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Acceptability Testing of Radioluminescent Lights for VFR-Night Air Taxi Operations

G. A. Jensen

January 1985

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Richland, Washington 99352

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SUMMARY

Tritium-powered radioluminescent (RL) lights have been under development by the U.S. Department of Energy (DOE) for remote, austere, and tactical airfield lighting applications where electrical utility or portable power is unavailable or difficult to obtain. Because the technology has promise for use in civilian applications and military operations in Alaska and other similar locations, user organizations such as the U.S. Department of Defense (DOD), the State of Alaska Department of Transportation and Public Facilities (DOT&PF), and others have funded work to meet their specific objectives. In order to plan and coordinate the needs for the various funding organizations, a technical working group (TWG) has been formed using individuals from DOE, DOD, civilian sponsors, Oak Ridge National Laboratory (ORNL), and Pacific Northwest Laboratory (PNL). DOE-Headquarters chairs the TWG.

The State of Alaska has requested appropriate Federal Aviation Administration (FAA) approvals for use of the technology as a safe alternative lighting system to meet the airfield lighting needs of air taxi operations and general aviation in the state. The tests described in this report were performed by PNL for the DOE Defense Byproducts Production and Utilization Program and are a step towards gaining the required approvals.

The specific purpose of the evaluation was to provide a formal initial evaluation of the RL runway lighting system, which could lead to FAA approval for use in nighttime aircraft operations under Part 135 of the Federal Aviation Regulations (FAR). These tests apply only to Part 135 of the FAR, and other tests may be required to meet other parts of the FAR. The results from these tests will also aid in developing the lights for military purposes.

Test work was performed during September and early October 1984 at a selected rural runway near Richland, Washington. FAA and ORNL participation in the test was coordinated by State of Alaska and PNL personnel. The goals of this flight testing were to:

- Further evaluate human factors and other factors affecting the lights and their use.

- Evaluate landing procedures for Category A aircraft using the lights and suggest modifications in existing procedures that could be used by higher performance aircraft. Most aircraft and pilots using the RL system for civilian aviation will be flying smaller, Category A, lower performance aircraft.

All testing was completed under high visibility (10 miles or greater), visual flight rules (VFR) conditions. More testing may be needed at or near VFR minimums (2- to 3-mile visibility) before full approval for use of the lights is obtained.

Test results are quite favorable. All pilots could identify, maintain contact with, and use the runway from a minimum of 1.5 miles during approach and in preparation for landing. Although full-stop or touch-and-go landings were not permitted, most pilots felt that they would have no difficulty landing to the lights. In addition, pilots reported that they could use the lights for runway alignment from distances greater than 2 miles under very dark clear conditions and between 1.5 and 2 miles under 3/8 to 2/3 moonlight and hazy conditions. Some pilots and observers reported visual contact with the runway at 3 to 5 miles along the extended runway centerline and 2 to 2.5 miles when 90° from the runway direction.

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1.0 INTRODUCTION

Tritium-powered radio-luminescent (RL) lights have been under development by the U.S. Department of Energy (DOE) for remote, austere, and tactical air-field lighting applications where electrical utility or portable power is unavailable or difficult to obtain. Because the technology has promise for use in civilian applications and military operations in Alaska and other similar locations,⁽¹⁻⁸⁾ user organizations such as the U.S. Department of Defense (DOD), the State of Alaska Department of Transportation and Public Facilities (DOT&PF), and others have funded work to meet their specific objectives. In order to plan and coordinate the needs for the various funding organizations, a technical working group (TWG) has been formed using individuals from DOE, DOD, civilian sponsors, Oak Ridge National Laboratory (ORNL),^(a) and Pacific Northwest Laboratory (PNL).^(a) DOE-Headquarters chairs the TWG.

