ACCEPTABILITY TESTING OF RADIOLUMINESCENT 
LIGHTS FOR VFR-NIGHT AIR TAXI OPERATIONS

by

G. A. Jensen
Pacific Northwest Laboratory
Richland, Washington 99352

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DIVISION OF PLANNING
RESEARCH SECTION
2301 Peger Road
Fairbanks, Alaska 99701-6394

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Leroy Leonard  
Chief of Energy and Buildings Research, State of Alaska Department of Transportation and Public Facilities

Karl Haff  
Program Manager, Radioisotope Development and Applications, Oak Ridge National Laboratory, Oak Ridge, Tennessee

Tom Hardy  
Project Officer, Air Force Engineering and Service Center, Tyndall Air Force Base, Florida
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.
IMPLEMENTATION STATEMENT

Following the results of the FAA evaluations described in this report, plans were immediately undertaken to move forward with the installation of the first permanent RL runway lighting system. At this writing, these plans are still being finalized and therefore can not be described in detail here. However, the highlights of this continuation of the RL lighting development work by the DOT&PF Research Section are as follows:

- Secure a set of lights from the U.S. Department of Energy which will be permanently dedicated to the DOT&PF in Alaska.
- Install the lights at a State operated airport in Alaska where there is an identifiable need.
- During the autumn and winter of 1985-1986, conduct further tests and evaluations as a joint effort with the FAA to finalize the approvals and necessary policy for Part 135 FAR.
- Continue to work on a cooperative basis with the U.S. Department of Energy to resolve the remaining issues of product improvement, product licensing, and the technology transfer to industry.

Throughout the next year, these tasks will be addressed; and it is anticipated that when and if they are complete, the job of implementing the RL system into the State's aviation system will be effectively accomplished.

Leroy E. Leonard
Facilities Research Manager
Alaska DOT&PF
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1.0 *INTRODUCTION*

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 need for a usable low-cost, self-powered lighting system for rural Alaskan runways has been identified, and results of demonstrations and tests show that RL lighting can meet this need. Thus, the Alaska DOT&PF has requested that the Alaskan Region of the Federal Aviation Administration (FAA) approve 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

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(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.

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. 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.

- 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 unlit 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-

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, 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 hours 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

![Diagram of Flight Test Runway](image)

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

<table>
<thead>
<tr>
<th>Runway c</th>
<th>Position</th>
<th>Pilot's Call</th>
<th>1st Run</th>
<th>2nd Run</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>&quot;A&quot;</td>
<td></td>
<td>20 ok</td>
<td>20 ok</td>
</tr>
<tr>
<td>90</td>
<td>&quot;B&quot;</td>
<td></td>
<td>20 ok</td>
<td>19 ok</td>
</tr>
<tr>
<td>90</td>
<td>&quot;C&quot;</td>
<td></td>
<td>20 ok</td>
<td>20 ok</td>
</tr>
</tbody>
</table>

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

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

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

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.
- More human factors evaluation work is needed to understand the possible effects of diminished acquisition, both visual contact and usable acquisition, under varying meteorological conditions. Much of this 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.
REFERENCES


APPENDIX A

PROJECT TEST PLAN
RL AIRFIELD LIGHT TESTING

G. A. Jensen
Technical Working Group Test Supervisor

TEST PLAN

Hanford, Washington
1984

Purpose: The purpose of these tests is to provide a formal initial evaluation of the RL runway lighting system, which could lead to approval by the FAA for use for nighttime aircraft operations under Part 135 of the Federal Aviation Regulations. The results from this test are also needed for military purposes as well.

Rationale: Previous work has largely involved the demonstration of the RL lighting systems to potential military and civilian users. Some test and evaluation work has been completed during these demonstrations, but much more is required before the FAA or other regulatory organizations can be expected to give formal approval for the system's early use to proceed to further full development and technology transfer.

Goals:

1) Evaluate the human and other factors affecting the lights and their use. Specifically, for this test, the usefulness of the navigation and landing aid system will be evaluated using a specific configuration.

2) Evaluate a procedure or procedures for landing to the lights that may involve modifications for changes in existing criteria used for high-performance aircraft. Most aircraft and pilots using the RL system for civilian aviation will be flying smaller lower performance aircraft.

