technical note technical

Evaluation of Runway Guard Light Configurations at North Las Vegas Airport

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16. Abstract

Runway guard lights (RGL) both in pavement and elevated, when used in conjunction with Federal Aviation Administration-approved illuminated signs and painted hold position markings, have successfully reduced runway incursions at major air carrier airports. RGLs have not yet been recommended for use at general aviation (GA) airports.

Typically, in pavement RGLs are installed in sets of eight parallel to the hold position marking. This research effort also evaluated the effectiveness of adding additional lights perpendicular to the hold position marking, creating a T-configuration.

The purpose of this research effort was to determine if RGLs in the in-pavement, elevated, or T-configurations could offer the same safety enhancement to GA airports as they do for air carrier airports, even though GA airports are smaller in size, are far less complex in design, and have less separation between runways and taxiways. Eight test locations were selected for evaluation at the North Las Vegas Airport. Subject pilots were asked to navigate a vehicle on the airport surface to indicate the distances at which selected lights, signs, and markings became visible, and to clearly indicate the point at which the pilot must stop until clearance to enter or cross an active runway is received for air traffic control.

The evaluations showed that the standard illuminated sign performed the best during daylight conditions, and the elevated RGLs were most effective during dusk, dawn and nighttime conditions. The proposed alert zone lighting configuration did not offer any significant enhancement, especially when approached from a 90-degree angle. Of the pilots polled, 60% ranked the elevated RGL as the most effective visual aid for identifying the taxiway hold position.

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LIST OF ACRONYMS

AC	Advisory Circular
ATC	Air traffic control
CFR	Code of Federal Regulations
EAL	Enhanced airport lighting
FAA	Federal Aviation Administration
GA	General aviation
ORD	Chicago O'Hare International Airport
R&D	Research and development
RGL	Runway guard lights
VGT	North Las Vegas Airport

EXECUTIVE SUMMARY

This research evaluated the relative distances at which selected lights, signs, and markings would clearly indicate to the pilot the point at which he must stop until clearance to enter or cross an active runway is received from air traffic control. In particular, the test was designed to compare the effectiveness of various standard and proposed standard sign, marking, and lighting configurations used at general aviation (GA) airports. The test was conducted at the North Las Vegas Airport during the period of January to September 2004.

Elevated and in-pavement runway guard light (RGL) systems, used in conjunction with Federal Aviation Administration-approved L-858R signs and painted hold position markings, have been successful at major air carrier airports in reducing the potential for runway incursions. RGLs have not yet been recommended for use at GA airports where aircraft are smaller in size and have lower cockpit heights. Additionally, GA airports are usually less complex and have far less separation between runways and taxiways. This project was intended to assess the suitability of such RGL systems for use at GA airports.

The evaluations showed that the standard illuminated sign performed the best during daytime conditions, and the elevated RGL performed best during dusk, dawn, and night conditions. The proposed alert zone lighting configuration (T-configuration) did not offer any additional warning, especially when approached from a 90-degree angle. The painted markings were rated the least useful.

Of the pilots polled, 60% ranked the elevated RGL as the single component that was most effective in identifying the taxiway hold position.

It was also noted that in some locations, airport geometry limited the amount of real estate available for positioning the elevated RGL fixtures, and in many cases, required the RGL unit to be placed in front of other surrounding visual aids (signs or lights).

INTRODUCTION

PURPOSE.

This research evaluated the relative distances at which selected lights, signs, and markings would clearly indicate to the pilot the point at which he must stop until clearance to enter or cross an active runway is received from air traffic control (ATC). The test was conducted at the North Las Vegas Airport (VGT) during the period of January to September 2004. The test was designed to compare the effectiveness of four progressively more complex standard and proposed standard sign, marking, and lighting configurations used at general aviation (GA) airports.

1. The basic hold position configuration includes standard painted runway hold position markings with associated L-858R mandatory instruction signs (white runway designation on a red background), see figure 1(a).

2. The basic hold position configuration with the addition of L-804 elevated runway guard lights (RGL), see figure 1(b).

3. The basic hold position configuration with the addition of elevated RGLs and L-852G in-pavement RGLs, see figure 1(c).

4. The basic hold position configuration with the addition of both elevated and in-pavement RGLs and alert zone lighting (T-configuration), see figure 1(d).