The need for a usable low-cost, self-powered lighting system for rural Alaskan runways has been identified;^(1,3,8) and results of demonstrations and tests show that RL lighting can meet this need.^(1-3,8) Thus, the Alaska DOT&PF has requested that the Alaskan Region of the Federal Aviation Administration (FAA) approve^(b) RL runway lighting systems for use for nighttime operations in rural Alaska under Parts 91 and 135 of the Federal Aviation Regulations (FAR). Additionally, similar discussions were held with FAA Headquarters and FAA Technical Center personnel.

The result was a request to the chairman of the TWG for a test, providing that agreement could be reached between the Alaska DOT&PF and the FAA on the criteria for the testing. Possible locations were in Alaska and Richland, Washington. Richland was proposed as a possible site since the work could be performed under the DOE Defense Byproducts Production and Utilization Program, trained PNL personnel were available, the location was central for all possible participants, the rural character resembled Alaska, major airport facilities

(a) ORNL is operated for DOE by Martin Marietta Company. PNL is operated for DOE by Battelle Memorial Institute.

(b) For information on discussions with or correspondence between the State of Alaska DOT&PF and the FAA, contact the Alaska DOT&PF, Facilities Research, Fairbanks, Alaska.

were close to known rural runways, there were longer periods of darkness relative to Alaska during the proposed test period, and logistical requirements could to be met.

Thus, at the request of the TWG, a preliminary plan and cost breakdown was submitted in July 1984 to perform flight testing to establish light performance and determine acquisition distances. This information was needed to demonstrate the acceptability of RL lights to FAA flight standards personnel for meeting Part 135 of the FAR for nighttime air taxi landing operations. The work was performed during September 1984 at a selected rural runway near Richland, Washington. FAA participation in the test was coordinated by State of Alaska and PNL personnel. The authorization for detailed planning was given in September, a final test plan was prepared, and the testing was completed on schedule.

1.1 PURPOSE AND SCOPE OF WORK

Although RL lights have been demonstrated for runway lighting and marking applications, regulatory approval by the FAA for use under various parts of the FAR requires specific flight testing and evaluation.^(a) Therefore, the purpose of the evaluation was to provide a formal initial evaluation of the RL runway lighting system, which could lead to FAA approval for use in nighttime aircraft operations under Part 135 of the FAR. These tests apply only to Part 135 of the FAR, and other testing may be required to fully meet Part 135 as well as other parts of the FAR. The results from these tests could also aid in developing the lights for military purposes. The goals of this flight testing were to:^(b)

- Further evaluate human factors and other factors affecting the lights and their use.
- Evaluate landing procedures for Category A aircraft using the lights and suggest modifications in existing procedures that could be used by higher performance aircraft. Most aircraft and pilots using the RL system for civilian aviation will be flying smaller, Category A, lower performance aircraft.

(a) FAA correspondence from W. T. Breanan, Manager, Air Transportation Division, Office of Flight Operations to L. E. Leonard dated July 10, 1984.

(b) Correspondence from L. E. Leonard, State of Alaska, DOT&PF to T. H. Paprocki, FAA, Atlantic City, New Jersey, dated July 16, 1984.

Thus, the scope of the effort was to develop a procedure for using a RL runway lighting system and determine the suitability of the lights for providing nighttime visual guidance for approach and landing operations to safely support FAR 135 commercial air taxi operations. Specific activities included:

- Coordinate with the State of Alaska and the FAA to develop a procedure for using the system.
- Identify suitable runways and select a site for the tests.
- Ensure that the logistical needs of the test were met.
- Coordinate with FAA Technical Center personnel in Atlantic City, New Jersey, to ensure that sufficient subject pilots and aircraft were available for the test and that other test needs were met.
- Report results as appropriate.

1.2 REPORT ORGANIZATION

The following sections of the report provide a brief background on Alaskan needs for RL lighting, the criteria development and implementation work, a summary of the results of the effort, and recommendations for future work. RL lighting principles and cost advantages of RL runway lighting are described in detail elsewhere⁽¹⁻²³⁾ and will not be repeated here. An FAA report was prepared⁽²⁴⁾ and is a particularly important reference since it includes information tape recorded by those flying in the aircraft that was not supplied to the author who was on the ground for most of the test.

