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EVALUATION OF RADIO-LUMINESCENT LIGHTING SYSTEM

Thomas H. Paprocki

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16. Abstract

This report describes the evaluation of a newly developed Tritium powered Radio-Luminescent Runway Lighting System intended to support landing operations at remote, unattended airports.

The prototype Radio-Luminescent Lighting System was installed for evaluation near Richland, Washington. Subject pilots, having flight experience levels appropriate for pilots conducting FAR 135 Air-Taxi operations, were afforded the opportunity of flight testing the system under remote site environmental conditions.

Pilot opinion as to system effectiveness was favorable for the test weather conditions encountered. Since it was not possible to evaluate the system in the lower visibility visual flight rules (VFR) weather conditions of 2 to 3 statute miles, as required by the agreed upon test criteria, no determination of system suitability for all VFR weather conditions was possible. It was recommended that the R/L Lighting system should be evaluated further under weather and environmental conditions that include visibility restrictions at the minimum values specified by the criteria and to be anticipated for remote site usage. In addition, the system should be tested under such unique conditions as may be expected to prevail within the area of most probable use; i.e., snow-covered terrain, blowing snow, and bright moonlight.

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EXECUTIVE SUMMARY

The purpose of this evaluation was to determine the suitability of a prototype Radio-Luminescent (R/L) Lighting System for providing nighttime visual guidance for approach and landing operations, under Visual Meteorological Condition (VMC), to safely support FAR 135 commercial operations. Results of this test will be considered for possible approval for use of the R/L Lighting System by FAR 135 operations only at remote landing sites where electrical power is either not available or impractical and other approved lighting systems cannot be installed.

The R/L Lighting System, as evaluated at the McWhorter Ranch, Richland, Washington, consisted of the following basic elements: Runway Edge Lights; Theshold Lights; Airport Identification Beacon, and a Lighted Wind Direction Indicator.

Minimum criteria for the R/L Lighting System evaluation was established covering light intensity/recognition under specific flight orientation and visibility conditions.

The evaluation was accomplished during the period September 24 to October 2, 1984, at the McWhorter Ranch, immediately adjacent to the Department of Engery Reservation at Richland, Washington. A total of 20 subject pilots were involved in the evaluation. Minimum flight crew included the Subject Pilot, a designated Safety Pilot, and a project Observer/Data Recorder.

From analysis of the evaluation test results, it was concluded that:

1. The R/L Lighting System provided satisfactory visual guidance under the limited and favorable environmental conditions encountered during the test period.

2. Since no restricted visibility weather conditions, less than a 2,300-foot AGL, scattered cloud layer, and 12 miles or better visibility were encountered during the test period, it is not possible to make a determination of the suitability of the R/L Lighting System for use in lower visibility conditions.

3. Due to the nature of the unique light characteristics of the R/L source used with this system, and due to a lack of operational experience with such light sources, it is not possible to extrapolate the results obtained during this evaluation effort to predict system effectiveness under conditions of further reduced visibility.

It was recommended that the R/L Lighting System should be evaluated further under weather and environmental conditions that include visibility restrictions at the minimum values specified by the criteria and to be anticipated for remote site usage. In addition, the system should be tested under such unique conditions as may be expected to prevail within the area of most probable use; i.e., snow-covered terrain, blowing snow, and bright moonlight.

EVALUATION OF RADIO-LUMINESCENT LIGHTING SYSTEM

PURPOSE.

The work described in this report has been performed in response to a request from the Office of Flight Operations, Flight Technical Programs Branch, AFO-210, and was accomplished under Technical Center Project No. T19-03K, "State-of-the-Art Improvements." The Technical Center Project Manager was Thomas H. Paprocki, ACT-310.

The purpose of this evaluation was to determine the suitability of a prototype Radio-Luminescent (R/L) Lighting System for providing nighttime visual guidance for approach and landing operations, under Visual Meteorological Condition (VMC), to safely support FAR 135 commercial operations. Results of this test will be considered for possible approval for use of the R/L Lighting System by FAR 135 operators only at remote landing sites where electrical power is either not available or impractical and other approved lighting systems cannot be installed.

SYSTEM DESCRIPTION.

The R/L Lighting System (figure 1), as evaluated at the McWhorter Ranch, Richland, Washington, consists of the following basic elements:

1. Runway Edge Lighting Units - intended to define the lateral limits of the available landing surface.

2. Threshold Lighting Units - intended to define the longitudinal limits of the available landing surface.

3. Airport Identification Beacon - intended to provide long-range identification of the general airport/runway location.

4. Lighted Wind Direction Indicator - intended to provide wind direction information to pilots overflying the runway at pattern altitude.

The basic R/L light fixture (figure 2) utilized in the assembly of the various system components is a one-foot-square tube holder containing seven Tritium filled phosphorized tubes to provide the light source. Once the Tritium gas is injected into the phosphor-coated tube, Beta emission from the decaying Tritium gas excites the phosphor to cause a continuous emission of visible light. Having a half-life of approximately 12 years, the Tritium activated device is expected to provide useable light, without need for external power, for an extended period of time.

The Runway Edge Lighting Unit (figure 3) consists of six basic R/L light fixtures, as described above, assembled into a holder so as to display two fixtures, side by side, in each of the two possible approach directions, and single fixtures directed outboard of the runway to provide circling guidance.