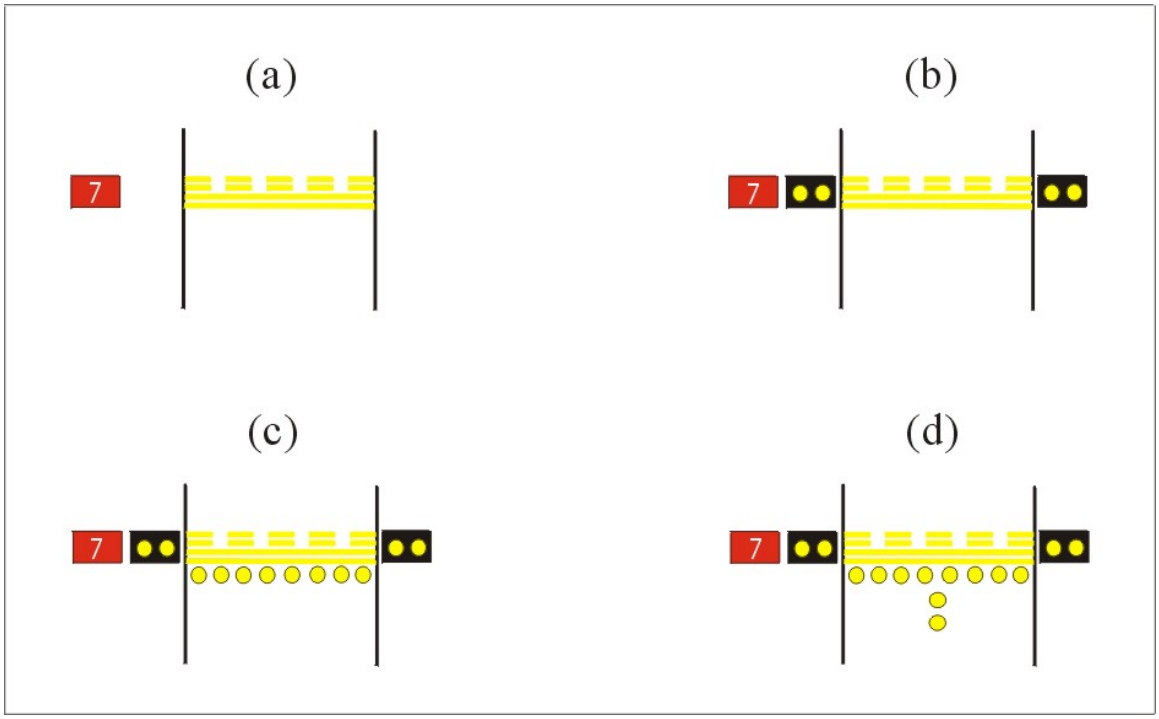

Figure 1. Evaluation Configurations

Elevated and in-pavement RGL systems, used in conjunction with L-858R signs and painted hold position markings, have been successful at major air carrier airports in reducing the potential for runway incursions. They have not yet been recommended for use at GA airports where aircraft are smaller in size and have lower cockpit heights. Additionally, GA airports are usually less complex and have far less separation between runways and taxiways. This project was intended to assess the suitability of such RGL systems for use at GA airports.

BACKGROUND.

The simplest RGL system (on which the basic hold position configuration is based) consists of a pair of elevated L-804 fixtures located on each side of a taxiway, in line with the runway hold position marking. For increased conspicuity, a series of pulsing yellow in-pavement L-852G fixtures may be used in addition to the elevated L-804 fixtures, positioned equally at 8-foot spacing in front of the runway hold position marking and between the two elevated L-804 fixtures. The two configurations, when used together, offer enhanced visual cues to pilots that they are approaching the hold position marker, and that they need further clearance to proceed, thus reducing the likelihood of causing a runway incursion.

The RGL system was designed to be used as a supplemental warning device that would increase the conspicuity of the runway hold position in low visibility conditions. Pilots have indicated that the RGL systems, both in-pavement and elevated, greatly assist them in identifying the location of the hold position marking. These fixtures, however, are typically used only at airports that frequently operate under low visibility conditions and are not commonly seen at smaller airports that do not operate in low visibility conditions. It has been suggested that the RGL system would also enhance safety at other airports, both commercial and GA, leading to a significant reduction in runway incursions.

It has been further suggested that the elevated and in-pavement RGL systems might be further enhanced by the addition of other L-852G in-pavement fixtures positioned 50-feet apart along the taxiway centerline, extending from the existing in-pavement configuration in the approach direction to at least 100 feet from the runway hold position, and in the configuration of the letter T. This alert zone, T-configuration RGL, was suggested for two reasons. First, it would act as an early warning for aircraft approaching the runway hold position, which would provide up to 200 feet of advanced warning. Second, it might provide a visual reference for pilots to gauge their clearance past the hold position when exiting the runway.

RELATED ACTIVITIES AND DOCUMENTATION.

A preliminary investigation of the effectiveness of the proposed alert zone, T-configuration RGL was conducted at the William J. Hughes Technical Center on November 18, 2003. The promising results of this limited test effort led to including the T-configuration in the evaluation described here.

A preliminary evaluation was conducted at the North Las Vegas Airport January 26-29, 2004, by personnel from the Airport Safety Technology Section of the Airport Technology Research and Development (R&D) Branch (ATO-P R&D). The preliminary evaluation collected baseline data on the acquisition distances for holding position signs and markings at seven specific runway

hold position locations. The data collected during that evaluation was summarized and included in an internal report entitled "Evaluation of Runway Guard Light Configurations at North Las Vegas Airport—"Quick Look" Report," February 2004. The purpose of this evaluation was to collect data at the seven test locations prior to planned construction activities that would include installation of RGL systems at all runway entrance locations.

Another evaluation was conducted from August 22-27, 2004, to collect additional sign and marking baseline data for acquisition distances at the original seven locations and two additional locations that were identified as critical by the VGT air traffic control manager. The data collected during this effort was analyzed and included in an internal report entitled "Evaluation of Runway Guard Light Configurations at North Las Vegas Airport—Phase Two Report," September 2004.

The third and final evaluation was conducted from September 20-23, 2004, to collect sign, marking, and lighting data at each of the nine test locations. The third evaluation was the first evaluation after the lighting system was energized. By relating the data from the third evaluation to the data collected during the two prior evaluations, differences in acquisition distances for the signs, markings, and lights could easily be determined. The data collected during this effort was analyzed and included in an internal report entitled "Evaluation of Runway Guard Light Configurations at North Las Vegas Airport—Phase Three Report," October 2004.

During development of the elevated L-804 fixture specification, the Federal Aviation Administration (FAA) ATO-P R&D performed some tests to determine the optimum flash rate, and this effort is described in the FAA report "Evaluation of L-804 Runway Guard Light Fixtures," DOT/FAA/AR-TN96/18, March 1996.

Since the now standard RGL system was adopted, very little research or developmental effort has been required. In 2002, ATO-P R&D conducted an evaluation of alternating versus simultaneous flashing modes for the in-pavement RGL system at Chicago O'Hare International Airport (ORD). It was learned that backscattered light generated from the in-pavement light fixtures was causing considerable confusion for pilots approaching the fixtures from the reverse side while exiting the runway. This investigation revealed that the problem existed not only at ORD, but also at other in-pavement RGL installations throughout the country. As a result of the study, ORD has adopted a simultaneous flashing mode as their standard.

The following FAA Advisory Circulars (AC) contain additional information about the standard RGL system:

- AC 150/5340-30B, Design and Installation Details for Airport Visual Aids
- AC 150/5345-46B, Specification for Runway and Taxiway Light Fixtures

EVALUATION APPROACH

An initial decision was made to use certificated pilots, of varying experience and age levels, as subjects to drive conventional vehicles through a predetermined course on the airport movement area. While occupied with the task of driving, the subjects were required to indicate the point at

which they could acquire the various sign, light, and marking configurations under evaluation. Project personnel in the vehicle measured the distances at which each configuration was acquired.