Procedure: The following sections outline the procedure to be used during testing of the lights. Safety and security plans developed for previous tests have been modified in accordance with the testing to be conducted in this work.

Flight Tests: Flight tests will be conducted in accordance with Attachment A. Attachment A was developed by FAA flight test personnel stationed at the FAA test center, Atlantic City, N.J., with input from State of Alaska and PNL personnel. This test plan has the approval of FAA headquarters in Washington, D.C. As shown in the test plan, low approach flyovers will be made but not touch and go or landings to a final stop. Emergency landing to a final stop may be required for safety and provisions will be made to ensure that a reasonably safe landing can be made. A rented aircraft, Cessna 206, 185 or equivalent, will be used in these tests.
Airstrip Location: Several landing strips have been identified and evaluated for suitability for the test work. Locations include the abandoned Old Hanford airport, an airstrip 2 miles west of the Yakima Gate on the Hanford reservation, an airfield on the Yakima Firing Range, and an airstrip located on the McWhorter ranch on the south side of Rattlesnake Ridge. These locations are identified on the map in Attachment B. Each airfield was evaluated for flying hazards, landing surface, light system security needs, distance from Richland, logistical needs, general safety, radiation protection, and overall DOE security requirements based on the requirements identified in Attachment A. The Old Hanford Airport, considered as the first choice initially, was dropped when DOE-RL requested that the tests be conducted outside the boundaries identified for the proposed Hanford reservation restricted area. The four airfields were rated on a point scoring basis of 1 to 5 with 1 being best and 5 being worst. Thus, the airfield having the lowest scoring will be the most desirable for the test. As seen from Table 1 (Attachment B), the Old Hanford airfield, even having a high point scoring for Hanford Security, rates as first choice. However, the McWhorter site is acceptable, offsite, it is fenced and locked private property, and rates second. Thus, per our recommendation and since the FAA test supervisor agrees, it will be used, because touch-and-go or full-stop landings will not be required. A contract for use of the airfield with appropriate liability coverage will be in force for the duration of the test.

Pilot Selection and Criteria: A FAA check pilot will fly in the copilot seat at all times and will act as aircraft commander. The test subject will fly the aircraft in the left seat as pilot and will fly the aircraft. Selected passengers may also be in the aircraft. The test subject (pilot) will have to have a commercial pilot and instrument rating and 500 hours of flying time as a minimum. We hope to use as many volunteers as possible during the evaluations and will provide appropriate insurance coverage under the aircraft rental agreement. FAA and other government employees or their contractors on assignment are covered by their respective agencies or contractors.

Ground Personnel: Principal ground personnel involved in the testing have participated in all previous demonstrations of the lights and are familiar with the overall deployment, test, and evaluation procedures. We expect visitors to be present as observers during these tests and all visitors will be briefed on safety and security needs at the site. Preliminary evaluations at the ALE site prior to flight tests will be conducted using procedures established in May 1984 for static testing and during deployment. During aircraft operation, safety and security procedures identified in previous work will apply.

Safety and Security: See Attachments D and E for plans.
Schedule:

August 27 - Ground testing to establish status acquisition distance of the
September 20: landing aid configurations. Also establish logistical and
other requirements, resolve problems. Sufficient lights are
available for ground test.

September 12: Receive full set of lights from ORNL.

September 13- Prepare airstrip for test.
September 20:

September 20 and 21: Set up airfield for flight tests and establish distance marking
procedures. Handle ground needs.

September 24- Flight testing.
October 5:

October 1-3: Prepare lights and equipment for shipment back to ORNL for
military tests this winter.

October 4: Ship lights.

There are reporting and other follow-up actions that will be
required during FY 1985. A draft report will be prepared and
issued for comment by the end of January 1985.
ATTACHMENT A

FAA FLIGHT TEST PLAN
PROJECT TEST PLAN

PURPOSE
The purpose of this evaluation is to determine the suitability of a prototype Radio-Luminescent (R/L) Lighting System for providing night-time 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.

