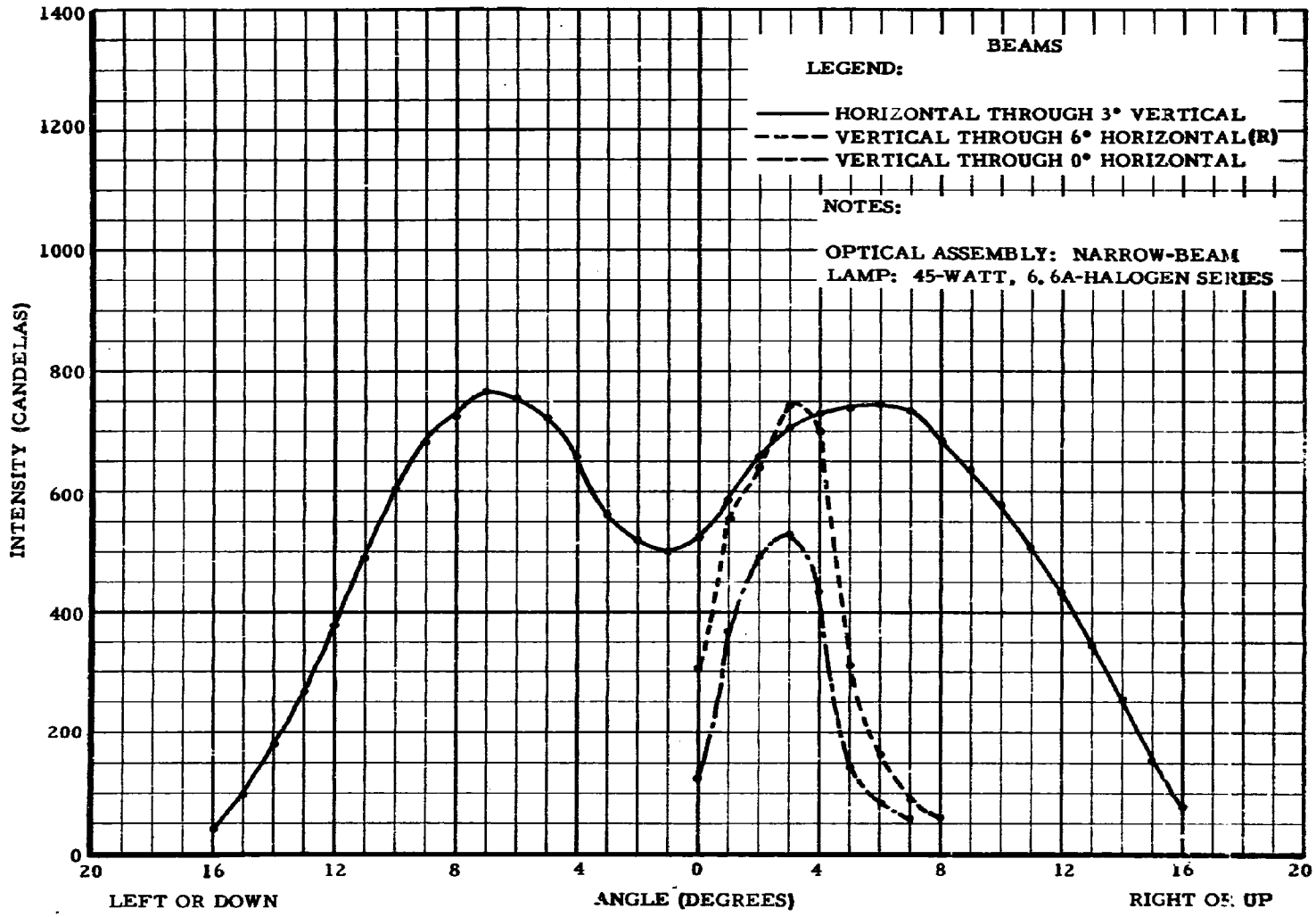

FIG. 17 BEAM CHARACTERISTICS OF REDESIGNED L-842 BASE WITH A NARROW-BEAM OPTICAL ASSEMBLY

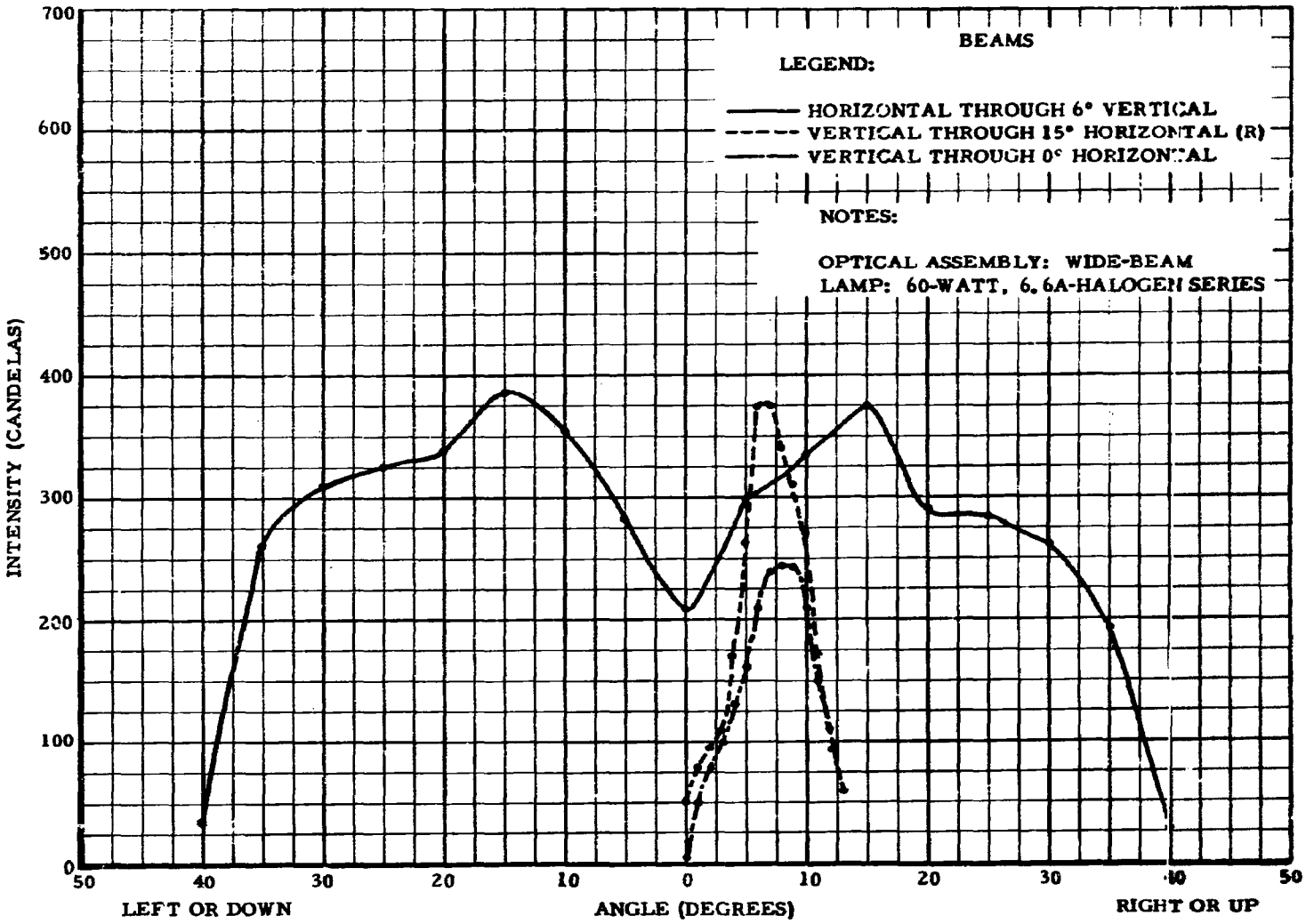

FIG. 18 BEAM CHARACTERISTICS OF REDESIGNED L-842 BASE WITH A WIDE-BEAM OPTICAL ASSEMBLY

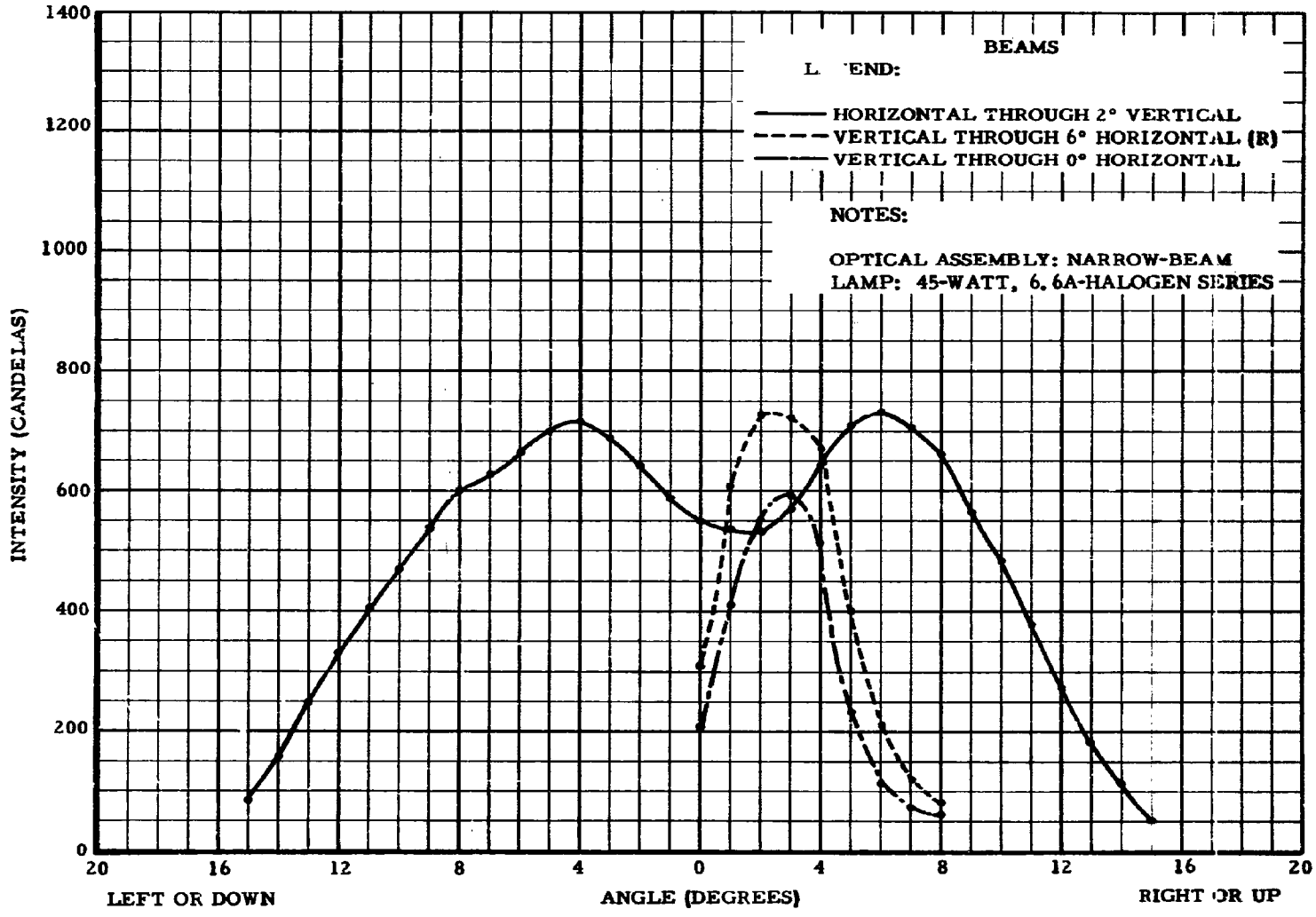

FIG. 19 BEAM CHARACTERISTICS OF L-852 BASE
WITH A NARROW-BEAM OPTICAL ASSEMBLY

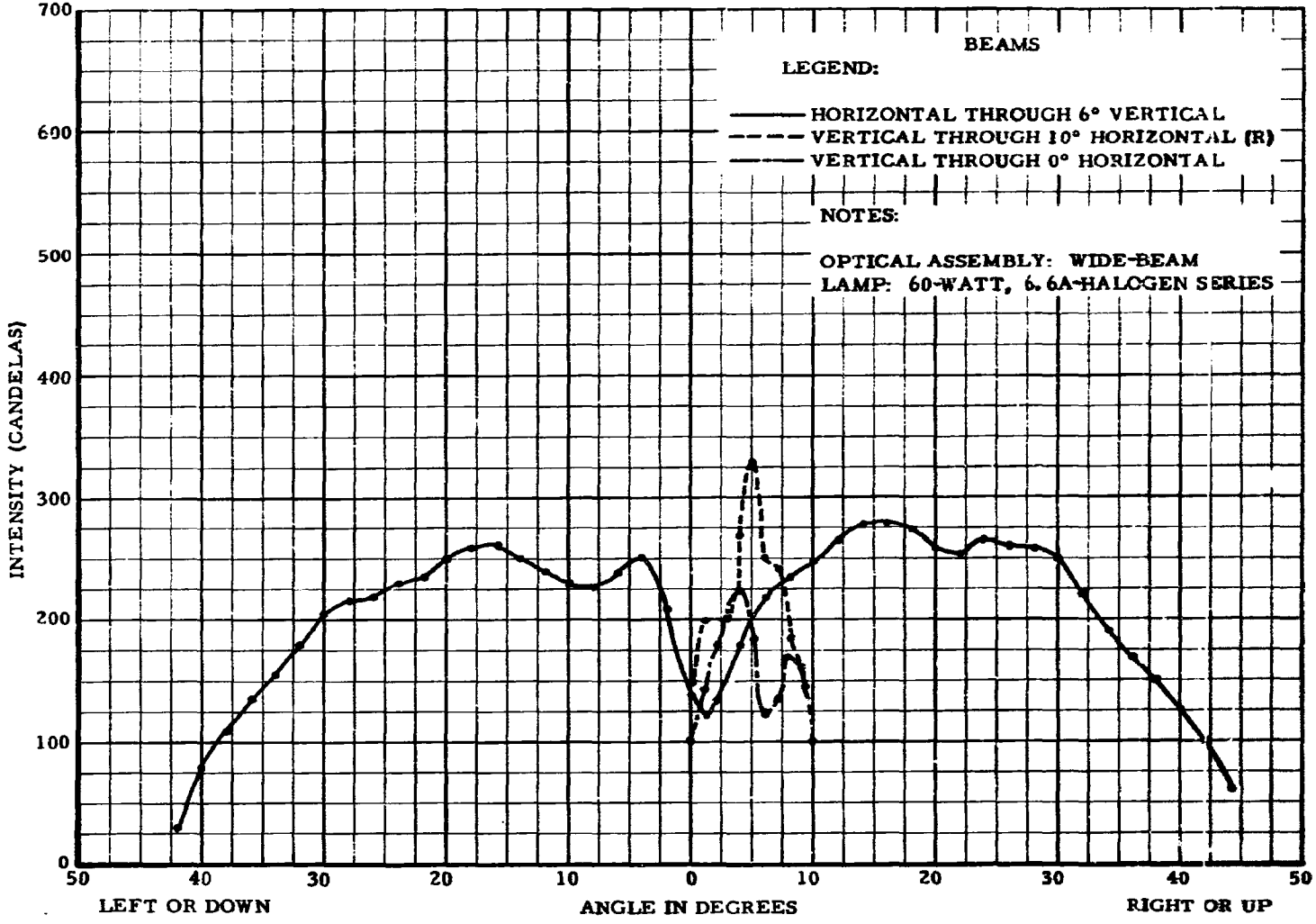

FIG. 20 BEAM CHARACTERISTICS OF L-852
WITH A WIDE-BEAM OPTICAL ASSEMBLY

Taxiway J at NAFEC: The results obtained from the questionnaire (Appendix A) were as follows:

1. Pattern B was the minimum acceptable configuration for making 90° turns at intersections.

2. The retro-reflective edge markers generally provided adequate guidance along the edges of straight sections of the taxiway. (The quality of guidance provided depended upon the position of the lights on the aircraft being used.) Guidance within the curved fillet areas was very poor.

3. A hold bar of three lights was considered by all pilots to be the minimum acceptable.

4. The hold bar was considered an effective aid in holding clear of runways and intersections.

5. Nine of the 10 pilots noted that the close spacing of lights near Taxiway B (Pattern E) did not provide adequate warning of approach to the intersection.

6. Only one subject answered yes to both parts of No. 5. He preferred the hold bar to the close spacing of lights to warn of the approach to intersections.

7. Yellow was the color preferred by all subjects for use in the hold bar.

8. Wide spacing (6 foot) was more effective than the close spacing (3 foot) for the hold bar when only three lights were used.