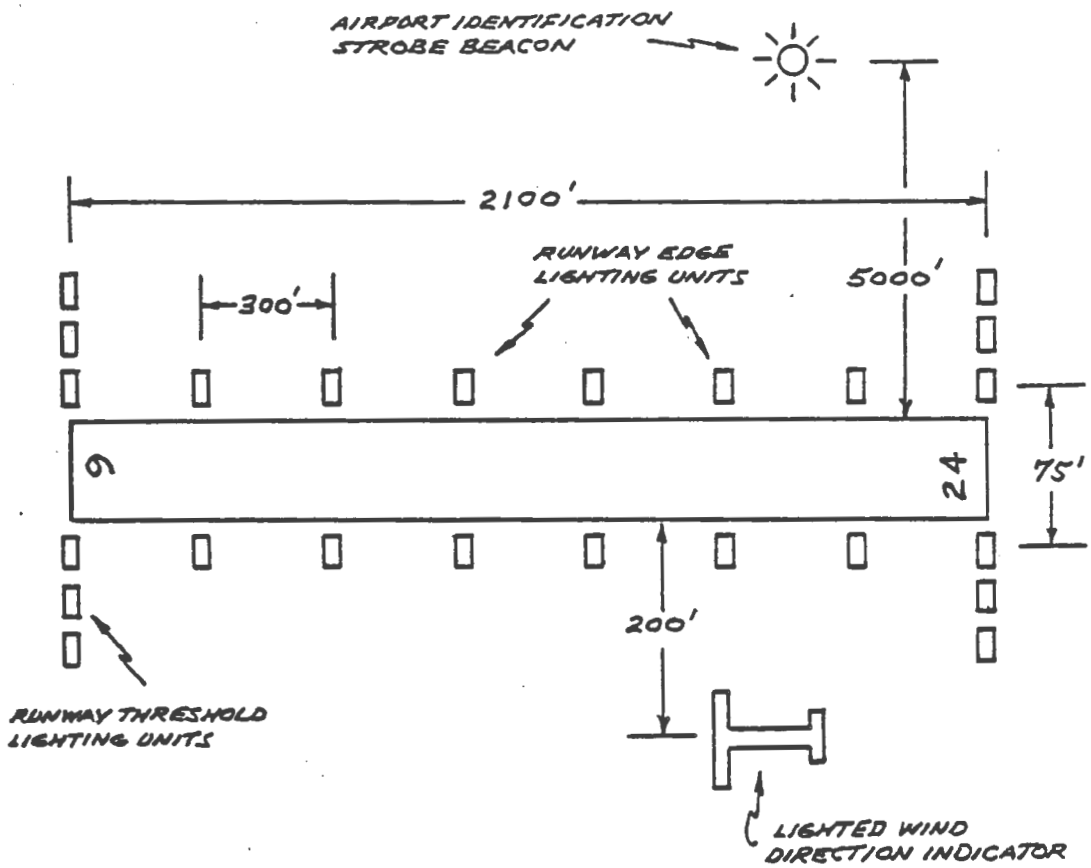

FIGURE 1. R/L LIGHTING SYSTEM LAYOUT

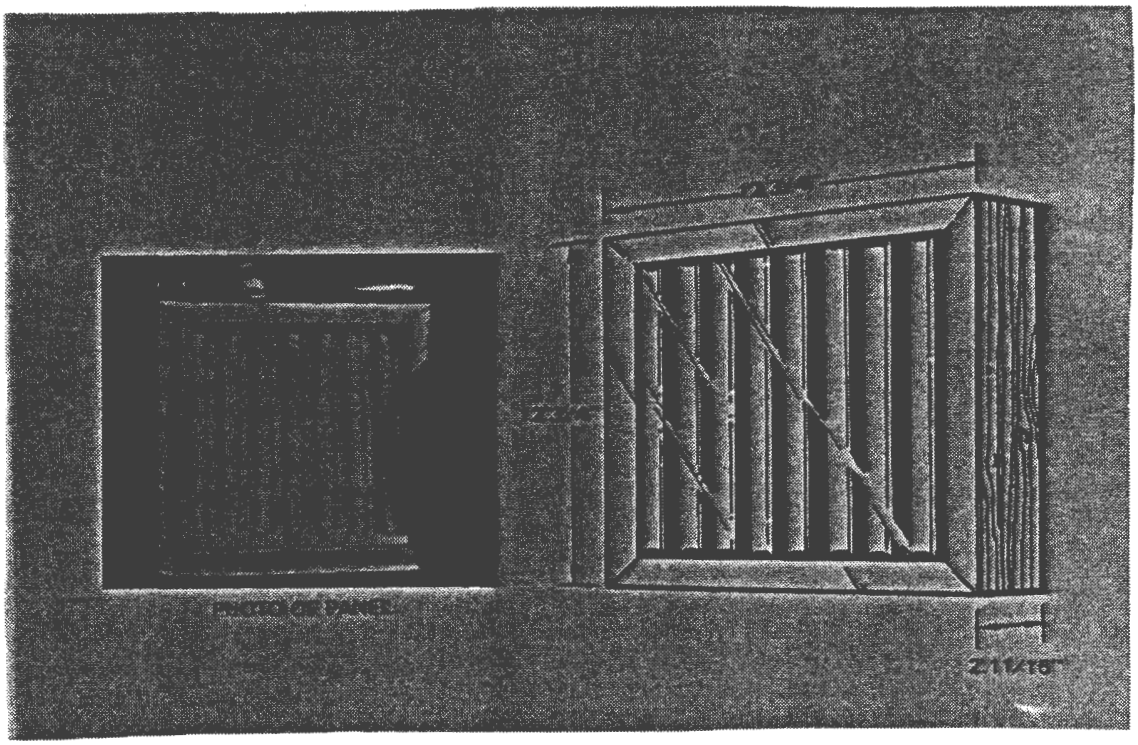

FIGURE 2. BASIC R/L LIGHT FIXTURE

FIGURE 3. R/L EDGE LIGHTING UNIT

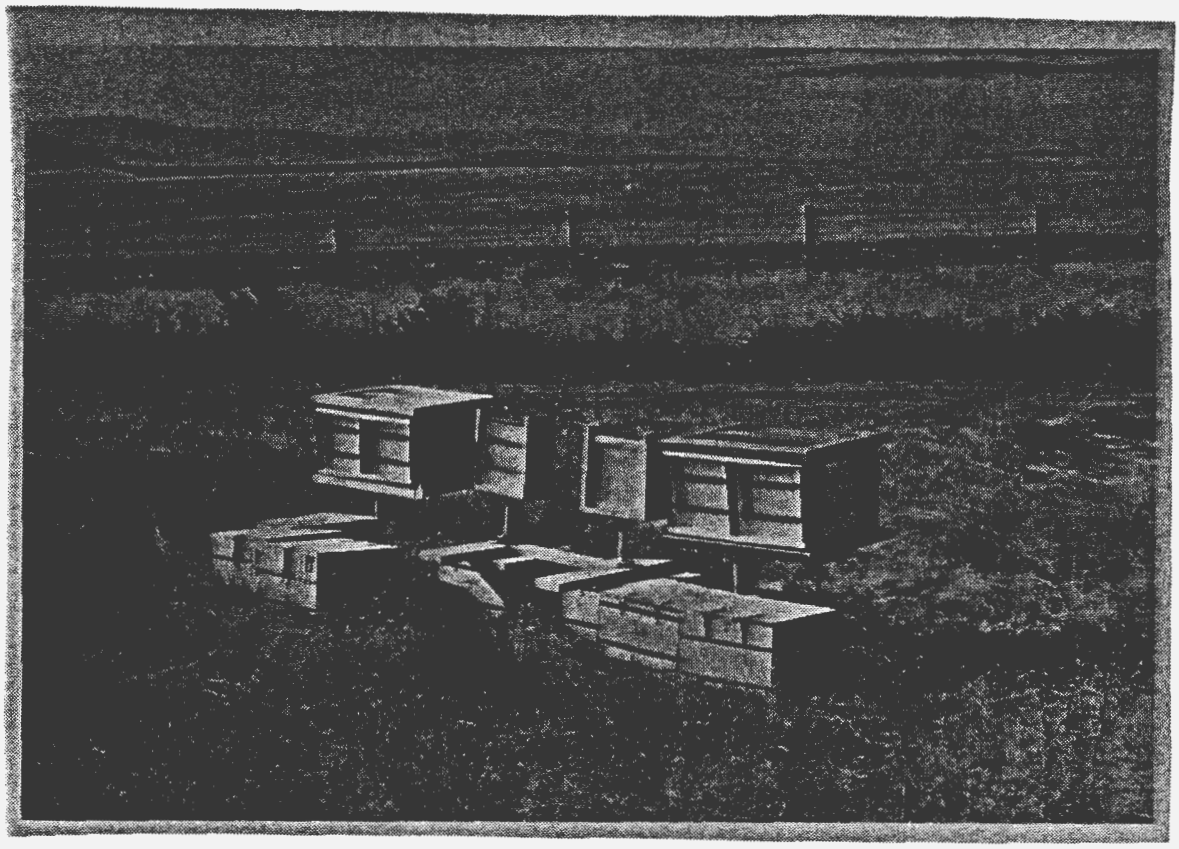

FIGURE 4. R/L THRESHOLD LIGHTING UNIT

The Threshold Lighting Unit (figure 4) consists of 14 basic R/L light fixtures assembled into a holder so as to display 6 fixtures, side by side, in each of the 2 approach directions, and single fixtures directed outboard of the runway to provide circling guidance. The use of four additional fixtures facing in each landing direction provided an enhanced indication of the runway threshold and opposite runway end.

The Airport Identification Beacon consists of a low-powered (15 watt) battery-operated strobe light which emits alternate green and white flashes at 3-second intervals. It does not contain any Tritium R/L lighting components.

The Lighted Wind Direction Indicator (figure 5) consists of 12 basic R/L light fixtures, mounted horizontally on top of a tubular "T" shaped structure which is free to turn into the direction of the prevailing wind. The appearance of the indicator is that of a small airplane whose alignment with the runway indicates the required landing direction.