2.0 BACKGROUND

Discussions of the need for self-powered lighting systems in the North and the current strategy for meeting rural Alaskan airfield lighting needs are provided in this section.

2.1 NEED FOR SELF-POWERED LIGHTING

In winter, much of the land- and water-based transportation in Alaska (and the Arctic) becomes impassable. Thus, for much of the North, air transportation becomes the only alternative to meet the needs for goods and services of the significant but widely scattered population. These pockets of habitation exist for a variety of reasons: native American traditions, resource development and exploration, government agency and military requirements, etc. The separation from the greater economic infrastructure of the nation, the extreme environmental conditions, and short winter daylight hours at high latitudes place several limits and demands on personnel, equipment, and systems operating, used, and/or installed in Alaska or other northern locations. In addition, only a small number of existing Alaskan runways are lighted. Thus, commercial air carriers must have more aircraft and pilots to operate during the short daylight hours, which severely restricts their ability to provide safe and timely service.⁽²³⁾ Ground maintenance and operations are affected by the cold; electrical systems and batteries fail; and other means for providing backup airfield lighting in emergency and critical situations are improperly used, adding to the problem of providing safe, reliable air service to the rural population. Efficiency and safety could be significantly improved if civilian airfields were equipped with self-powered lights.

2.2 SYSTEMS

Currently, there are two types of lighting commonly used to aid commercial night operations in Alaska:

- FAA-approved medium-intensity runway lighting (MIRL) or high-intensity runway lighting (HIRL) as described in FAA Advisory Circular

#AC 150/5340-24 - These lighting systems include electric incandescent runway edge and threshold lights, blue taxiway lights, a rotating locator beacon, and a lighted wind direction indicator (wind T).

- flare pots or lanterns for night visual flight rules (VFR) for only nonpassenger-carrying commercial aircraft (Part 91 of the FAR) or under special permission granted a carrier by FAA under Part 135.229 of the FAR if passengers are aboard. This system consists of flare pots or lanterns spaced at 400-ft intervals along both edges of the runway and some means of communicating wind direction information to the pilot.

MIRL and HIRL systems are specified in detail and can only be modified by special waiver from the FAA in Washington, D.C. These systems are costly and difficult to maintain and operate in rural Alaska.^(1,3,8) The use of flare pots and lanterns is interpreted more loosely by the regulators and can be modified within the jurisdiction of a particular region of FAA, such as the Alaska region. There are severe problems related to the use of flare pots or lanterns. These relate to having them correctly placed along the runway for landing operations, personnel willing to place them at all in the severe weather or darkness, and other factors.^(a) RL runway lighting systems should be an attractive alternative for use in the state since they have a modest cost and low maintenance and are self-powered and reliable.⁽¹⁻⁴⁾

2.3 POSSIBLE IMPLEMENTATION STRATEGY

A possible implementation strategy for the RL system use within Alaska is:^(1,8)

- Use of the RL system would begin at selected presently unlighted rural runways as an alternative to flare pots or lanterns under Parts 91 and 135 of the FAR. After a period of time during which satisfactory results are shown and the system proved its worth in Alaska, users would be expected to seek federal approval for RL systems as substitutes for MIRL systems.

(a) Based on personal interviews with air taxi, FAA pilots, and other pilots in Alaska.

- When the RL system has gained full FAA acceptance, the state would accelerate its installation rate at unlighted airports and begin replacement of particularly troublesome electric systems. As existing electric systems reach the practical limit of their life cycles, the state would make further replacements with RL light systems, working toward eventual standardization of the RL lighting system.

The tests and results described in this report are a start to implementing this strategy to ensure safe and reliable runway lighting at rural northern locations.

3.0 CRITERIA DEVELOPMENT AND TEST IMPLEMENTATION

Criteria development and test implementation are discussed in the following paragraphs.