9. The guidance provided by the three-light hold bar color coded yellow was as effective as the five-light hold bar color coded green.

In answer to the questions concerning the exit lighting into Taxiway J to decrease runway occupancy time, all eight pilots participating in the program at night recommended its use. The pilot of a Convair 880 reported the lights were not useful during daylight. The pattern acceptable to the pilots was the one that continued on out to a point of tangency with the runway centerline.

A few pilots recommended the use of an imminence signal ahead of the intersection. A 50-foot spacing was considered to be too great with the 25-foot spacing considered to be about right. One pilot thought the green exit lights might be confused with reflections on a wet pavement from the runway end lighting, an indication that green should not be used for color of both end and exit lighting.

Toward the end of the evaluation on exit lighting, an idea developed concerning a minimum configuration for indicating the location of taxiway exits using color coding for runway centerline lighting. It was thought that where runway centerline lighting existed, color coding three or four of the centerline lights "green" opposite the "throat" of a taxiway would indicate to the pilot that he could make "best time" to the nearest group of green lights and turn 90° opposite the lights to exit the runway. This was given a limited test by a few pilots at the end of the program and was found to be a promising signal for reducing runway occupancy time. It can be seen that where taxiway centerline lighting crosses a runway, the group of green lights would direct the pilot to the taxiway lights in the runway much more rapidly than possible without the lights since the crossing taxiway lights are not visible until very close to them and they could be missed or overrun. Thus, the technique appears useful with or without taxiway centerline lights in the runway surface.

Taxiways A, B, and I Installations at NAFEC: For the crossings at 90° angles, (L-842 fixtures) pilots were unable to see the lights. For the crossings at 45° angles (L-842 fixtures) the lights were viewed as three or four very low intensity, single source, green lights spaced widely apart. All participating subject pilots accepted the taxiway centerline lights in the runway as not presenting any problems of confusion with other visual aids. No transient pilot has, to our knowledge, indicated any problem with the taxiway centerline lights crossing runways at NAFEC.

All pilots rated taxiway intersection guidance as inadequate when viewed with no imminence of intersection signal available. Since it was not possible to provide the yellow hold-bar tested previously, yellow filters were installed in all fixtures for a distance of 300 feet ahead of the intersection for Taxiways B and I. Use of yellow filters corrected the deficiencies and all pilots rated taxiway guidance as adequate.

Taxiways G and I Installations at Washington National Airport: The results of the in-service trials on retro-reflective markers installed on Taxiways G and I for exit purposes at Washington National Airport were quite favorable. The markers were visible at an adequate distance to make the exit, they were of sufficient brightness, they were not confused with any other lighting pattern, and all responses, except for a very small percentage, indicated the desire to see greater use made of these reflectors as an aid to exiting runways at night. Pilots were divided as to whether the curve was large or short radius but this should have occurred since the exits would be classed in a medium-radius curve category.

After 6 months of operation, the first four reflectors leading from the runway centerline were fractured at each of the two exits. This indicated failure due to aircraft operations since no snow removal equipment was used during this period. The eight reflectors were replaced and were reported to be in good condition in December 1969 except for one additional fractured marker near the runway centerline.

Rubber from aircraft tires was deposited on the upper part of the reflecting surface leaving the lower part to provide illumination with little maintenance involved.

Analysis of Test Results

Application of Taxiway Centerline Lights at Intersections: When taxiing with extremely low visible ground segments of the order of 600 feet and less, pilots will need to taxi aircraft along curves at intersections lighted with taxiway centerline fixtures. However, in better visibilities, a well-designed taxiway guidance system will permit pilots to maneuver offset (adequate fillet for the aircraft being available) from his centerline guidance where the configuration consists of straight sections intersecting at approximately 90°. A requirement exists for imminence of intersection lighting, wide beam fixtures adjacent to the intersection, and a sufficient number of lights on short sections of taxiway to provide directional guidance.

A three-light yellow cross bar provides a minimum adequate imminence of intersection signal. Closely spaced green lights were inadequate. Examination of the use of color coding taxiway intersections at a major airport by locating yellow lights in the taxiway centerline showed that due to the complexity of numerous intersections with short sections, the technique would convert the major portion of the system to a yellow taxiway centerline lighting system. Consequently, this method was dropped in favor of using a yellow hold bar as the best solution to providing imminence of intersection signaling. The yellow hold bar provides additional guidance since it can be used as a safe holding point along a taxiway when advised by ground control to hold clear of a taxiway intersection.