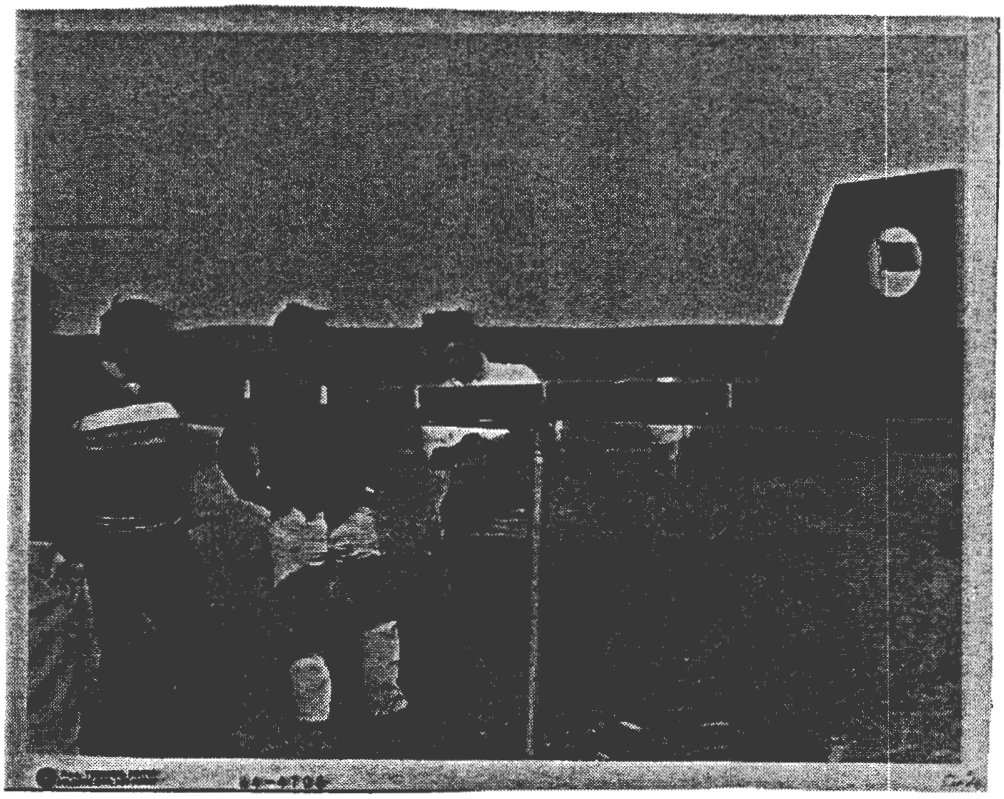

FIGURE 5. R/L LIGHTED WIND DIRECTION INDICATOR

A diagram of the configuration in which the various components were dispersed for the evaluation is shown as figure 1. The Runway Edge Lighting Units were spaced laterally at 75 feet and longitudinally at 300-foot intervals for the total runway length of 2,100 feet. The Airport Identification Beacon was located at a point 5,000 feet distant from the runway center. The Lighted Wind Direction Indicator was located 200 feet from the runway edge nearly abeam of the runway center point.

CRITERIA.

The minimum criteria for the R/L Lighting System evaluation was established as follows:

1. The R/L Lighting System must be of sufficient luminescence to provide immediate recognition of the aircraft's orientation with respect to the runway while maneuvering at 1,000 feet above ground level (AGL) at all points in the runway traffic pattern within a distance of 1.3 nautical miles (nmi) of the runway. Once seen, the R/L runway and threshold lights must provide this immediate recognition throughout the airport traffic pattern and approach. The mere detection of a light source which would indicate the presence of a runway without recognition of the runway orientation is not acceptable.

2. The R/L Lighting System must be capable of meeting this operational criteria under the following conditions:

a. Prevailing visibility of 2 to 3 statute miles.

b. Clear moonlit night where the contrast between the runway surface and the adjacent area is such that the definition of the runway cannot be determined without the aid of runway edge lights.

3. The system must include a low-powered airport identification beacon located within 5,000 feet of the runway and of sufficient intensity to permit identification of the runway/airport location at a distance of 10 statute miles in visibility conditions of 10 statute miles or more.

4. The system must include an illuminated wind direction indicator capable of providing wind direction information to a pilot overflying the runway at pattern altitude.

FACILITY, PILOT, AND EQUIPMENT REQUIREMENTS.

The prototype R/L Lighting System equipment and components were to be installed at a mutually agreed upon test site by the U. S. Department of Energy. The test site airport should have had the following characteristics in order to serve as a suitable evaluation facility:

1. An adequate landing surface of at least 3,000-foot length and 100-foot width, where the contrast between the landing surface and the adjacent area is such that the definition of a runway could not be determined without the aid of runway edge lights.

2. Be located in a relatively remote area, free from any significant concentration of ambient light sources. To simulate these conditions it may be necessary to set up lights in the configuration of a runway in an open field which has the same terrain and foliage as the area surrounding the test landing surface.

3. Be located close to (within approximately 50 miles) the major community from which the subject pilot(s) and aircraft resources will be drawn. Subject Pilots participating in this evaluation should have, at least, an experience level equal to that expected of pilots normally employed in the conduct of FAR 135 air-taxi operations.

Aircraft used for the evaluation should be of the type normally utilized in remote site air-taxi operations; i.e., Category A, general aviation aircraft of the Cessna Model 206 type. Single- or multi-engine aircraft capable of carrying at least five passengers, in addition to the pilot, would be best suited to the needs of the project. Dual VHF communication equipment capability is required for project coordination and communication with the ground support personnel.

METHOD OF APPROACH

The flight evaluation effort included three separate but related phases to be accomplished during each flight test session. Minimum flight crew included the Subject Pilot, a designated Safety Pilot, and a project Observer/Data Recorder.

Phase I

In order to determine the suitability of the R/L Lighting System in providing the required guidance for pilots to safely conduct approach and landings, three observation points were designated as shown on attached figure 6. The Safety Pilot positioned the aircraft at each of these locations and indicated to the Subject Pilot the direction in which to look in order to visually acquire the runway lighting system. From this position, approximately 1.3 nautical miles from the runway, the Subject Pilot was required to announce his relative orientation to the runway, using one of the following three terms:

Position A - "Runway Centerline"
Position B - "45 Degrees to Runway"
Position C - "Abeam the Runway"

This announcement or "call" had to be made within 2 or 3 seconds after the runway direction was provided to the Subject Pilot to verify that the visual guidance provided by the lighting system was self-apparent and unambiguous.

The project Observer/Data Recorder noted the Subject Pilot's call, either correct or incorrect, in the appropriate location on the pilot questionnaire form.