CRITERIA
The minimums that the R/L system must meet in order to be accepted for FAA approval have been established as follows:

1. The R/L Lighting System must be capable of providing an acceptable definition of the runway of sufficient brilliance on a full moonlit night so that a pilot can immediately determine the aircraft's orientation relative to the runway while conducting normal aircraft maneuvering in the airport traffic pattern within a distance of 1.3 nautical miles without the assistance of other devices or aids. This would include: maneuvering to crosswind, downwind, and base legs.

2. The system must include a low-powered airport identification beacon within 5,000 feet of the landing area and of sufficient intensity to identify the general runway location at a distance of 10 statute miles in visibility conditions equivalent to 10 statute miles or more.
3. The system must include an illuminated wind direction indicator capable of providing wind direction information to a pilot over-flying the runway at pattern altitude.

4. The foregoing performance criteria for R/L Lighting Systems would apply with the atmospheric transmissivity equivalent to 2 to 3 statute miles or more during full moonlight night conditions.

FACILITY, PILOT, AND EQUIPMENT REQUIREMENTS

The prototype R/L Lighting System equipment and components will be installed at a mutually agreed upon test site by the U.S. Department of Energy. The test site airport should have 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 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 will be of a type usually utilized in 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 will be required for project coordination and communication with the ground support personnel.

**METHOD OF APPROACH**

The flight evaluation effort will include three separate but related phases to be accomplished during each flight test session. Minimum flight crew will include 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 will be designated as shown on attached Figure 1. The Safety Pilot will position the aircraft at each of these locations and indicate 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 will be
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" must be made within 2 or 3 seconds after the runway direction is provided to the subject Pilot to verify that the visual guidance provided by the lighting system is self-apparent and unambiguous.

The project Observer/Data Recorder will note 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 will position the aircraft for entry into a downwind leg at a distance of 1.3 nautical miles from the runway centerline. The subject Pilot will then be required to fly the aircraft through the downwind, base leg and final approach portion of the traffic pattern, to either a low approach or landing, 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.

Should the subject Pilot lose visual guidance, or not be able to maintain continuous orientation with the R/L Lighting System, he will be required
to announce this condition to the Observer/Data Recorder in the aircraft. The subject Pilot will also be 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.

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 will be required to execute an approach to the runway from a distance of 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 will position 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 will take note of the manner in which the Subject Pilot is able to accomplish the required tasks and record their observations, along with appropriate subject Pilot comments, on the questionnaire form.

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

Recorded data and contents of the pilot questionnaire responses will be analyzed at the FAA Technical Center, subsequent to the conduct of the flight tests, to determine the extent to which the R/L Lighting System meets the established criteria. The Visual Guidance Section, FAA Technical Center, will then publish a Technical Center Technical Note Report describing the results of the evaluation effort and drawing conclusions from the data analysis. This information will be provided to the office of Flight Operations as sponsor of the project.
PILOT QUESTIONNAIRE AND DATA SHEET

Date: ___________ Pilot's Name: ________________ Pilot Hours: ___________
A/C Type: ___________ Wx. Observation: ________________________________

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

Position "A"  Pilot's Call:  First Run: _______  2d Run: _______
Position "B"  Pilot's Call:  First Run: _______  2d Run: _______
Position "C"  Pilot's Call:  First Run: _______  2d Run: _______

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 _______  NO _______  ONLY MARGINALY _______

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 _______  NO _______  ONLY MARGINALY _______

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 _______  NO _______  ONLY MARGINALY _______

4. Did the R/L lighting system provide sufficient runway definition for the flare, landing and takeoff maneuvers?
   YES _______  NO _______  ONLY MARGINALY _______

COMMENTS: ________________________________________________________
______________________________________________________________
______________________________________________________________
______________________________________________________________

A.12
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_______ NO_______ ONLY MARGINALLY_______

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_______ NO_______ ONLY MARGINALLY_______

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?