Comparison of acquisition distances obtained, with and without RGL lighting system enhancement at each location, was intended to provide a measure of the increase in hold position conspicuity attained with the addition of the various RGL components. In addition, participating subjects were asked to complete a postsession questionnaire.

Three specific taxiway and runway intersections on the VGT movement area were selected for evaluating the configurations, since each was provided with a different RGL configuration in addition to the standard signs and markings. Referencing the airport diagram (see figure 2), the following intersection and configuration combinations were used. Photographs of these test locations are shown in figures A-1 through A-9 in appendix A.

- Delta 1—Basic Configuration with L-804 elevated RGL, L-852G in-pavement RGL, and L-852G Alert Zone Lighting (T-configuration)—Runway 12R-30L and Taxiway H (NE side) (figure A-1).

- Delta 2—Basic Configuration with L-804 elevated RGL and L-852G in-pavement RGL—Runway 12R-30L and Taxiway C (NE side) (figure A-2).

- Delta 3—Basic Configuration with L-804 elevated RGL—Runway 12L-30R and Taxiway H (SW side) (figure A-3).

Six additional intersections were selected because they either represented locations where local airport users felt there was some confusion as to the holding position location (Alpha 1, 2, 3, 4, and Gulf 1) or provided extra distance for observations and data collection (Hotel 1). Lighting enhancement at these locations included only installation of elevated RGLs. Location details for these intersections were:

- Hotel 1—Basic Configuration with L-804 elevated RGL and L-852G in-pavement RGL—Runway 12L-30R and Taxiway H (NE side) (figure A-4).

- Alpha 1—Basic Configuration with L-804 elevated RGL—Runway 12L-30R and Taxiway A (E side) (figure A-5).

- Alpha 2—Basic Configuration with L-804 elevated RGL—Runway 7-25 and Taxiway F (S side) (figure A-6).

- Alpha 3—Basic Configuration with L-804 elevated RGL—Runway 12R-30L and Taxiway A (W side) (figure A-7).

- Alpha 4—Basic Configuration with L-804 elevated RGL—Runway 12L-30R and Taxiway A (W side) (figure A-8).

- Golf 1—Basic Configuration with L-804 elevated RGL—Threshold of Runway 12R and Taxiway G (SW side) (figure A-9).

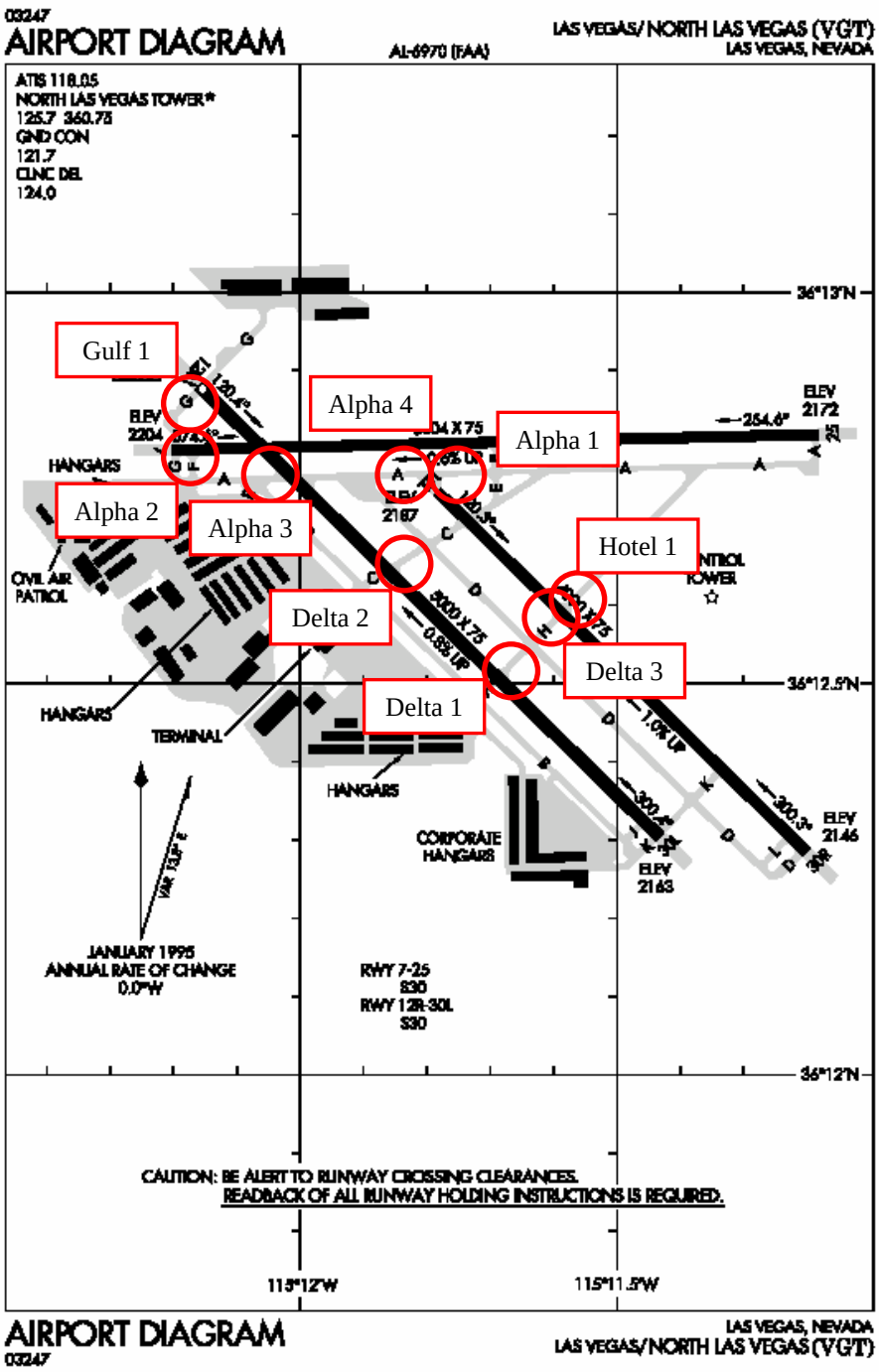

Figure 2. Airport Diagram of Test Locations

Throughout a 9-month period, project personnel from both ATO-P R&D and ATO-TD (AND-520) frequently visited six different flight schools and charter airline companies that conduct heavy flight activity at VGT. Each of the six organizations received briefings about the project and indicated a willingness to support the research effort. Many of the pilots participated in both the preliminary and final evaluations.