To determine the spacing of lights on short straight sections, the first 150 feet should not be considered since this length is of secondary value for guidance especially where long-bodied aircraft are involved. Installation of a minimum of four lights is required in the remaining distance for short taxiway sections. (See Figure 21.) Three lights are necessary to provide adequate guidance. The fourth light would provide a desirable safety factor in the event of a fixture failure.

Wide-beam fixtures adjacent to taxiways intersecting at 90° provide guidance to pilots when offset in a maneuver where the pilots' judgment is used to maintain aircraft tires on the full-strength taxiway pavement.

Wide-beam taxiway centerline lights should be used for that portion of the taxiway within 150 feet of the intersection out to and including the fourth light from the 150-foot point as shown in Figure 21. Narrow-beam assemblies should be used within the intersection and beyond the distance shown in Figure 21 since the intensities will be more suitable for daytime guidance.

Generally speaking, retro-reflectors have not proved effective for outlining the edge of the taxiway at intersections where off-centerline maneuvering is required by long-body aircraft. Blue edge lights should be used in the fillets of intersections where long-body aircraft are operated and the width of the full-strength pavement is considered marginal for the maneuver required.

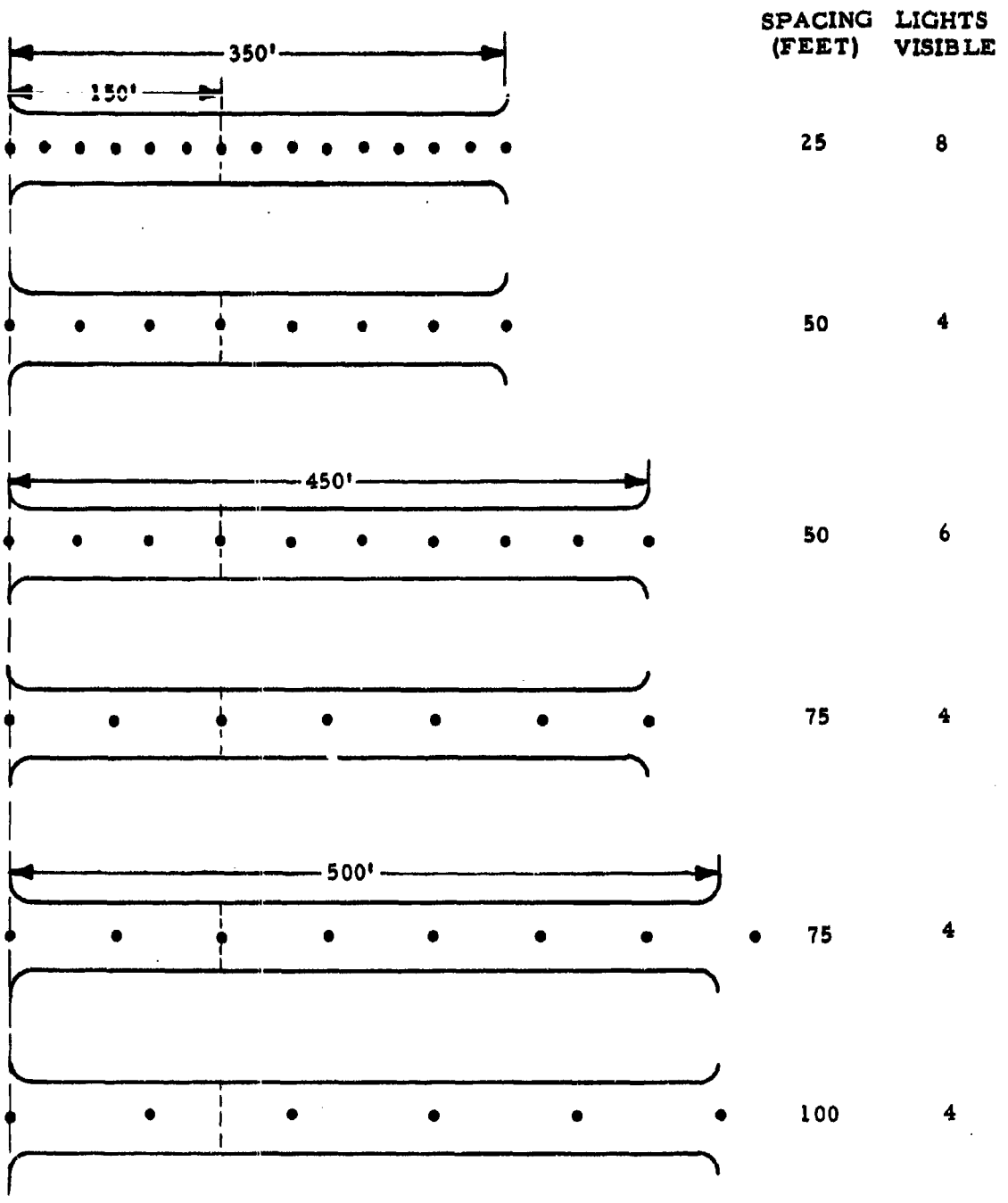

FIG. 21 SPACING OF LIGHTS
FOR STRAIGHT SECTIONS OF TAXIWAY

Green Taxiway Lights and Reflectors Located in the Runway Surface: From these tests, some of which have been continued over a considerable period of time to obtain exposure to industry pilots, sufficient information is available to show that green lights and reflectors can be used in the surface of runways for (1) exit purposes on short-radius curves and (2) to maintain continuity of taxiway centerline lighting across runways. A safeguard exists in converting the runway end lighting from green to red. An additional safeguard would be to restrict the use of exit lighting on runways within a reasonable distance from the runway threshold. This could be 2,500 feet, for example, since few aircraft can use an exit much sooner than this distance anyway. Another safeguard would be to require shielding of taxiway centerline lighting in the approach direction where crossing angles are less than 45°. Such shielding could be accomplished by installing lights on runways with the axis aligned off the taxiway centerline sufficiently to maintain a 45° angle of the fixture axis with the runway centerline. This suggestion is applicable for the L-842 Fixture, the type evaluated in the program at NAFEC.