_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________
_________________________________________________________________

THANK YOU!
ATTACHMENT B
AIRFIELDS AND RATINGS
<table>
<thead>
<tr>
<th>McWhorter (Private)</th>
<th>Score</th>
<th>Old Hanford (Government)</th>
<th>Score</th>
<th>West Gate (Government)</th>
<th>Score</th>
<th>Yakima Firing Range (Government)</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flying hazards explanation</td>
<td>Ridge to North 2 mi, 500 ft above airfield, parallel to runway</td>
<td>2</td>
<td>Ridge to West 1 to 2 mi, parallel to runway</td>
<td>2</td>
<td>Small ridges 3 to 4 mi either side of runway, telephone line 1/2 mi</td>
<td>3</td>
<td>2000 ft ridge 4 mi to South, 1500 ft ridge 1-1/2 mi to North</td>
</tr>
<tr>
<td>Runway surface</td>
<td>Dirt, needs weed removal</td>
<td>3</td>
<td>Old emulsion, needs weed removal</td>
<td>2</td>
<td>Dirt, needs brush and weed removal</td>
<td>3</td>
<td>Asphalt</td>
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<tr>
<td>Light security</td>
<td>Private land, remote</td>
<td>2</td>
<td>Government land, remote</td>
<td>1</td>
<td>Government land, near road</td>
<td>5</td>
<td>Government land, remote</td>
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<tr>
<td>Distance, mi</td>
<td>16</td>
<td>1</td>
<td>19</td>
<td>1</td>
<td>28</td>
<td>3</td>
<td>60</td>
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<tr>
<td>Logistical needs</td>
<td>Close, easily accessible, in use rent</td>
<td>3</td>
<td>Close, onsite</td>
<td>1</td>
<td>No access road, fairly long distance, no support facilities</td>
<td>5</td>
<td>Long distance, but good support facilities</td>
</tr>
<tr>
<td>Radiation protection</td>
<td>Offsite but close</td>
<td>2</td>
<td>Onsite</td>
<td>1</td>
<td>Onsite but distant</td>
<td>3</td>
<td>Army needs to be contacted</td>
</tr>
<tr>
<td>General safety</td>
<td>Good access, close to town in case of accident</td>
<td>2</td>
<td>Good access, close to town in case of accident</td>
<td>1</td>
<td>Poor access, more distant in case of accident</td>
<td>4</td>
<td>Good access, close to Yakima in case of accident</td>
</tr>
<tr>
<td>Hanford security</td>
<td>No problem</td>
<td>1</td>
<td>Onsite, in proposed restricted area</td>
<td>4</td>
<td>Onsite, outside proposed restricted area</td>
<td>3</td>
<td>Army</td>
</tr>
<tr>
<td>Total scores</td>
<td></td>
<td>16</td>
<td></td>
<td></td>
<td></td>
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<td>Order of preference</td>
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<td></td>
<td>1</td>
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</tbody>
</table>
ATTACHMENT C

RADIOLUMINESCENT LIGHT PROGRAM

SAFETY PLAN

1. Purpose. The purpose of the safety plan is to anticipate both general and radiological accidents thus reducing, controlling, and eliminating hazardous conditions during evaluations and tests of radioluminescent lights. Before ground installation and air operations can begin at the test site, approval must be granted from the Technical Working Group (TWG) Test Director, the Airfield Manager, and the PNL custodian of the tritium.

2. Overall Safety Responsibility. The Test Director or designated TWG supervisor is responsible for enforcing the overall safety program for the test. The Airfield Manager or his designated representative is the Safety Officer during all air operations. The TWG Test Director or designated TWG supervisor is the Safety Officer for all other events at the test site. The TWG Test Director or designated TWG supervisor will maintain close coordination with the Airfield Manager on all safety matters. Dr. G. A. Jensen from PNL has the custodial responsibility for the tritium lights while they are in PNL custody. Mr. Carl W. Haff has custodial responsibility for the tritium lights while they are in ORNL custody.

3. Safety Areas. The safety requirements of the test have been divided into two separate areas:
   a. General Safety
   b. Radiological Safety

4. General Safety. The responsibility for general site safety resides with the Airfield Manager. The authority to execute specific safety directives related to the tritium lights and their testing is delegated to the TWG Test Director or designated TWG supervisor.
   a. Safety Briefing. The TWG Test Director or designated TWG supervisor will brief all test personnel on the safety hazards at the test site.
b. Visitors. Visitors will be allowed at test sites in accordance with the procedures outlined in this test plan. Visitors having access to the tritium lights shall be instructed on applicable area safety regulations whenever possible either by public notice at the airfield, publications, or briefings.