3.1 CRITERIA DEVELOPMENT

Since RL lighting represents a new technology for aircraft runway lighting and marking, criteria needed to be developed for its use so that pilots using the system gain the advantages of the system while not compromising safety. Thus, the Alaska DOT&PF, with the aid of PNL, developed performance criteria based on discussions with the FAA.^(a) The results of this effort are summarized as follows:

1. RL lighting systems will consist of the following components:
 - unitized RL lights (unitized panels, etc.) placed along both sides of the runway beginning at the threshold and located at a maximum of 400-ft intervals ending at the opposite threshold
 - a spatially separated array of unitized RL lights placed along the left-hand edge of the primary approach end of the runway to provide visual glide slope information
 - an electric strobe beacon located a maximum of 1 mile from the runway; an alternating white and green color pattern will flash approximately 15 to 20 flashes per min.
2. Performance criteria:
 - RL edge lights will produce an outline of the runway of sufficient brilliance that a pilot with average visual acuity can positively determine the aircraft's orientation relative to the runway while conducting normal aircraft maneuvering within the airport traffic pattern, including maneuvering to crosswind, downwind, and base legs and circling at a radius and altitude appropriate to the type of air-

(a) Correspondence from L. E. Leonard, State of Alaska, DOT&PF to T. H. Paprocki, FAA, Atlantic City, New Jersey, dated July 16, 1984.

craft that will be operating on the runway as prescribed in FAA's flight training handbook (AC-61-21A). For aircraft with approach speeds of 90 knots or less, a minimum of 1.3 nautical miles (NM) beyond the perimeter of the landing surface is required. The above will apply under any night VFR conditions in which operations are permitted under appropriate FARs. In addition, the illumination shall be sufficient to permit the same pilot to begin and maintain a stabilized final approach immediately upon completion of the base to final turn when following the RL-VFR operational procedure described below (Item 3).

- The RL visual glide slope indicator shall be of sufficient brilliance and clarity to provide a pilot with average visual acuity a visual indication of the aircraft's adherence to the glide slope appropriate for the terrain^(a) (normally 3°) beginning not less than 1 statute mile from the threshold during a stabilized final approach. This requirement shall be valid for any night VFR condition permitted under the appropriate FARs.
- A locator beacon will be mounted so that it is clearly visible within a minimum of 10 miles radius of the airport to an aircraft flying at an altitude of 5000 ft above ground level (AGL) during a night VFR condition where the visibility is 10 statute miles or more.

3. When operating at an airport equipped with an RL runway lighting system under night VFR conditions, the following flight procedure will be followed:

- The pilot will navigate to the vicinity of the airport by whatever means are at his disposal.
- Upon approaching the vicinity of the airport, the pilot will attempt to identify the locator beacon, which will be distinguishable by alternate white and green flashes. The pilot will fly a course intended to overhead the beacon while initiating a preliminary descent at a rate appropriate to the terrain and intended to achieve approximately 800 ft AGL upon arrival at the beacon.

(a) This may not be possible where mountains or similar terrain variations are close to the airport.

- Upon approaching the beacon, the pilot will identify the runway and its orientation by the RL edge lights. The pilot will continue to fly to the beacon overheading the airport and maneuvering the aircraft to enter the appropriate downwind leg^(a) of a normal VFR traffic pattern. Continuing downwind, the pilot will begin to turn base leg at approximately a 45° angle from the end of the runway. A descent should be initiated at the beginning of the turn to base continuing in a normal VFR traffic pattern and turning to a final approach intended to intersect an extended runway centerline at approximately 450 ft AGL and assuming a stabilized approach to a landing with aid of the RL visual glide slope indicator as required.
- If the pilot is unfamiliar with the airport, he should adjust the procedure described above as follows. The pilot will initiate a preliminary descent intended to overhead the beacon at an altitude of 1500 to 2000 ft AGL. At this point, the pilot will identify the runway and proceed to enter the normal VFR traffic pattern, circling the airport while descending to approximately 800 ft AGL, entering the appropriate downwind leg, and proceeding as above.^(b)