All testing sessions consisted of a pre-evaluation briefing, the actual evaluation, and a brief postevaluation debriefing period for each participant. During the pre-evaluation briefing, the subject pilot was provided with a short narrative explaining the purpose and conduct of the effort, along with details of his or her duties during the evaluation (as shown in appendix B).

After the pre-evaluation briefing, the subject was directed to maneuver the test vehicle along a designated route leading to each of the nine specific holding position configuration displays. The project personnel, also in the vehicle, provided all radio contact with ATC while on the movement area. A taxiing path, as shown in figure 3, was developed that provided the maximum opportunity to observe the holding position identifiers (signs, lights, and markings) and minimum interference with routine air traffic taxi operations. The route was coordinated with the local VGT ATC facility before testing began and again prior to each test session.

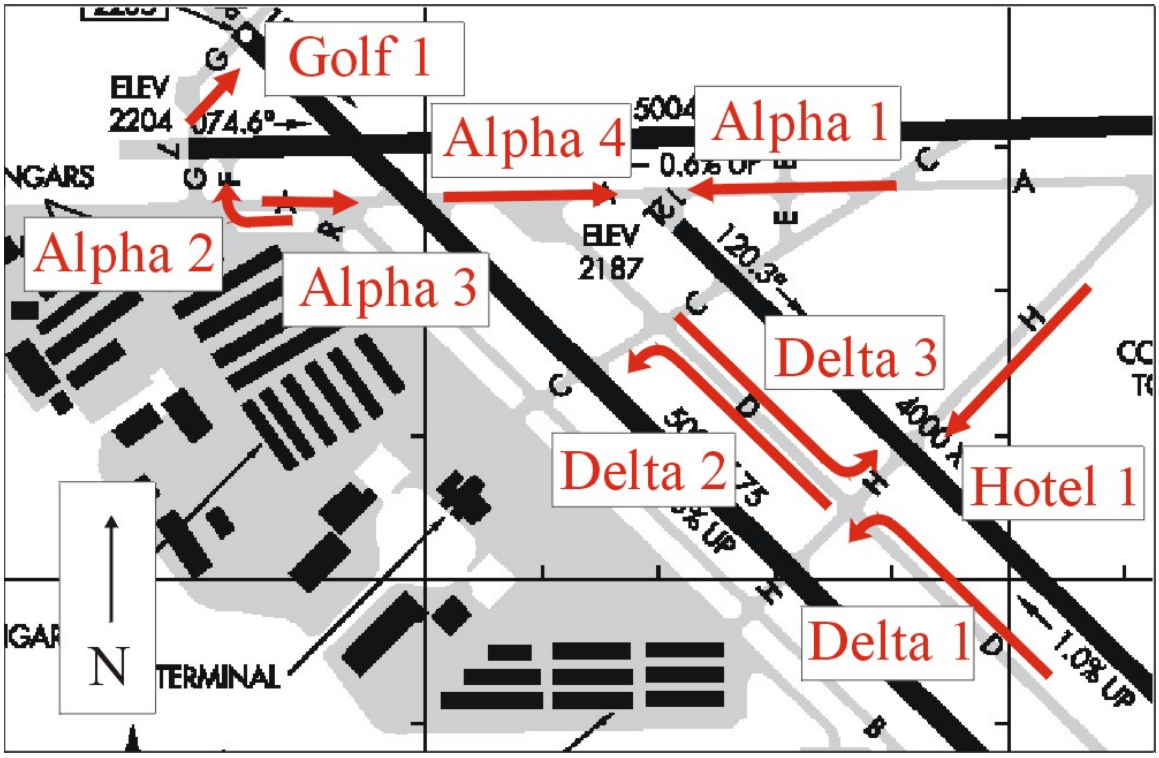

Figure 3. Taxi Routes

The subject pilot was instructed to announce to the accompanying project observer the point at which they first identified the actual holding position location, and was also expected to explain which visual aid (signs, painted marking, or lights) provided the identification information. At this time, a second project personnel onboard the test vehicle began measuring the distance of the

vehicle from the hold line using a wheeled measuring device deployed outside the vehicle. The signs were identified by the participant's ability to read the legend since, especially at night, several different holding position signs might be seen (acquired) from a single observation point. The painted markings were determined to be identified whenever the dashed line portion of the marking configuration could be discerned. The project personnel onboard the vehicle documented the sequence and recorded the distance at which each visual aid was acquired. The form used for this purpose is shown in figure 4.

Testing sessions were conducted under lighting conditions of dawn, daylight, dusk, and night. The daylight and night conditions were relatively easy to define, while the periodic extent of the dawn and dusk conditions were calculated using the official definition of sunrise and sunset as stated in Title 14 Code of Federal Regulations (CFR) Part 1. These definitions take precedence in all civil aviation matters. In accordance with 14 CFR Part 1, night is defined as the "time between the end of evening civil twilight and beginning of morning civil twilight as published in the American Air Almanac." For the purposes of this report, the nighttime period starts about 30 minutes after sundown and ends about 30 minutes before sunrise. The twilight period varies slightly by latitude, but is approximately 30 minutes in the lower 48 states and Hawaii. Astronomers or persons doing celestial navigation most commonly use the American Air Almanac.

Daylight is simply the time between sunrise and sunset. Dawn would be analogous to morning civil twilight, which starts about 30 minutes before sunrise and ends at sunrise. Dusk is similarly analogous to evening civil twilight, which starts at sunset and ends about 30 minutes after sundown.