5. **Test Personnel Safety Responsibilities.** Careful attention to the hazards at the test site must be stressed at each level of supervision. The purpose of the safety plan is to outline the most important precautions to be taken at the test site. This plan does not cover all the possibilities; but as new problems arise, new safety measures will be established to cope with the circumstances. In the interim, common sense must be applied to insure that safety prevails. This entire Safety Plan must be closely followed by all personnel and enforced by all supervisors. These procedures shall be accepted as minimum standards until the TWG Test Director, with the concurrence of DOE, ORNL, PNL, and the Airfield Manager, authorize deviation.

a. **Vehicle Safety.** Speeds shall not exceed 30 mph when driving on unpaved roads. Seat belts will be used at all times while vehicles are in motion. Speed within the immediate area of the test site shall not exceed 10 mph. When a vehicle is parked, the hand brake will be set and the transmission placed in reverse (standard shift) or park (automatic).

b. **Hypothermia and Frostbite.** Extremely cold weather is expected during the test period in cold regions. This has the potential for hypothermia, frostbite and accidents caused by impaired physical ability. Arctic orientation training will be required for each test-team member as they arrive in cold areas. Procedures set by the military for emergency supplies required during air travel and field operations will be imposed on non-military personnel involved in the test. Arctic clothing will be issued to personnel participating in military tests as required.

6. **Accident Reporting (Emergency)**

a. **Scope.** This standard procedure is intended to serve as a guide to expedite medical care as a result of an accident. All "post
emergency" reporting and accident investigation will be performed by current DOE, DOD, ORNL, and PNL regulations and is not within the scope of this procedure.

b. Responsibility. It is the responsibility of every person involved in this program to be completely familiar with the emergency reporting procedures established by this plan and to immediately implement these procedures after an accident. It is the responsibility of the TWG Test Director or designated TWG supervisors to familiarize all personnel with this procedure.

c. Emergency Reporting Procedures. After an accident at the test site, the following procedure will be followed:

(1) The senior supervisor at the scene of an accident will direct appropriate first aid. Caution will prevent aggravation of an accident-related injury.

(2) The nature of the accident, including apparent condition of the injured person, and the location of the accident will be assessed. The TWG Test Director or the TWG senior supervisor at the scene shall determine whether transfer of the injured to the nearest dispensary or hospital is required. If hospitalization is needed for the injured, the nearest hospital will be immediately notified and appropriate transport to the hospital will be arranged.

(3) If it is determined that the accident does not require transport to a dispensary or hospital, first aid will be administered at the site. If further medical attention appears necessary, the injured person will be taken to appropriate emergency medical care by normal transportation.

d. First Aid. An adequate supply of first aid items will be maintained at the test site.

7. Radiological Safety. While PNL/ORNL personnel will perform the responsibilities of the Radiation Protection Officer at the test site, the complete authority for the enforcement of all NRC requirements and
procedures while on DOD real property at civilian or military test sites lies with the appropriate military commander or civil authority. The safety information or procedures for handling, transporting, storing, and installing the RL fixtures at the test site are specified below:

a. Hazard. These tritium-filled tubes do not emit any beta radiation outside their sealed glass containers. In the event of tube breakage, Type-2R containers will be on hand to package the broken tube or fixture for safe transport to ORNL for disposal. Personnel exposure calculations have been made for a maximum credible accident involving 1000 Ci tritium (one shipping container of wands). A single light fixture breakage would result in an exposure equal to 10% of the value shown in the 1000 Ci release calculation. (See ORNL/PNL calculations of dose in runway lighting accident.)

b. Responsibility. PNL/ORNL personnel will be acting as Radiological Protection Officer (RPO) to advise and act in radiation incidents. The Airport Manager will be in charge of radiation-related problems and will advise the PNL custodian and act in an overall position of authority should a radiation incident occur during the test. Should an incident occur, the PNL custodian or his representative shall take appropriate action to handle the situation onsite. Should the PNL custodian or his representative not be available, K. W. Haff at ORNL shall be notified, per the security plan.

