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Modified Touchdown Zone Lighting

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16. Abstract

A simulator evaluation was conducted to determine the adequacy of the standard touchdown zone (TDZ) lighting system under extremely low visibility conditions and to develop, if necessary, a modified TDZ lighting system. All testing was conducted using the Federal Aviation Administration (FAAs) B-727 simulator at the Mike Monroney Aeronautical Center, Oklahoma City. The adequacy of the lighting system guidance was determined through pilot comments and by noting the aircraft track during the rollout. A post-flight questionnaire was completed by the test pilots. Only 10 out of 14 (71 percent) pilots were able to determine their location relative to centerline at 300 feet runway visual range (RVR) with the standard TDZ lighting system. Some of the pilots could only determine their location down to 500 feet RVR, so a modified system was developed. With the modified system all pilots were able to achieve adequate centerline orientation at 300 feet RVR. From the results of this simulator evaluation we must conclude that, given a true reduced visibility condition of 300 to 500 feet RVR and with an automatic landing (auto-land) system malfunction which delivered the aircraft to a touchdown point immediately over the TDZ lighting system, a pilot would not have sufficient lateral guidance to achieve adequate centerline orientation during rollout.

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EXECUTIVE SUMMARY

During landing operations in Category III-B and III-C weather, the present Federal Aviation Administration (FAA) standard touchdown zone (TDZ) lighting configuration may not provide the required visual cues to maintain proper runway centerline guidance. The Visual Guidance Section of the Airport Technology Branch, ACD-110, conducted a simulator evaluation to determine the adequacy of the standard TDZ lighting system and to develop, if necessary, a modified TDZ lighting system.

Advisory Circular, AC 120-28C, "Criteria for Approval of Category III Landing Weather Minima," describes acceptable means for obtaining approval for Category III landing weather minima. Operations in visibilities down to 300 feet runway visual range (RVR) require a fail-passive rollout system as part of the automatic landing (auto-land) system for runway centerline guidance. Operations below 300 feet RVR require a fail-operational rollout guidance system. Considering the limitations of these requirements for electronic guidance, the adequacy of the standard TDZ lighting system in visibilities as low as 300 feet RVR should be determined. Below 300 feet RVR the pilot would be guaranteed a redundant electronic rollout system for required centerline guidance.

In order to have repeatability of test conditions and because actual flight testing would be impossible, all testing was conducted using the FAA's B-727 simulator at the Mike Monroney Aeronautical Center, in Oklahoma City. The adequacy of the lighting system guidance was determined through pilot comments and by noting the aircraft track, towards or away from centerline, during the rollout. A post-flight questionnaire was completed by the test pilots.

Only 10 out of 14 (71 percent) pilots were able to determine their location relative to centerline at 300 feet RVR or lower with the standard TDZ lighting system. Some of the pilots could only determine their location down to 500 feet RVR, so a modified system was developed. With the modified system all pilots were able to achieve adequate centerline orientation at or below 300 feet RVR. From the results of this simulator evaluation it is concluded that, given a true reduced visibility condition of 300 to 500 feet RVR and with an auto-land system malfunction which delivered the aircraft to a touchdown point immediately over the TDZ lighting system, a pilot would not have sufficient lateral guidance to insure recapture of the runway centerline during rollout.

INTRODUCTION

PURPOSE.

During landing operations in Category III-B and III-C weather, the present FAA standard touchdown zone (TDZ) lighting configuration may not provide the required visual cues to maintain proper runway centerline adherence. At the request of Airports Division, AAS-200, the Visual Guidance section of the Airport Technology Branch, ACD-110, conducted a simulator evaluation to determine the adequacy of the standard TDZ lighting system and to develop, if necessary, an enhanced TDZ lighting system. This task was transmitted through the Airport Technology and Advanced System Branch, ADS-240, and accomplished under the Technical Center project number T1903N, "Airport and Heliport Lighting and Marking." The technical project manager is Paul H. Jones, ACD-110.

BACKGROUND

Automatic landing (auto-land) systems for Category III operations are designed to position an aircraft on or near the centerline of the runway during landing operations. Normally, with the existing runway lighting systems, the transition from instrument to visual conditions is easily accomplished. As a result of prior auto-land failure evaluations and from airline pilot comments, concern has arisen that, given aircraft landing offset over one row of the TDZ fixtures under extremely low visibility conditions, a pilot may not have sufficient visual cues to determine his position relative to the runway centerline. During this phase of the landing the pilot might not be able to positively identify the few lighting fixtures visible to his left or right as either the edge or centerline lighting system.