Phase II

In order to determine the effectiveness of the R/L Lighting System in providing continuous visual guidance to the pilot while maneuvering in the traffic pattern, the Safety Pilot positioned the aircraft for entry into a downwind leg at a distance of 1.3 nautical miles from the runway centerline. The Subject Pilot was then required to fly the aircraft through the downwind base leg, and final approach portion of the traffic pattern, to a low approach, using the guidance provided by the R/L Lighting System and without using guidance from onboard or ground-based devices other than night VFR flight instruments.

If the Subject Pilot lost visual guidance, or was not able to maintain continuous orientation with the R/L Lighting System, he was required to announce this condition to the Observer/Data Recorder in the aircraft. The Subject Pilot was also required to complete the post-flight pilot questionnaire, after termination of the flight, to provide his opinion as to the suitability of the R/L Lighting System in providing the required guidance for approach and landing.

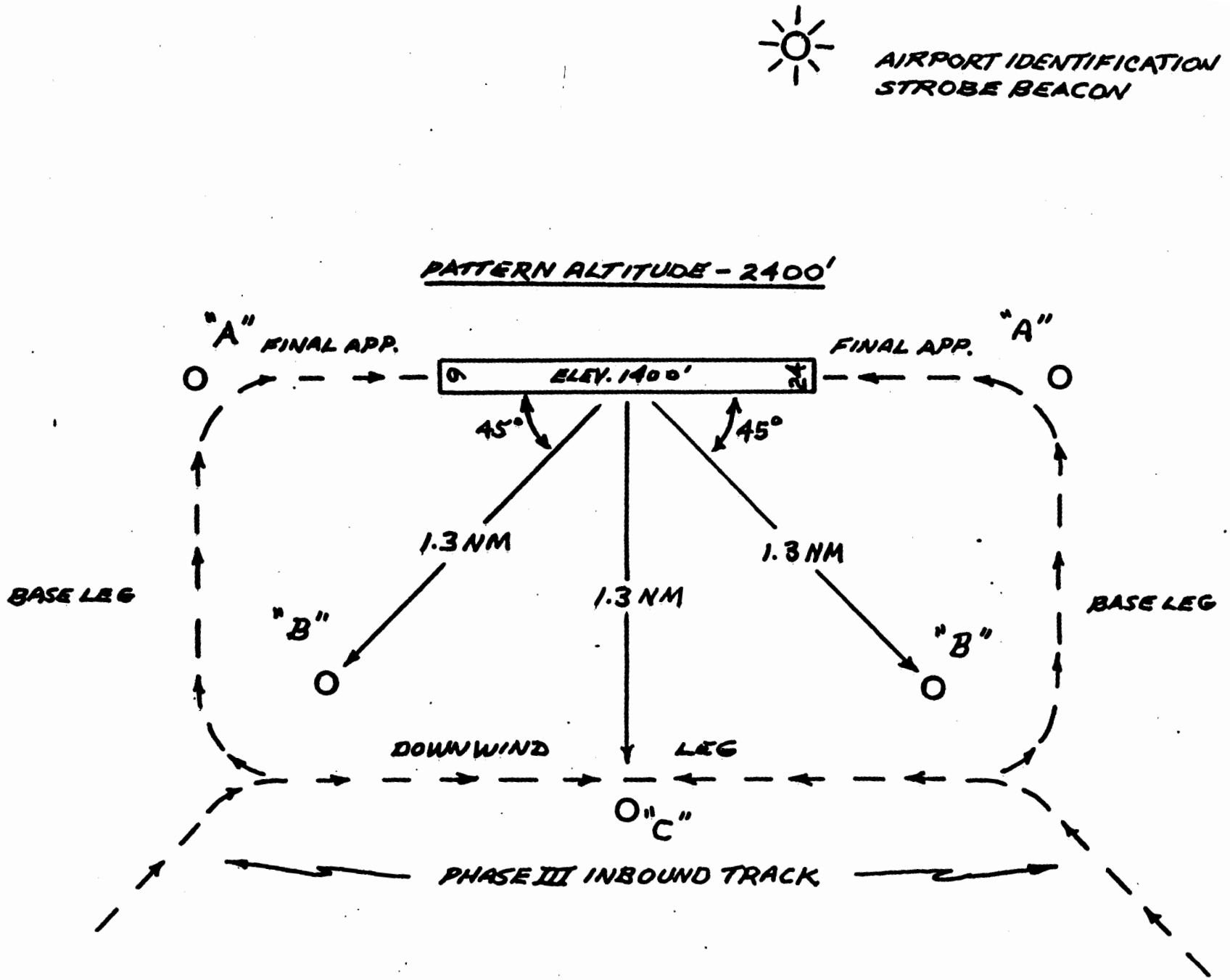

FIGURE 6. PRODEDURE PATTERN AND OBS. POINT DIAGRAM

Phase III

In order to determine the effectiveness of the combined components of the remote runway lighting system; i.e. the Airport Identification Beacon, the Illuminated Wind Direction Indicator, and the R/L Runway Lighting System, the Subject Pilot was required to execute an approach to the runway from a distance of approximately 4 statute miles, determine the appropriate landing direction from the illuminated wind direction indicator, and execute the proper traffic pattern maneuvers to a landing or low approach. The Safety Pilot positioned the aircraft for initiation of this approach at the 4-statute-mile distance and an altitude of 2,000 feet above ground level (AGL). The Observer/Data Recorder and Safety Pilot took note of the manner in which the Subject Pilot was able to accomplish the required tasks and recorded their observations, along with appropriate Subject Pilot comments.