Applying the official FAA definition of sunrise and sunset, the following times were calculated for the North Las Vegas, Nevada, location (W115° 08', N36° 12') by the United States Naval Observatory in Washington, DC, using the national time standard astronomical application.

Date	Sunrise	Sunset
September 20, 2004	6:27 AM	6:40 PM
September 21, 2004	6:28 AM	6:38 PM
September 22, 2004	6:29 AM	6:37 PM
September 23, 2004	6:30 AM	6:35 PM

After the test session, the participant was required to complete a brief postevaluation questionnaire that solicited opinions, comments, and preferences relating to the configurations that they had just viewed.

Name:		Date:		Time:	
Conditions:			Wx:		
Site	Visual Aid	Pilot Distance	Comment	Copilot Distance	Comment
Delta 1	"T" Viewable In-Pavement Viewable Elevated Viewable Sign Readable Marking Identified Final Measurement				
Delta 2	In-Pavement Viewable Elevated Viewable Sign Readable Marking Identified Final Measurement				
Delta 3	Elevated Viewable Sign Readable Marking Identified Final Measurement				
Hotel 1	In-Pavement Viewable Elevated Viewable Sign Readable Marking Identified Final Measurement				
Alpha 1	Elevated Viewable Sign Readable Marking Identified Final Measurement				
Alpha 2 (F)	Elevated Viewable Sign Readable Marking Identified Final Measurement				
Alpha 3	Elevated Viewable Sign Readable Marking Identified Final Measurement				
Alpha 4	Elevated Viewable Sign Readable Marking Identified Final Measurement				
Gulf 1	Elevated Viewable Sign Readable Marking Identified Final Measurement				
End Time:			Veh. ID	Coord.	Data Obsrv.

Figure 4. Sample Data Collection Sheet

EQUIPMENT.

Due to the high temperatures that were in the VGT area during the evaluation period, ground vehicles were used to provide the participant with a more comfortable environment for the evaluation. To expedite the data collection process, two minivan-type vehicles were used for the evaluations. The vehicles, using call signs FAA 1 and FAA 2, allowed simultaneous operations and permitted larger numbers of participants to run through the evaluation in a given amount of time.

EVALUATION SUBJECTS.

Individuals used as evaluation subjects were drawn principally from the local VGT pilot population (i.e., GA pilots, fixed-base operator instructor pilots, students, and Civil Air Patrol).

Members of ATO-P R&D and ATO-TD visited each of the six organizations residing on the airport during the first practice day to begin signing pilots up for participation in the data collection effort. Throughout the week, one member of ATO-TD continued to solicit subjects to obtain the maximum number of pilots.

RESULTS

A total of 42 subject pilots participated in the evaluation. As described earlier, acquisition distances for lighted red and white mandatory hold signs, yellow surface holding position painted markings, and three configurations of RGLs were obtained at nine different taxiway and runway intersections at VGT.

Of the 42 subjects, 33 completed a postsession questionnaire expressing their opinion as to the effectiveness and relative need for each of the holding position indicator configurations. Questionnaire results, expressed as a percentage of the 33 ratings obtained for each question, are provided in figure 5.

Some of the locations are situated, relative to the track of the sun, so that they will exhibit difficult glare conditions at times of low sun position (dawn and dusk). In addition, the proliferation of ramp lights on the east side of the airport creates acquisition problems at night. For such locations, and at locations where other unfavorable situations were observed, a brief description of the particular problem is provided in the narrative for that site.

Typical daylight photographs of each location are provided in appendix A. Results are presented separately for each of the locations evaluated.

ELEVATED RUNWAY GUARD LIGHT EVALUATION
EVALUATOR POST-SESSION QUESTIONNAIRE
(Final Evaluation)

Date: 9/21-23/2004 Name: 33 Respondents Time: All Sessions

Please rate the value of the visual aid components of the Enhanced Airport Lighting (EAL) system that you are presently evaluating. This a subjective evaluation and, as such, we are relying on your aviation background and experience to provide us with your best opinion on the matter. We are asking you to address and evaluate each component, in turn, for it's effectiveness in identifying the runway/taxiway holding position.

1. Basic Red/White Lighted Sign:

Essential: 85% Very Useful: 15% Convenient: 0% Unnecessary: 0%

2. Basic Red/White Non-Lighted Sign:

Essential: 36% Very Useful: 64% Convenient: 0% Unnecessary: 0%

3. Painted Markings:

Essential: 82% Very Useful: 6% Convenient: 9% Unnecessary: 3%

4. Elevated Runway Guard Lights:

Essential: 52% Very Useful: 33% Convenient: 12% Unnecessary: 3%

5. In-pavement Runway Guard Lights:

Essential: 27% Very Useful: 43% Convenient: 30% Unnecessary: 0%

6. In-pavement Alert Zone "T" Configuration:

Essential: 27% Very Useful: 39% Convenient: 30% Unnecessary: 3%

7. Of the visual components viewed, which do you rank as having the most effectiveness?

Markings: 8% Signs (Lighted): 26% Signs (Non-lighted): 2%

Elevated RGL: 60% In-pavement RGL: 2% Alert Zone "T": 2%

Figure 5. Questionnaire Responses in Percentage

DELTA 1.

This data acquisition location was the first of three approaches (identified as Delta 1, 2, and 3) to either of two runways (12R-30L and 12L-30R) from parallel taxiway D. The Delta 1 observation and data collection path was in a northerly direction along taxiway D to obtain acquisition distances for the configuration identifying the holding position at the intersection of taxiway H and runway 30L-12R (see figure 2 for illustration). The configuration at this location was comprised of standard painted runway holding position markings with associated L-858R mandatory instruction signs (white runway designation on a red background), L-804 elevated RGL, L-852G in-pavement RGLs, and L-852G alert zone lights (T-configuration).

Table 1 provides the average of all data points (observations) obtained from the 42 subjects.