For the test and evaluation, the minimum acceptable criteria for the RL lighting system were modified from those above as follows:

-
- (a) The appropriate downwind leg will be determined by a lighted wind indicator or direct radio communication with observers on the ground. The pilot is also advised to use the overhead of the airport and the downwind leg to look carefully at the landing surface in an attempt to identify any hazardous obstructions that are sometimes encountered on remote airports.
 - (b) The RL lights are of low intensity and not intended to provide positive visual reference beyond the limits of a normal traffic pattern (1.3 miles beyond the perimeter of the landing zone), although they may be visible at much greater distances under favorable conditions. The locator beacon is intended to be the only visual navigational reference outside the normal traffic pattern boundary. Thus, the pilot is advised to always use the system as per the above procedure, noting the positional relationship of the aircraft, beacon, and runway during all operations. If, while maneuvering in the airport vicinity, the pilot is required to operate outside the normal traffic pattern boundary (for example, to accommodate other traffic), the correct procedure requires that an approach to the beacon again be initiated, entering the pattern as described above.

- The RL lighting system must be of sufficient luminescence to provide immediate recognition of the aircraft's orientation with respect to the runway while maneuvering at 1000 ft AGL at all points in the runway traffic pattern within a distance of 1.3 nautical miles of the runway. Once seen, the RL runway and threshold lights must provide this immediate recognition throughout the airport traffic pattern and approach. The mere detection of a light source that would indicate the presence of a runway without recognition of the runway orientation is not acceptable.
- The RL 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.
- The system must include a low-powered airport identification beacon located within 5000 ft of the runway and of sufficient intensity to permit identification of the runway/airport location at a distance of 10 statute miles in unlimited visibility conditions.
- The system must include an illuminated wind direction indicator capable of providing wind direction information to a pilot overflying the runway at pattern altitude.

While the 1.3-knot distance criterion described above has been developed for Category A aircraft,^(a) the lighting system could be adapted to larger higher performance aircraft once more experience with the system is available. On the basis of the above criteria, a test procedure was developed by FAA Technical Center personnel in coordination with PNL and State of Alaska DOT&PF.

The test procedure consisted of three phases. Each phase was completed twice for a left- and right-landing pattern. In Phase I, the subject pilots were flown to three locations 1.3 miles away from the runway. At each location, they were told the general location of the runway and the safety pilot asked if they could clearly see the runway and to point to its location.

(a) Category A aircraft are the primary aircraft used by air taxi operations in Alaska.

In Phase II, the pilots were located at a flight path parallel to the runway centerline (downwind leg) and given control of the aircraft. The safety pilot then directed the subject pilot to complete the approach to the runway and make a low flyover to demonstrate that he had the required alignment and position for landing. In Phase III, the safety pilot flew the aircraft to a location between 4 and 5 miles from the airport. The subject pilot was then given control of the aircraft and asked to locate the airfield using a battery-powered strobe (Figure 1) placed approximately 1 mile north of the runway. The pilot then overflew the runway, located the wind T and identified the direction it was pointing, and made the appropriate downwind, base, and final low approach. Touch-and-go and full-stop landings were not required. Each pilot filled out a questionnaire and added comments at the end of the test.^(a)

The pilot selection criteria were based on having subjects with air taxi qualifications and experience. Thus, pilots were required to have a minimum of 500 h flying time, an instrument rating, and a commercial rating. Twenty pilots having these qualifications participated, including FAA flight standards personnel, a NASA test pilot, volunteers from the flight service supplying the aircraft, and several local pilots. Locally available Cessna 206 and 172 aircraft were chosen for the tests because they are typical aircraft used for air taxi operations.