The brief investigation at NAFEC on the feasibility of color coding three (or four if needed for "balance") runway centerline lights "green" opposite the "throat" of taxiways shows promise for reducing runway occupancy time where more costly installations of curved lighting on exits are not available.

CONCLUSIONS

Based on the results of this evaluation, it is concluded that:

1. In the interest of economy, taxiway centerline lighting at intersections when operating in short visual ground segments of approximately 600 feet and above can be used by pilots for negotiating turns provided:

a. The lighting system provides imminence of intersection warning.

b. Wide-beam centerline lights are used adjacent to the intersection.

c. A sufficient number of lights is available on short sections to provide directional guidance.

d. Blue edge lights are used at fillets of intersections where long-body aircraft are operated and the width of the full-strength pavement is considered marginal for the maneuver required.

2. A three-light yellow cross bar with spacings of 5 feet between lights provides a minimum adequate imminence of intersection signal.

3. Wide-beam taxiway centerline lights should be used for that portion of the taxiway within 150 feet of the intersection out to and including the fourth light from the 150-foot point.

4. Lights on short sections of taxiways should be spaced so that at least four lights will be available for guidance beyond a point 150 feet from the intersection.

5. Green lights and reflectors can be used in the surface of runways for exit purposes on short radius curves and to maintain continuity of guidance where taxiway centerline lighting crosses runways that use red end lighting. Additional safeguards can be implemented to prevent confusion with threshold lighting by limiting the location of exits within a given distance of the threshold and by shielding at intersections with taxiways to prevent pilots from viewing bright lights in the runway surface.

CONCLUSIONS (Continued)

6. Color coding three or four runway centerline lights "green" opposite the "throat" of a taxiway shows considerable promise as a low-cost, minimum configuration for reducing runway occupancy time where curved exits are unavailable.

APPENDIX A

QUESTIONNAIRES

TAXIWAY VISUAL AIDS

PROJECT NO. 430-301-04X

FEDERAL AVIATION ADMINISTRATION
National Aviation Facilities Experimental Center
Test and Evaluation Division
Guidance Branch
Atlantic City, New Jersey

Date_____

QUESTIONNAIRE
Project 430-301-04X
Taxiway Visual Aids

Pilot_____ Aircraft_____

1. Which configuration of taxiway centerline lighting did you consider the minimum acceptable for making 90 turns at intersections? Pattern A_____, Pattern B_____, Pattern C_____, Pattern D_____, or Pattern E_____?