Table 1. Delta 1 Acquisition Distances

Visual Aid	Time of Day			
	Dawn (ft)	Daylight (ft)	Dusk (ft)	Night (ft)
Sign	480	465	403	394
Elevated RGL Lights	776	310	852	836
In-Pavement RGL Lights	480	222	797	701
Alert Zone T-Configuration	248	181	396	415
Markings	206	298	155	155

The approach to this holding position, as well as those for the other two Delta locations, required making observations along a path primarily at right angles to the signs, lights, and markings; therefore, one would expect greater difficulty in acquiring and identifying the configuration components. This is evident when considering the relatively short distances at which the signs could be read, a result of the acute viewing angles at which observations were begun. Obviously, the signs would have been much more effective if viewed head-on initially, as is borne out at other locations (Hotel 1, Alpha 1, etc.). The elevated lights, on the other hand, provided approximately double the acquisition range during three of the four daylight and night conditions. The elevated lights were less effective during full daylight, when the yellow light could not compete with the bright Nevada sunlight. The in-pavement lights, in the T-configuration, were of only reduced effectiveness due to the physical cutoff of the lenses recessed within the fixture combined with the acute viewing angles along the approach path. The relatively narrow beam of the in-pavement lights normally restrict their utility to situations wherein they are viewed principally from angles well within the main beam.

It should be noted that during the dusk period, a pilot approaching the Delta 1 hold position faces directly into the setting sun once turning onto taxiway H. In this situation, the lighting array was more effective than the sign in identifying the critical location, and certainly more effective than the glare-masked markings.

DELTA 2.

This data acquisition location was the second approach to either of two runways (12R-30L and 12L-30R) from parallel taxiway D. The Delta 2 observation and data collection path was again in a northerly direction along taxiway D to obtain acquisition distances for the configuration identifying the holding position at the intersection of taxiway C and runway 30L-12R (see figure 2 for illustration).

The configuration at this location was comprised of standard painted runway holding position markings with associated L-858R mandatory instruction signs (white runway designation on a red background), L-804 elevated RGLs, and L-852G in-pavement RGLs.

Table 2 provides the average of all data points (observations) obtained from the 42 subjects.

Table 2. Delta 2 Acquisition Distances

Visual Aid	Time of Day			
	Dawn (ft)	Daylight (ft)	Dusk (ft)	Night (ft)
Sign	522	581	486	472
Elevated RGL Lights	607	352	936	678
In-Pavement RGL Lights	522	252	630	603
Markings	160	212	149	143

The Delta 2 location is similar in some ways to the Delta 1 location, in that the observation path is at a slightly greater than 90° angle to the hold position. As a result, comments pertaining to sign and elevated light effectiveness for the Delta 1 location apply here also, i.e., that the elevated lights proved better acquisition distances in all but the full daylight condition. In-pavement light effectiveness is marginally increased over the Delta 1 location due to the fact that taxiway C intersects taxiway D at a somewhat greater than a 90° angle, thus making the physical cutoff less critical. Marking effectiveness is reduced, to some extent, by the fact that the taxiway hold position elevation, relative to the elevation of taxiway D, is considerably higher at Delta 2 than at Delta 1.

Here again, a pilot approaching the Delta 2 hold position faces directly into the setting sun once turning onto taxiway C. As before, the lighting array was more effective than the sign in identifying the critical location, and certainly more effective than the glare-masked markings.

DELTA 3.

This data acquisition location was the third approach to either of two runways (12R-30L and 12L-30R) from parallel taxiway D. The Delta 3 observation and data collection path was in a southerly direction along taxiway D to obtain acquisition distances for the configuration identifying the holding position at the intersection of taxiway H and runway 12L-30R (see figure 2 for illustration). The approach to this holding position involved making observations along a

path principally at right angles to the signs, lights, and markings; therefore, one would expect greater difficulty in acquiring and identifying the configuration components.

The configuration at this location was comprised of standard painted runway holding position markings with associated L-858R mandatory instruction signs (white runway designation on a red background) and L-804 elevated RGLs.

Table 3 provides the average of all data points (observations) obtained from the 42 subjects.

Table 3. Delta 3 Acquisition Distances

Visual Aid	Time of Day			
	Dawn (ft)	Daylight (ft)	Dusk (ft)	Night (ft)
Sign	358	498	393	426
Elevated RGL Lights	580	260	1030	907
Markings	176	253	151	151

The Delta 3 location is the last of the three Delta sites and is, once again, approached from a most acute angle along taxiway D. As expected, the lights (in this case, only elevated fixtures) are notably more effective than either the sign or markings, except during full daylight. A rather unique affect was observed during afternoon periods when the sun was in its western quadrant, shining directly on the yellow filters of the elevated lights. In this situation, both lights of the elevated RGL appeared to be illuminated, and no wig-wag effect was discernable.

HOTEL 1.

The Hotel 1 observation and data collection path was in a southwesterly direction along taxiway H to obtain acquisition distances for the configuration identifying the holding position at the intersection of taxiway H and runway 12L-30R on the northwest side (see figure 2 for illustration). The approach to this holding position involved making observations along a path directly toward the holding position; therefore, one might expect greater acquisition distances than with the right angle approaches (Delta 1, 2, and 3).

The configuration at this location was comprised of standard painted runway holding position markings with associated L-858R mandatory instruction signs (white runway designation on a red background), L-804 elevated RGLs, and L-852G in-pavement RGLs.

Table 4 provides the average of all data points (observations) obtained from the 42 subjects.

Table 4. Hotel 1 Acquisition Distances

Visual Aid	Time of Day			
	Dawn (ft)	Daylight (ft)	Dusk (ft)	Night (ft)
Sign	1041	1075	792	725
Elevated RGL Lights	1223	1252	1358	1224
In-Pavement RGL Lights	1223	1188	739	1224
Markings	188	223	184	124

At this location, the approach path taken by the subject began at the intersection of taxiways A and H and proceeded directly toward the Hotel 1 hold position at the intersection with runway 30R-12L. In each instance, and under all daylight and night conditions, the subjects were able to acquire and identify the elevated lights from the turnaround point (maximum range) at taxiways A and H intersection. The in-pavement lights were also acquired at the maximum range, except during the dusk period when the setting sun was directly facing the viewer. The sign was also visible at the maximum range, but could not be read (a requirement) before reaching the somewhat closer distance shown in table 4. The markings were, as with the previous sites, effective only at close range during the day or when illuminated by the vehicle headlights after dark.