If the Subject Pilot was unable to locate the airport, enter the proper landing pattern, and successfully complete a landing/low approach, or if the Pilot lost visual guidance at any point in the maneuver, the R/L System was to be considered inadequate for the particular Subject Pilot.

TEST RESULTS

The evaluation of the R/L Lighting System was accomplished during the period September 24 to October 2, 1984, at the McWhorter Ranch, immediately adjacent to the Department of Energy Reservation at Richland, Washington. All of the facility, pilot, and equipment requirements were met, with the exception that the specially prepared test strip was of such narrow configuration and short length that landings were not possible. All traffic pattern maneuvers were accomplished as described in the Method of Approach, except that final approaches were terminated at a height of 100 to 200 feet above the runway.

Twenty Subject Pilots completed the three phases of the evaluation, each pilot accomplishing his evaluation during a single flight departing from and returning to the nearby Tri-City Airport at Pasco, Washington. All Subject Pilots held at least Commercial category FAA Pilot Certificates with the appropriate current Medical Certificate and a valid instrument rating. Minimum pilot experience was 1600 flight hours, with the average of all 20 pilot experience levels being 4365 flight hours. Pilot occupational status was as follows:

FAR 135 Air Taxi Pilots	- 12
FAA Flight Standards Pilots	- 4
Corporate Pilots	- 3
NASA/Ames Test Pilot	- 1

Aircraft used for the evaluation flights were leased from Bergstrom Aircraft, Inc., Tri-City Airport, and were of the Category "A" type normally used for air-taxi operations to remote sites. Following is the breakdown of aircraft types and number of pilots involved:

Cessna 172M - N584WA - 16 Subject Pilots
Cessna 206 - N9379Z - 4 Subject Pilots

Weather conditions encountered during the 2-week test period were not of a sufficiently diversified nature to permit evaluation of the R/L Lighting System under

the range of VFR conditions specified in the Criteria; i.e., with atmospheric transmissivity equivalent to 2 to 3 statute miles or more during full moonlit night conditions. In fact, visibilities, as obtained from the nearby Pasco ATC Tower and verified in flight over the test site, were at least 12 miles or more, with the minimum cloud cover at any one time established as 2,300 feet AGL scattered. The lights of the city of Pasco, Washington, at a distance of approximately 23 nautical miles from the site, were clearly visible during each evening's flight activities. In connection with this, it should be noted that the tests were conducted during the only period within which the R/L Lighting System components were available, and thus no other time period, more favorable for the occurrence of lower visibility weather conditions, could have been chosen. Moonlit night conditions were encountered during four of the nine evaluation flight sessions.

In addition to having been afforded a complete preflight briefing concerning the purpose and conduct of the evaluation, all Subject Pilots were given the opportunity to view typical R/L Lighting System components installed on the Bergstrom Aircraft Company ramp area. The purpose of this preview of system components was to insure that the Subject Pilots appreciated the difference in the appearance of R/L lights as compared to conventional lighting system fixtures.

A summary of pilot questionnaires is shown as figures 7A and 7B, and should be referred to for clarification during the test results discussion which follows.

Phase I Test Results - All pilots, with the exception of one, were able to determine correctly, and almost immediately, their orientation with respect to the R/L lighted runway from each of the three test observation points. In the one instance where an incorrect call of "abeam" at the 45-degree point was made, the Subject Pilot shortly thereafter corrected his initial call by noting his correct orientation.

Phase II Test Results - All pilots indicated, in answer to questions 1 and 2, that they had no difficulty in maintaining contact and deriving guidance from the R/L Lighting System while executing the downwind and base leg flight maneuvers within the traffic pattern at a maximum distance of 1.3 nautical miles from the runway. Further, all pilots, except one, indicated, in answer to question 3, that they experienced no difficulty in maintaining proper glidepath and alignment with the runway centerline during the final approach portion of traffic pattern maneuvering. The single dissenting pilot indicated that the guidance derived during this final approach maneuver was not insufficient, but rather only marginal. Even though the approaches were terminated at a point above the runway surface, without landing, 13 of the Subject Pilots answered question 4 affirmatively, indicated that they would anticipate a successful landing and subsequent takeoff had they been allowed to attempt these maneuvers. The remaining seven Subject Pilots did not answer this question, or marked the answer "N/A" (not applicable), since they were not afforded the opportunity to land.

Phase III Test Results - All pilots, with the exception of one, indicated, in answer to questions 1 and 2, that they had no difficulty in locating the airport/runway as identified by the strobe beacon from a distance of approximately 4 statute miles. The single dissenting pilot rated this guidance as "only marginal," but not as insufficient. It should be noted that virtually all Subject Pilots were able to identify the Airport Identification Beacon, during the approach to the test site, while in the vicinity of Richland Airport, a distance of approximately

SUMMARY

PILOT QUESTIONNAIRE AND DATA SHEET

Date: 9/24-10/2/84 Pilot's Name: 20 SUBJECTS Pilot Hours: AVE: 4365

A/C Type: C-206 / C-172 Wx. Observation: MINIMUM 2,300' SCT, 12+ VIS.

Phase I - Aircraft Orientation with Runway (Observer's Data)

R/W ℄	Position "A"	Pilot's Call:	First Run: ALL OK	2d Run: ALL OK
45°	Position "B"	Pilot's Call:	First Run: ALL OK	2d Run: 19 OK / 1 "ABEAM"
ABEAM	Position "C"	Pilot's Call:	First Run: ALL OK	2d Run: ALL OK

Phase II - System effectiveness in displaying runway orientation. (Subject Pilot's Evaluation)

1. While flying the downwind leg of the traffic pattern, were you able to maintain visual contact with the R/L lighting system so as to judge the proper point at which to initiate the turn to base leg?