c. Damaged Lights. Breakage can occur if a fixture is dropped. All test panels and fixtures are designed and manufactured to meet or exceed ANSI 540 Standards for Self Luminous Light Sources. Thus, they should be able to withstand normal field handling. However, if a light fixture is dropped, it will be carefully identified and placed in a well-ventilated area for observation. On a DOE site, the radiation protection organization shall be notified and appropriate tests shall be made to ensure a tube is not broken. At a remote location, the fixture shall be monitored; and if dimming of a tube occurs, the light shall be placed in a type 2R container for shipment to ORNL for disposal. However, if dimming does not occur,
the light can be left in place, but upon removal, shall be placed in a type 2R container until appropriate testing of the fixture can be completed to ensure its integrity.

d. Training. The Test Director or his representative will brief individuals who will install and dismantle lights prior to any assignment. The installation briefing will cover the following areas:

(1) Safe handling.

(2) Proper installation.

(3) Breakage hazards.

(4) Physical security.
# APPENDIX B

## PARTICIPANTS

<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>George A. Jensen</td>
<td>PNL test director</td>
<td>Pacific Northwest Laboratory</td>
</tr>
<tr>
<td>Leroy E. Leonard</td>
<td>Alaska DOT&amp;PF test supervisor</td>
<td>State of Alaska Department of Transportation and Public Facilities (DOT&amp;PF)</td>
</tr>
<tr>
<td>Lorena Hegdal</td>
<td>Ground staff</td>
<td>State of Alaska DOT&amp;PF</td>
</tr>
<tr>
<td>J. Andrew Tompkins</td>
<td>Ground staff/ORNL observer</td>
<td>Oak Ridge National Laboratory</td>
</tr>
<tr>
<td>Richard McWhorter</td>
<td>Property owner</td>
<td>--</td>
</tr>
<tr>
<td>Thomas H. Paprocki</td>
<td>FAA test supervisor</td>
<td>Federal Aviation Administration (FAA) Test Center</td>
</tr>
<tr>
<td>Paul Jones</td>
<td>FAA observer</td>
<td>FAA Test Center</td>
</tr>
<tr>
<td>Bret Castle</td>
<td>FAA observer</td>
<td>FAA Test Center</td>
</tr>
<tr>
<td>Guy Brown</td>
<td>FAA observer</td>
<td>FAA Test Center</td>
</tr>
<tr>
<td>Dave Harrington</td>
<td>FAA Headquarters representative, volunteer pilot</td>
<td>FAA Headquarters, Washington, D.C.</td>
</tr>
<tr>
<td>Dale Anderson</td>
<td>Subject pilot</td>
<td>FAA, Alaska Region</td>
</tr>
<tr>
<td>Otto Van Bentum</td>
<td>Volunteer subject pilot</td>
<td>Bergstrom Aircraft Inc.</td>
</tr>
<tr>
<td>Roger I. Black</td>
<td>Volunteer subject pilot</td>
<td>Bergstrom Aircraft Inc.</td>
</tr>
<tr>
<td>Mike Warren</td>
<td>Volunteer pilot</td>
<td>Bergstrom Aircraft Inc.</td>
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<tr>
<td>Bill Webber</td>
<td>Volunteer pilot</td>
<td>Bergstrom Aircraft Inc.</td>
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<tr>
<td>David Lehman</td>
<td>Volunteer pilot</td>
<td>Bergstrom Aircraft Inc.</td>
</tr>
<tr>
<td>Walt Smith</td>
<td>Volunteer pilot</td>
<td>FAA, Spokane</td>
</tr>
<tr>
<td>Name</td>
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<td>Affiliation</td>
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<tr>
<td>James K. Fish</td>
<td>Volunteer pilot</td>
<td>Bergstrom Aircraft Inc.</td>
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<tr>
<td>Eugene W. Glatt</td>
<td>Volunteer pilot</td>
<td>Bergstrom Aircraft Inc.</td>
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<tr>
<td>Byron Popin-Donat</td>
<td>Volunteer pilot</td>
<td>Bergstrom Aircraft Inc.</td>
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<td>Jim Stanbock</td>
<td>Volunteer pilot</td>
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<td>John Schilke</td>
<td>Volunteer pilot</td>
<td>Bergstrom Aircraft Inc.</td>
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<td>Don Paul</td>
<td>Volunteer pilot</td>
<td>FAA, Spokane</td>
</tr>
<tr>
<td>M. Peterson</td>
<td>Volunteer pilot</td>
<td>Bergstrom Aircraft Inc.</td>
</tr>
<tr>
<td>Gordon H. Hardy</td>
<td>Volunteer pilot</td>
<td>NASA Aimes</td>
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<tr>
<td>John Foster</td>
<td>Observer</td>
<td>NASA Aimes</td>
</tr>
<tr>
<td>Arlyn Couch</td>
<td>Volunteer pilot</td>
<td>Pacific Northwest Laboratory</td>
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<tr>
<td>Jim Divine</td>
<td>Volunteer pilot</td>
<td>Pacific Northwest Laboratory</td>
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<tr>
<td>R. V. Hannigan</td>
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<tr>
<td>Jeff Gregory</td>
<td>Volunteer pilot</td>
<td>Pacific Northwest Laboratory</td>
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<tr>
<td>G. L. Tingey</td>
<td>Visitor</td>
<td>Pacific Northwest Laboratory</td>
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<tr>
<td>J. H. Jarrett</td>
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<td>Pacific Northwest Laboratory</td>
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<tr>
<td>J. L. McElroy</td>
<td>Visitor</td>
<td>Pacific Northwest Laboratory</td>
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<tr>
<td>Wendy Voss</td>
<td>Visitor</td>
<td>Pacific Northwest Laboratory</td>
</tr>
<tr>
<td>Mostafa Dayani</td>
<td>Visitor</td>
<td>DOE-Richland Operations</td>
</tr>
<tr>
<td>Col. Olmsted</td>
<td>Visitor</td>
<td>U.S. Army, Yakima Firing Center</td>
</tr>
<tr>
<td>Capt. Spanzi</td>
<td>Visitor</td>
<td>U.S. Army, Yakima Firing Center</td>
</tr>
<tr>
<td>Name</td>
<td>Function</td>
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</tr>
<tr>
<td>CW3 Stevens</td>
<td>Visitor</td>
<td>U.S. Army, Yakima Firing Center</td>
</tr>
<tr>
<td>D. T. Travis</td>
<td>Observer</td>
<td>City of St. Petersburg, Florida</td>
</tr>
</tbody>
</table>
APPENDIX C