Several subjects commented on the fact that even at the greater viewing distances, two sets of elevated lights (locations Hotel 1 and Delta 1) were seen at the same time. They also commented that this posed no particular problem, as they just assumed that the inner pair was actually the farther set of elevated RGLs for the next parallel runway.

ALPHA 1.

The Alpha 1 observation and data collection path was in a westerly direction along taxiway A to obtain acquisition distances for the configuration identifying the holding position at the intersection of taxiway A and runway 30R-12L on the eastern side (see figure 2 for illustration). The approach to this holding position involved making observations along a path directly toward the holding position; therefore, one might expect greater acquisition distances than with the right angle approaches (Delta 1, 2, and 3).

The configuration at this location was comprised of standard painted runway holding position markings with associated L-858R mandatory instruction signs (white runway designation on a red background) and L-804 elevated RGLs.

Table 5 provides the average of all data points (observations) obtained from the 42 subjects.

Table 5. Alpha 1 Acquisition Distances

Visual Aid	Time of Day			
	Dawn (ft)	Daylight (ft)	Dusk (ft)	Night (ft)
Sign	984	991	641	559
Elevated RGL Lights	1734	1546	1764	1729
Markings	208	252	210	154

As with the Hotel 1 location, the observation path along taxiway A is a relatively long one, and the elevated lights were discernable from the maximum viewing distance at the intersection of taxiways A and H. The sign, in this instance having the minimal legend 12L only, had a much smaller surface area than others having a two runway legend (i.e., 12L-30R) and was mixed in with a number of other taxiway location signs along the edge of the taxiway. During the dusk period, there was little decrease in sign effectiveness due to glare from the low angle of the afternoon sun and, though not as readily identifiable as the elevated lights, the sign performed well under all conditions in this situation. The marking was useable, as before, only under very close or well-illuminated conditions.

Subject pilots also noted here that two sets of elevated RGLs were visible at the same time (locations Alpha 1 and at the hold position on taxiway A and runway 12R) looking in the northwest direction. Again, the subject expressed no concern about this.

ALPHA 2.

The Alpha 2 observation and data collection path was in a westerly direction along taxiway A to obtain acquisition distances for the configuration identifying the holding position at the intersection of taxiway F and runway 7-25 on the southern side (see figure 2 for illustration). The approach to this holding position involved making observations along a path principally at right angles to the signs, lights, and markings; therefore, one would expect greater difficulty in acquiring and identifying the configuration components.

The configuration at this location was comprised of standard painted runway holding position markings with associated L-858R mandatory instruction signs (white runway designation on a red background) and L-804 elevated RGLs. A supplemental unlit sign was also present on the right side of the taxiway.

Table 6 provides the average of all data points (observations) obtained from the 42 subjects.

Table 6. Alpha 2 (Foxtrot) Acquisition Distances

Visual Aid	Time of Day			
	Dawn (ft)	Daylight (ft)	Dusk (ft)	Night (ft)
Sign	321	330	217	215
Elevated RGL Lights	217	178	424	417
Markings	321	305	149	98

The Alpha 2 location, involving the hold position identifiers on taxiway F at the intersection with runway 7-25, presents a unique situation. The approach path westward along taxiway A results in the signs, markings, and lights only being visible at a very acute angle since the hold location is only 12 feet north on taxiway F from the edge of taxiway A. As shown in table 6, the standard signs and markings provide an adequate, if not superior, warning during daylight, but become relatively ineffective in darkness. The elevated lights, on the other hand, serve well at night and resulted in higher acquisition values.

ALPHA 3.

The Alpha 3 observation and data collection path was in an easterly direction along taxiway A to obtain acquisition distances for the configuration identifying the holding position at the intersection of taxiway A and runway 12R-30L on the western side (see figure 2 for illustration). The approach to this holding position involved making observations along a path directly toward the holding position, but only for a relatively short distance.

The configuration at this location was comprised of standard painted runway holding position markings with a pair of associated L-858R mandatory instruction signs (white runway designation on a red background) and L-804 elevated RGLs.

Table 7 provides the average of all data points (observations) obtained from the 42 subjects.

Table 7. Alpha 3 Acquisition Distances

Visual Aid	Time of Day			
	Dawn (ft)	Daylight (ft)	Dusk (ft)	Night (ft)
Sign	580	571	575	581
Elevated RGL Lights	580	571	575	581
Markings	153	212	145	155

The distance at which the approach to the Alpha 3 was initiated was, of necessity, quite short (580 feet). As a result, both the signs and the elevated lights were noted and identified by virtually all subjects immediately upon starting the approach. The painted markings were acquired only as the vehicle approached close and, during nighttime conditions, illuminated the paint with headlights.

It was noted that the L-858B sign on the left of the taxiway was blocked by another taxiway information sign positioned approximately 25 feet prior to the hold line. Pilots noted that the sign was blocked, but still were able to recognize the sign's message.

ALPHA 4.

The Alpha 4 observation and data collection path was in an easterly direction along taxiway A to obtain acquisition distances for the configuration identifying the holding position at the intersection of taxiway A and runway 12L-30R on the western side (see figure 2 for illustration). The approach to this holding position involved making observations along a path directly toward the holding position; therefore, one might expect greater acquisition distances than with the right angle approaches (Delta 1, 2, and 3).

The configuration at this location was comprised of standard painted runway holding position markings with associated L-858R mandatory instruction signs (white runway designation on a red background) and L-804 elevated RGLs.

Table 8 provides the average of all data points (observations) obtained from the 42 subjects.

Table 8. Alpha 4 Acquisition Distances

Visual Aid	Time of Day			
	Dawn (ft)	Daylight (ft)	Dusk (ft)	Night (ft)
Sign	858	901	844	642
Elevated RGL Lights	858	988	974	982
Markings	117	282	204	176

The elevated lights were acquired and identified by most subjects immediately upon commencing the approach to the Alpha 4 hold position. The lighted signs were acquired concurrently, but probably due to variations in subject eyesight capabilities, not always identified (read) at that instant. The markings again were not perceived until considerably later in the approach to the hold position.