   YES 20 NO 0 ONLY MARGINALLY 0

2. While on base leg, did the R/L lighting system provide the visual runway alignment guidance necessary for judging correctly the point at which to initiate your turn onto final approach?

   YES 20 NO 0 ONLY MARGINALLY 0

3. During the final portion of the approach, did the R/L lighting system adequately define the outline of the runway so as to permit you to maintain the proper glide path and alignment with the runway centerline?

   YES 19 NO 0 ONLY MARGINALLY 1

4. Did the R/L lighting system provide sufficient runway definition for the flare, landing and takeoff maneuvers?

   YES 13 NO 0 ONLY MARGINALLY 0 NO ANSWER 7

   COMMENTS: SEE REPORT TEXT

FIGURE 7A. PILOT QUESTIONNAIRE SUMMARY (1 of 2 Sheets)

SUMMARY

PILOT QUESTIONNAIRE AND DATA SHEET
(CONTINUED)

Phase III - Visual Approach Procedure (Subject Pilot's Evaluation)

1. From the point at which the visual approach to the airport was started, did the Airport Identification Beacon provide an adequate indication of the airport location?

   YES 19 NO 0 ONLY MARGINALLY 1

2. While overflying the Airport Identification Beacon, were you able to verify the runway orientation (direction) and most appropriate approach direction by reference to the R/L lighting system and illuminated wind direction indicator?

   YES 19 NO 0 ONLY MARGINALLY 1

3. Would you please give your comments on the suitability of the R/L lighting system for use at remote airports under the weather conditions encountered during this flight test session?

   SEE REPORT TEXT

THANK YOU!

FIGURE 7B. PILOT QUESTIONNAIRE SUMMARY (2 of 2 Sheets)

14 statute miles from the site. This fact was noted by the Safety Pilot during the course of each evening's flight activities.

During the conduct of the Phase III approaches to the airport/runway location, the Safety Pilot requested that the Subject Pilot indicate the point at which, during the descending approach to pattern altitude, the Subject Pilot was able to unmistakably identify the runway outline as defined by the runway R/L Lighting System Components. Once this call was made, the Safety Pilot determined the approximate distance for acquisition, through reference to known ground lights, and caused the value to be noted by the Observer/ Data Recorder. Results of this acquisition range determination, obtained while making approaches at a 45-degree angle to the runway orientation, are shown in figure 8. In summary, range for acquisition of the R/L Lighting System on the dark moonless nights averaged 2.1 nautical miles, while for partially moonlit nights the average was reduced to 1.5 nautical miles. This apparent diminishment of range with moonlit conditions can be attributed to the reduction in contrast between the relatively low-intensity R/L lights and the surrounding moonlight illuminated ground surface. Ground reference lights and other reference points were sufficiently distinctive to permit range determinations with an accuracy of plus or minus one-tenth nautical mile. For checkpoints in totally dark areas, battery-powered, low-intensity lights were accurately positioned on the ground prior to each evening's flight activities.

Recorded Subject Pilot Comments - Subject Pilot in-flight comments were tape recorded by the Project Observer/Data Recorder during the course of flight operations in the C-172 aircraft. The following excerpts from the tapes, while not necessarily exact quotes of all pilots, reflect the general nature of the in-flight, spontaneous comments. Noted after each typical comment are the number of pilots expressing essentially the same opinion.

Reflections of cockpit instrument lights on the windscreen reduce the effectiveness of the R/L Lighting System.	(9 Pilots)
Use of landing lights on final approach reduces the effectiveness of the R/L Lighting System.	(7 Pilots)
A Visual Approach Slope Indicator (VASI) would be very helpful. Vertical depth perception (determination of correct glidepath angle) difficult with R/L alone.	(5 Pilots)
Wind Direction Indicator effective, but only when viewed from directly overhead.	(4 Pilots)
R/L lights dimmer on downwind leg than on base or final.	(4 Pilots)
No problem maintaining horizontal alignment on final approach.	(4 Pilots)
Anticipate no problem with completing the landing.	(3 Pilots)

Run #	No Moon Acquisition Range Calls		Moonlight Acquisition Range Calls		Remarks
	1st	2d	1st	2d	
1	1.7	1.8			
2	3.0	3.5			Faint Glow of Lights Only
3					Not recorded in C-206 A/C
4					Tape Recorder Failure
5	1.75	1.75			
6	1.9	1.9			
7	2.25	2.5			Safety Pilot did not see
8					Not recorded in C-206 A/C
9	2.0	2.5			
10	1.8	1.8			
11	2.0	1.95			
12	1.7	1.6			
13			1.6	1.5	3/8 Moon - Clear
14			1.6	1.45	3/8 Moon - Clear
15			1.6	1.75	1/2 Moon - Thin Overcast
16			1.65	1.65	1/2 Moon - Clear
17			1.5	1.3	1/2 Moon - Clear
18			1.5	1.5	2/3 Moon - Clear
19			1.45	1.4	2/3 Moon - Clear
20			1.3	1.3	2/3 Moon - Clear
N.Miles	2.01	2.14	1.53	1.48	Average of recorded values
N.Miles	2.08		1.51		Average for both calls

FIGURE 8. ACQUISTION RANGE DATA TABLE

Wingtip-mounted aircraft strobe lights reduce R/L Lighting System effectiveness.	(3 Pilots)
Approach angle was high due to low intensity of the R/L Lighting System.	(2 Pilots)
System adequate for remote site VFR operations.	(2 Pilots)
Definitely need Airport Identification Beacon to find airport/runway.	(1 Pilot)
Should test system further to full landing.	(1 Pilot)

Subject Pilot Questionnaire Comments - Subject Pilot comments, as recorded by the pilots on the post-flight questionnaire form, are shown below in order to decreasing occurrence. The excerpts, while not necessarily exact quotes of all pilots, reflect the general nature of the written comments.