2. Did the retro-reflective edge markers provide adequate guidance along the edges of the taxiway with the above selected pattern? Yes_____ No_____

3. Which pattern of the hold-bar did you consider the minimum acceptable? Five lights_____, Three lights_____, Two lights_____?

4. Is the hold-bar considered a desirable aid in holding clear of runways and intersections? Yes_____ No_____

5. Do the close spacings near Taxiway E (Pattern E) provide adequate warning of approach to intersections? Yes_____ No_____. Does the hold-bar provide adequate warning of approach to intersections? Yes_____ No_____.

6. If the answer to 5 above is Yes for both patterns, which pattern do you prefer? Close spacings_____ Hold-bar_____?

7. Use this space for any comments not covered above.

Pilot Check Sheet
(Data to be used in completing the final questionnaire.)

Run Number	Centerline Guidance		Hold-Bar Guidance		Edge Reflectors	
	Adequate	Inadequate	Adequate	Inadequate	Adequate	Inadequate
1(A)						
2(A)						
3(B)						
4(B)						
5(C)						
6(C)						
7(D)						
8(D)						
9(E)						
10(E)						

Additional Comments

QUESTIONNAIRE

Date:_____

Aircraft:_____ Pilot:_____

Day:_____ Night:_____

Visibility:_____ Background Brightness (Day)_____

1. Guidance received from the taxiway centerline lights on straight sections, without the elevated blue edge lights was:

   a. More than adequate_____
   b. About right_____
   c. Inadequate_____

2. Guidance received from taxiway centerline lights on straight sections, with reflective edge markers was:

   a. More than adequate_____
   b. About right_____
   c. Inadequate_____

3. Guidance received for turning from TW/B into TW/A was:

   a. More than adequate_____
   b. About right_____
   c. Inadequate_____

4. Guidance received for turning from TW/B to the right, into TW/I was:

   a. More than adequate_____
   b. About right_____
   c. Inadequate_____

5. Did the yellow lights on Taxiway I prove useful as a warning that you were approaching an intersection when taxiing along Taxiway I toward the intersection with Taxiway B?
Yes_____No_____
Comment:

6. Guidance received for turning from TW/B into TW/J was:

a. More than adequate_____
b. About right_____
c. Inadequate_____

7. Would you recommend the use of green taxiway exit lighting as installed from the runway centerline into Taxiway J for use in decreasing runway occupancy time?
Yes_____No_____
Comment:

8. When operating on Runway 13/31 or Runway 8/26, did any of the green taxiway centerline lights appear bold enough to be mistaken for runway threshold lights?
Yes_____No_____
Comment:

9. The yellow hold-bar on Taxiway J is:

a. More than adequate_____
b. About right_____
c. Inadequate_____

If inadequate, what changes would you suggest?

10. Which color should be used in the taxiway hold-bar?
Green_____Yellow_____.

11. Is the close_____or the wide_____spacing most effective for the taxiway hold-bar when only three lights are used?

12. Is the guidance provided by the three-light hold-bar color coded yellow as effective as the five-light hold bar color green?
Yes_____No_____.

QUESTIONNAIRE

REFLECTIVE MARKERS FOR TAXIWAYS G AND I

WASHINGTON NATIONAL AIRPORT

Pilot_____Flight No. _____Airline_____

1. The green reflectors were: (Check one)

   a. Not seen at all_____.

   b. Were visible at an adequate distance to make the exit_____.

   c. Were visible too late to make use of the exit_____.

(Complete the following if either b or c were checked above.)

2. The reflectors appeared bright_____, dim_____ragged_____.

3. When first seen, the pattern formed by the reflectors appeared to be that of a large radius curve_____, a short radius curve_____, a straight line_____, a blob of light_____, or other. (Please explain.)

4. I do_____, do not_____ consider that the reflectors could be confused with any other aviation lighting signal. (If you do, please explain.)

5. The reflectors were of considerable assistance_____, some assistance_____, no assistance_____, in exiting the runway.

6. I would _____, would not_____ like to see greater use made of the reflectors as an aid to exiting runways at night.

7. Additional comments.

APPENDIX B

BIBLIOGRAPHY

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5. FAA SRDS Report No. RD-66-78, "Development of 60 Watt Wide Angle Taxiway Light for Short Radius Taxiway Turns," dated June 1966.

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