3.2 TEST IMPLEMENTATION

After considering several sites, a dirt strip near Benton City, Washington, was selected and mutually agreed to by the PNL test director and the FAA test supervisor (Figure 2). The site was chosen because it was: 1) located in a relatively remote area, free from significant concentrations of ambient light sources; 2) located in an open field with the same terrain and foliage as the area surrounding the test landing surface; and 3) located close to (within approximately 25 miles) the major community from which the subject pilots and aircraft resources could be drawn.

(a) A more detailed discussion of this procedure is presented in Reference 24.

FIGURE 1. Strobes Used for Evaluations Near Benton City, Washington

FIGURE 2. Site of Federal Aviation Administration Test

The 2100-ft runway was configured as shown in Figure 3. Incandescent 1.3-mile markers were placed as needed for distance identification (Figure 2). The runway was shorter and narrower than identified in the FAA test plan; however, the contrast between the landing surface and the surrounding area were such that lights were needed to define the runway. Since touch-and-go and full-stop landings were not permitted, this difference was of minimal concern. Six RL lighting panels using the newer tritium tube design developed by ORNL during 1983^(1,2,7) were mounted in newly designed edge light support fixtures (Figures 4 and 5). This fixture design was evaluated in static tests on the Arid Lands Ecological (ALE) Site on DOE's Hanford reservation and was found to provide superior illumination than those designed for earlier Alaskan testing.^(1-3,8) The thresholds were constructed using 14 RL light panels mounted in a mixture of the edge light fixtures and those designed and used in Alaska (Figure 6). A lighted wind T (wind direction indicator) consisted of 12 RL light panels mounted horizontally on a T-shaped channel (Figure 7). The

FIGURE 3. Flight Test Runway

FIGURE 4. Radioluminescent Lighting Panel

FIGURE 5. Edge Lighting Fixture

FIGURE 6. Threshold Configuration at East End of Test Runway

FIGURE 7. RL-Lighted Wind Direction Indicator

T-shaped channel was free to turn in the direction of the prevailing wind and resembles a small airplane whose alignment indicates the required landing direction.

Flight testing was initiated September 27 and completed October 3, 1984. The night of October 3 was reserved for video and photographic documentation, evaluation of the visual glide slope indicator, and some flight tests to identify maximum acquisition (where the runway could first be seen) distance. The system was then disassembled and returned to ORNL on schedule.

4.0 TEST RESULTS AND DISCUSSION

Additional details of the test results are documented in the FAA report.⁽²⁴⁾ This section is limited to a brief discussion and summary of the results.

4.1 TEST RESULTS

Twenty pilots participated in these tests. Each pilot departed from and returned to the Tri-Cities Airport at Pasco, Washington. Each subject pilot was accompanied by the FAA test supervisor and an FAA observer when the Cessna 172 aircraft was used and by an FAA flight standards pilot, an FAA observer, and others observing the test when the Cessna 206 aircraft was used. The FAA test supervisor and flight standards pilots were also the safety pilots and in command of the aircraft. All subject pilots held at least a commercial category FAA pilot certificate, current medical certificates, and valid instrument ratings. In addition, the average experience level of all 20 pilots was 4365 flight hours; minimum pilot experience was 1600 flight hours. All pilots were briefed on the test procedure and the evaluation needs and given an opportunity to view several lights installed on the ramp at the Tri-Cities Airport. This procedure was followed to ensure that the pilots understood the test procedure and appreciated the difference in appearance of the RL lights as compared with conventional lights.

Pilot responses to Phase I, II, and III portions of the test are summarized in a sample pilot questionnaire (Figure 8). With one exception, in Phase I, all pilots correctly identified their location relative to the airfield. The one pilot corrected his initial call after noting his correct position. In Phase II, all pilots said they had no difficulty maintaining visual contact and guidance with the runway on the downwind and base of the approach at a minimum of 1.3 nautical miles away from the runway. One pilot reported that the RL system only marginally defined the runway outline to permit proper alignment and guide path on final approach but commented that it "may take a little time to get used to dimmer lights." All other pilots responded to Phase II Question 3 affirmatively, indicating that they experienced no difficulty in maintaining proper glide path and alignment with the