GOLF 1.

The Golf 1 observation and data collection path was in a northwesterly direction along taxiway G to obtain acquisition distances for the configuration identifying the holding position at the intersection of taxiway G and runway 12R-30L on the western side (see figure 2 for illustration). The approach to this holding position involved making observations along a relatively short path with a right-hand dog-leg toward the holding position.

The configuration at this location was comprised of standard painted runway holding position markings with associated L-858R mandatory instruction signs (white runway designation on a red background) and L-804 elevated RGLs. A supplemental unlit runway sign was also present on the right side of the taxiway.

Table 9 provides the average of all data points (observations) obtained from the 42 subjects.

Table 9. Golf 1 Acquisition Distances

Visual Aid	Time of Day			
	Dawn (ft)	Daylight (ft)	Dusk (ft)	Night (ft)
Sign	470	567	595	562
Elevated RGL Lights	470	571	595	579
Markings	155	212	69	77

Taxiway G is a relatively short dog-leg to the right before terminating at the entrance to runway 12R. Virtually all subjects were able to acquire and identify both the signs and elevated lights from the approach starting point at the hold position south of runway 7-25. The painted markings were especially deficient in providing warning at this location since they were coated with aircraft exhaust and oil contamination and could only be identified, close in, by their appearance at the outermost edges of the taxiway.

In most cases, the pilots reported seeing the unlit reflective sign unit on the right side of the taxiway prior to seeing the illuminated sign, mostly due to the orientation and proximity of the unlit sign.

CONCLUSIONS

Upon reviewing the data collected from this evaluation effort, the following conclusions were made:

- For locations where the hold position was approached from a right angle:

  - The elevated runway guard light (RGL) units had the highest values during dawn, dusk, and night conditions.

  - The in-pavement RGL units ranked a close second to the elevated units during dawn, dusk, and night conditions.

  - The lighted sign unit performed the best during daylight conditions.

  The painted markings ranked low during all conditions, especially during low-light conditions, in extreme cases of sun glare, or when contaminated.

  - The in-pavement alert zone T-configuration did not offer any noticeable improvement over the standard in-pavement configuration.

- For locations where the hold position is approached from straight distance:

  - The elevated and in-pavement RGL units had the highest rankings during all conditions.

  - The lighted sign unit ranked a close second during all conditions.

  - The painted markings ranked low during all conditions, especially during low-light conditions, in extreme cases of sun glare, or when contaminated.

- In some locations, airport geometry limited the amount of real estate available for positioning the elevated RGL fixtures, and in many cases, required the RGL unit to be placed in front of other surrounding visual aids (signs or lights).

- Of the 33 respondents that completed the postsession questionnaire, the following visual aids were rated as "essential" to identify the runway/taxiway holding position:

  - Basic lighted sign (85%)
  - Painted markings (82%)
  - Elevated RGL (52%)

- Of the 33 respondents that completed the postsession questionnaire, the following visual aids were rated as "very useful" to identify the runway/taxiway holding position:

  - Basic nonlighted sign (64%)
  - In-pavement RGL (43%)
  - In-pavement alert zone T-configuration (39%)

- Of the 33 respondents polled, 60% ranked the elevated RGL as the single component that they felt had the most effectiveness in identifying the runway/taxiway hold position.

APPENDIX A—TEST SITES

Figure A-1. Delta 1—Runway 12R-30L and Taxiway H (Northeast side)

Figure A-2. Delta 2—Runway 12R-30L and Taxiway C (Northeast side)

Figure A-3. Delta 3—Runway 12L-30R and Taxiway H (Southwest side)

Figure A-4. Hotel 1—Runway 12L-30R and Taxiway H (Northeast side)

Figure A-5. Alpha 1—Runway 12L-30R and Taxiway A (East side)

Figure A-6. Alpha 2—Runway 7-25 and Taxiway F (Southwest side)

Figure A-7. Alpha 3—Runway 12R-30L and Taxiway A (West side)

Figure A-8. Alpha 4—Runway 12L-30R and Taxiway A (West side)

Figure A-9. Golf 1—Threshold of Runway 12R and Taxiway G (Southwest side)

APPENDIX B—EVALUATION OF RUNWAY GUARD LIGHT CONFIGURATION BRIEFING SHEET

The purpose of this evaluation effort is to determine the effectiveness of a newly developed building block concept for installing visual aids to identify the critical taxiway/runway holding position location. The expanded configuration will consist of a combination of signs, painted markings, elevated lights, and in-pavement lights. This Enhanced Airport Lighting (EAL) system has been installed for the first time at the North Las Vegas Airport (VGT) for evaluation by user pilots and airport operators.

Over the last few months, the surface of VGT has undergone some major improvements with its visual guidance systems. Not all components mentioned above will be located at every runway/taxiway intersection, but you will see both the entire system or individual components at various locations around the airport. We are requesting your assistance in obtaining data on how each of these components performs, both individually and collectively, in assisting you in locating the hold position locations.

You will be asked to operate the vehicle around the airport surface, specifically guided such that you will encounter nine particular hold lines that have a combination of the above mentioned light configurations. You will be read a series of taxi clearances that will lead you to a hold line. Please navigate the vehicle accordingly, and announce when you are able to positively identify the particular hold line you are to hold at. At the time you are able to identify the hold position, please stop the vehicle. At this time, a second member of our team who will be sitting in the rear of the vehicle will begin taking measurements to document your position, and capture any pertinent comments you may offer. We will continue this process until all of the visual aids have been identified at that particular hold location. Our personnel will handle the radio transmissions with ATC, and direct you to maneuver the vehicle as ATC requires. Please maintain no more than 10 mph during the measurement process, and no more than 20 mph when relocating the vehicle to the next location.

Please keep in mind that the two project members who will accompany you are researchers, and are NOT involved with any enforcement activities within the Federal Aviation Administration. They are solely documenting how well the lights, signs, or markings perform, and are not critiquing your piloting or vehicle operating capabilities in any way.

We greatly thank you for your assistance, in advance. It is with your help and participation in this effort that we will be able to provide a safer and more efficient airport environment for the future.