FEDERAL AVIATION ADMINISTRATION REPORT OF FLIGHT TESTING
EVALUATION OF RADIO-LUMINESCENT LIGHTING SYSTEM

Thomas H. Paprocki

November 1984
DOT/FAA/CT-TN84/49

Document is on file at the Technical Center Library, Atlantic City Airport, N.J. 08405

U.S. Department of Transportation
Federal Aviation Administration
Technical Center
Atlantic City Airport, N.J. 08405

C.1
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.

17. Key Words
Radio-Luminescent Runway Lighting Systems Remote Airports

18. Distribution Statement
Document is on file at the Technical Center Library, Atlantic City Airport, New Jersey, 08405

Unclassified        Unclassified        20

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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 Energy 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.
FIGURE 1. R/L LIGHTING SYSTEM LAYOUT

FIGURE 2. BASIC R/L LIGHT FIXTURE
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.

![Image of Lighted Wind Direction Indicator](image)

**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 abreast of the runway center point.
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.
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
SUMMARY

PILOT QUESTIONNAIRE AND DATA SHEET

Date: 9/24-10/2/64  Pilot's Name: 20 SUBJECTS  Pilot Hours: AVE: 4365
A/C Type: C-206  Wx. Observation: MINIMUM 2,300' SCT, 12+ VIS.

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

<table>
<thead>
<tr>
<th>Run &amp; Position</th>
<th>Pilot's Call:</th>
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<th>2d Run:</th>
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<td></td>
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<td>ALL OK</td>
</tr>
<tr>
<td>45°</td>
<td></td>
<td>ALL OK</td>
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<tr>
<td>ABEAM</td>
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<td>ALL OK</td>
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</table>

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)
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)
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)
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.