Date: 9/24 - 10/2/84 Pilot's Name: 20 Pilots Pilot Hours: Avg: 4365
Cessna 206
 A/C Type: Cessna 172 Wx. Observation: Clear, 12 Statute Miles +

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

Runway c	Position "A"	Pilot's Call:	First Run: <u>20 ok</u>	2d Run: <u>20 ok</u>
				<u>19 ok</u>
45	Position "B"	Pilot's Call:	First Run: <u>20 ok</u>	2d Run: <u>1 Abeam</u>
90 Abeam	Position "C"	Pilot's Call:	First Run: <u>20 ok</u>	2d Run: <u>20 ok</u>

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

- 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 ONLY marginally
 - 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 ONLY marginally
 - 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 ONLY marginally 1
 - Did the R/L lighting system provide sufficient runway definition for the flare, landing and takeoff maneuvers?
 YES 13 NO ONLY marginally No Answer 7
- COMMENTS: See Text
- _____
- _____
- _____

(Continued over)

FIGURE 8. Pilot Questionnaire and Data Sheet

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 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 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 Text

THANK YOU!

FIGURE 8. (Continued)

runway centerline during the final approach. The responses to the Phase III questions were similar to Phase II. No problems were experienced in locating the airstrip and maneuvering to a final approach. One pilot rated the strobe beacon as marginal but stated that it "could be located closer to the runway (otherwise, yes)." However, all pilots could identify the strobe beacon during their approach to the test site as they passed Richland, 14 statute miles from the site. All pilots indicated in their comments or responses that they believed they could have safely landed; 13 pilots answered "yes" to

Phase II Question 4, 5 pilots responded "N/A," and 2 chose not to respond. Several pilots indicated that they were "high" or the runway seemed further away on final approach than it really was. All commented that once they became used to the system, this would not present a problem. All pilots correctly identified the landing direction as indicated by the wind T. Ground personnel randomly aligned the wind T for either a west or east approach. Several pilots expressed that "they needed to be directly over the wind T or it was not definitive."

In order to identify usable acquisition distance, the safety pilot requested that the subject pilots unmistakably identify the runway outline as defined by the RL system. This determination was made while making approaches at a 45° angle to the runway and ranged from 1.5 nautical miles on bright moonlit nights to 2.0 nautical miles when the moon was dark. Comments and concerns that the subject pilots expressed on the questionnaires are found in Table I. The statements reflect the general nature of the written comments but are not exact quotations. The number of pilots expressing a concern or comment is also shown. Pilot comments or concerns were also recorded by the FAA observer in the aircraft.⁽²⁴⁾

Weather conditions during the test period were at least 12 miles visibility and, with two exceptions, clear. The two exceptions were September 29, when there was a thin overcast and some haze, and September 30, when the overcast was gone but the haze persisted. However, Pasco, Washington, 23 miles away, was still visible. The moon became a factor on September 29 when it reached 3/8 moon; it reached 2/3 moon by the end of the test period. Thus, in this test, we were not able to evaluate the RL lights under the minimum specified criteria (with a minimum prevailing visibility of 2 to 3 statute miles).

Some pilots and observers reported visual contact^(a) with the runway at 3 to 3.5 miles along the runway centerline and 2 to 2.5 miles at a 90° angle (abeam) from the runway direction. In one case, U.S. Army personnel in a UH-1 helicopter visiting the test site reported visual contact with the runway over Benton City, 5 miles away from the site.

(a) Visual contact or acquisition is defined as when an individual first sees a glow from the RL system.