Noted after each typical comment are the number of pilots expressing essentially the same opinion.

System satisfactory for the weather conditions flown.	(13 Pilots)
Anticipate no problem with completing the landing.	(9 Pilots)
Use of landing lights on final approach reduces the effectiveness of the R/L Lighting System.	(7 Pilots)
There is a need for more testing in marginal VFR weather (2 to 3 miles visibility).	(6 Pilots)
Must fly directly over the Lighted Wind Direction Indicator to use it effectively.	(5 Pilots)
Airport Identification Beacon essential for finding runway/airport location.	(5 Pilots)
A Visual Approach Slope Indicator (VASI) would be most helpful.	(4 Pilots)
Windshield glare, due to instrument reflections, can cause temporary loss of guidance.	(4 Pilots)
High on final glideslope due to relatively low intensity of R/L Lighting System.	(3 Pilots)
Lights harder to see on Downwind than on Base or Final Approach.	(3 Pilots)

High on final due to "Black Hole" effect.	(2 Pilots)
Testing should include landings to "full stop."	(2 Pilots)
Special training will probably be required for user.	(2 Pilots)
Higher level of ambient light could present problems.	(2 Pilots)
Wind Direction Indicator too close to runway lights.	(2 Pilots)
Moonlight decreased effectiveness of R/L Lighting System.	(2 Pilots)
Anticipate no problems with taking off.	(1 Pilot)

Safety Pilot Comments - The author of this report served as a Safety Pilot in the C-172 aircraft during 16 of the 20 flight evaluation sessions and thus had ample opportunity to observe Subject Pilot performance and reaction to the R/L Lighting System evaluation. The following are supplemental comments and observations by the author, and may not necessarily reflect Subject Pilot attitudes or opinions relative to the testing operation.

During Phases II and III a majority of the Subject Pilots assumed higher than normal final approach path angles (glidepath), correcting to less steep angles only during the latter portion of the approach. This would seem to be a result of Subject Pilot misinterpretation of distance from threshold while making the pattern turn from base leg to final approach, with the pilots, in this instance, thinking that they were more distant from the runway than they actually were. The R/L Lighting System is, in fact, of considerably lower intensity than the more conventional airport lighting systems that all pilots are accustomed to, and would give the appearance of being farther away to a pilot drawing on past experience and remembrance of normal airport lighting systems as an aid in determining distance from threshold and rate of closure. The Subject Pilots did, during the course of their flight sessions and as they became more familiar with the unique R/L system presentation, modify their final approach paths to a more conventional, lower angle. The fact that several Subject Pilots expressed the opinion that special training or exposure to the R/L Lighting System would be beneficial seems to support this hypothesis.

The criteria regarding Airport Identification Beacon performance specifies an acquisition range of 10 statute miles, while the Phase III evaluation procedure only afforded the Subject Pilots the opportunity of observing the Beacon from initial approach fixes located approximately 4 to 5 statute miles away. This was a result of procedural restraints imposed by critical terrain obstructions within the test site area. The Safety Pilot did, however, indicate to the Subject Pilot the approximate location of the Airport Identification Beacon while initially inbound to the test site area after departing the Tri-City Airport. In each and every instance, the Subject Pilots were able to identify and maintain contact with the beacon flashes from a point in the vicinity of the Richland Airport, at a range of at least 14 nautical miles (16 statute miles). More than a few Subject Pilots were

able to acquire and identify the beacon at even greater ranges during the approach flight.

The effect of moonlight conditions was rather striking, in that it seemed to reduce the R/L Lighting System effectiveness considerably. Contrast between the low intensity R/L lights and the surrounding moonlight-illuminated light-textured terrain was diminished noticeably, and one cannot help but be concerned over the problem that may be encountered in conducting flight operations at remote sites in the higher latitudes with extensive ground snow coverage.

Many Subject Pilots commented upon the glare or back-scatter effect encountered while using aircraft-mounted landing lights during the final approach. While this condition did diminish the effectiveness of the R/L lights somewhat, it did not seem, at least to the author, to be a critical factor. Most Subject Pilots merely commented that they would "probably leave off the landing lights," and dismissed the issue from further consideration.

CONCLUSIONS

From analysis of the evaluation test results, it is concluded that:

1. The R/L Lighting System provided satisfactory visual guidance under the limited and favorable environmental conditions encountered during the test period.

2. Since no restricted visibility weather conditions less than a 2,300-foot AGL scattered cloud layer and 12 miles or better visibility were encountered during the test period, it is not possible to make a determination of the suitability of the R/L Lighting System for use in lower visibility conditions of 2 to 3 miles as specified in the agreed upon criteria.

3. Due to the nature of the unique light characteristics of the R/L source used with this system, and due to a lack of operational experience with such light sources, it is not possible to extrapolate the results obtained during this evaluation effort to predict system effectiveness under conditions of further reduced visibility.

RECOMMENDATION

The R/L Lighting System should be evaluated further under weather and environmental conditions that include visibility restrictions at the minimum values specified by the criteria and to be anticipated for remote site usage. In addition, the system should be tested under such unique conditions as may be expected to prevail within the area of most probable use; i.e., snow-covered terrain, blowing snow, and bright moonlight.