TABLE 1. Pilot Concerns or Comments

<u>Concern or Comment</u>	<u>Pilots Responding</u>
System was satisfactory in the weather conditions flown	13
Anticipated no problems with completing the landing	9
Use of landing lights on final approach reduces the effectiveness of the RL lighting system	7
There is a need for more testing in marginal VFR weather (2 to 3 miles visibility)	6
Must fly directly over the lighted wind direction indicator to use it effectively	5
Airport identification beacon essential for finding runway/airport location	5
A visual approach slope indicator would be most helpful	4
Windshield glare, due to instrument reflections, can cause temporary loss of guidance	4
High on final glide slope due to relatively low intensity of RL lighting system and "black hole" effect	2-3
Lights harder to see on downwind than on base or final approach	3
Testing should include landings to full stop	2
Special training will probably be required for user	2
Higher level of ambient light could present problems	2
Wind direction indicator too close to runway lights	2
Moonlight decreases effectiveness of RL lighting system	2
Anticipated no problems with taking off	1

4.2 DISCUSSION

All pilots could identify, maintain contact with, and use the runway from 1.5 miles or greater during approach; and most felt they could have landed. In addition, pilots reported that they could use the lights for runway alignment from distances of 2 miles under very dark clear conditions and between 1.5 and 2 miles under 3/8 to 2/3 moonlight and hazy conditions. Some pilots and observers reported visual contact with the runway at 3 to 3.5 miles along the extended runway centerline and 2 to 2.5 miles when 90° from the runway direction. Visual contact was measured during approaches from east to west or while flying parallel to and south of the runway centerline. Other points include:

- The use of extra edge lights may be more effective than increasing the light emission from the threshold area.
- A navigational aid, such as a strobe light, is needed to lead civilian pilots to the airfield. Once the pilot is in the vicinity of the airfield, the RL lights are a good landing aid.
- FAA flight standards pilots evaluating the lights felt that they could be used for Part 135 FAR operation.
- The lights worked well under the weather conditions of the tests.
- A visual glide slope indicator was requested by pilots.
- Pilot vision and/or training may be an important factor and may account for the variation in visual contact, usable acquisition distances, and the high approach reported by several pilots.
- Improvement in the wind direction indicator was requested by pilots.

FIGURE 9. Possible Visual Glide Slope Indicators

Figure 1: Graph of a function with a shaded region.

Figure 2: Graph of a function with a shaded region.

5.0 RECDMMENDATIONS

The following recommendations resulted from the data and other information obtained during this test and evaluation. Additional recommendations and program needs have been identified elsewhere^(1,3,7,8) and will only be repeated here when pertinent or where clarification is required:

- Although the RL lights worked well under the atmospheric conditions encountered during the test, more flight testing will probably be needed under other weather conditions that approach the minimum VFR criteria of 2 to 3 miles visibility (fog, rain, snow, etc.) before unqualified FAA approvals under Parts 135 and 91 FAR are given.
- To accomplish the above, a rural RL-lighted runway is needed for further testing to take advantage of local minimal visibility conditions when they exist. This runway could be in Alaska, near Richland, Washington, or at another location in the contiguous 48 states. The runway should be located close to a major airport facility having appropriate instrument navigational aids to allow the test aircraft to go to and from the test site. However, it needs to be far enough away from cities or towns so that ambient light is not a significant factor.
- Further development and evaluations of candidate visual glide slope indicators are needed (Figure 9). Previous evaluations⁽⁸⁾ have shown that the top hat configuration is of minimal value, but an L-shaped configuration has shown promise (Figure 9). Further work in this area is needed.
- The intensity of the lights needs to be increased as much as possible. Better phosphors, enhanced reflector designs, and more efficient tube designs are all needed.
- The wind direction indicator should be improved. The basic design appears reasonable, but the intensity of the light output needs to be increased.

effort should be done in a static mode prior to flight testing to ensure that a knowledge base for using the light produced is established.

- The human factors evaluation should be accompanied by instrumental measurements to ensure that the human factors versus physical relationship is identified. These comparative data may be useful to designers who have to extrapolate to other meteorological conditions and provide suitable parameters for engineering designs for different locations and climates.
- The test criteria and procedure developed for this test worked well and should be used as a model for further testing involving Category A or higher performance aircraft.

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