Advisory Circular, AC 120-28C, "Criteria for Approval of Category III Landing Weather Minima" describes acceptable means for obtaining approval for Category III landing weather minima. Operations in visibilities down to 300 feet runway visual range (RVR) require a fail-passive rollout system as part of the auto-land system for runway centerline guidance. This type of system would allow a pilot to take over manually without any large changes in control movements if the auto-land system failed during rollout. Operations below 300 feet RVR require a fail-operational rollout guidance system. This type of rollout system has a backup on-line, and no pilot control input is required to complete the rollout successfully.

Considering the limitations of these requirements for electronic guidance, the adequacy of the standard TDZ lighting system in visibilities as low as 300 feet RVR should be determined. Below 300 feet RVR, the pilot would be guaranteed a redundant electronic rollout system for required centerline guidance.

DISCUSSION

TEST PROCEDURE.

A preliminary test session was conducted in order to fully understand the scope of the visual guidance problem. The session was held at the Aeronautical Center in Oklahoma City, using the FAA's Boeing 727 visual motion simulator. Mr. John (Bud) Ruddy, retired airline pilot and member of Air Line Pilot Association (ALPA) Airport Safety Committee, helped define the potential visual problem. In preparation for this session two different configuration patterns of the TDZ lighting were developed to provide, if needed, added centerline guidance for preliminary evaluation. These patterns are shown in figure 1. These directional patterns were created by de-energizing certain lights in the TDZ system. This modification to the standard system would be much easier to implement in the field than adding or moving fixtures because of the inset fixture used and its in-runway surface location.

During the initial simulator session the aircraft was positioned stationary over the center of one row of the TDZ lights (approximately 40 feet off centerline) and the visibility was reduced until it was difficult to differentiate the edge lighting from the centerline lighting. This visibility was found to be in the range of 200 to 300 feet RVR.

Test approaches were then flown with this 40-foot centerline offset using the simulator auto-land system. With the standard lighting system displayed, the guidance to centerline was inadequate. The test patterns were flown next. Guidance towards centerline was still lacking because the repetitive patterns were 500 to 600 feet in length and were not totally visible in the reduced visibility conditions. Without the full directional pattern visible, the de-energized (missing) lights looked more like random outages. It was determined that any useful modification would have to involve alterations of each and every bar of the TDZ lighting system. This meant that a new modification would have to include a change every 100 feet and would require moving a light fixture in each row.

Two new configurations were designed and tried on the simulator during a second test session. They are shown in figures 2 and 3. These changes included moving the inboard fixture of each TDZ barrette either 5 feet longitudinally away from the threshold or 5 feet laterally towards the centerline. After approaches were flown on both configurations, the one that had the fixture moved longitudinally was eliminated from consideration. This configuration, while readily interpreted when viewed from a motionless aircraft, was almost impossible to interpret while landing due to the relatively high landing speed at touchdown and low viewing angle. The configuration that had the inboard TDZ fixture moved laterally towards the centerline presented an easily interpreted pattern and will be hereafter referred to as the modified TDZ system.

TEST SESSION.

In order to have repeatability of test conditions and because actual flight testing would be impossible, all testing was conducted using the FAAs B-727 simulator at the Aeronautical Center. Before the test session began, each pilot practiced several approaches in the simulator for familiarization. The pilot test session consisted of approximately 10 approaches. All approaches were

auto-land coupled with the pilot instructed to manually correct to centerline once the aircraft had touched down on the runway surface. The simulator was adjusted to offset the aircraft randomly 40 feet left or right at touchdown so that the pilot had to determine direction to runway centerline only by visual clues from the lighting system. Approaches started at 500 feet RVR with a zero-foot ceiling in a homogeneous fog. During the succeeding approaches, the visibility was progressively reduced in 100-foot increments until the standard TDZ system failed to give the pilot the visual guidance needed to regain the runway centerline. Once this occurred, the modified TDZ system was substituted and approaches were started once again at 500 feet RVR. The simulated visibility was then progressively reduced until the modified system failed to provide the required centerline guidance. See test matrix, figure 4.

The adequacy of the lighting system guidance was determined through pilot comments and by noting the aircraft track, towards or away from centerline, during the rollout. A post-flight questionnaire (figure 5) was completed by the test pilots.

TEST RESULTS.

Fourteen pilots participated in the evaluation: twelve were airline pilots and two were test pilots from the FAA Technical Center. All subject pilots were qualified in the Boeing 727. Pilot experience varied from 3,000 to 17,600 hours, with the majority of pilots having over 10,000 hours.

Only 10 out of 14 (71 percent) pilots were able to determine their location relative to centerline at 300 feet RVR or lower with the standard TDZ lighting system. Two pilots could only determine their location down to 500 feet RVR. Actual data are shown in the summary sheet in figure 6. When asked if the standard TDZ system was adequate down to 300 feet visual range, only 9 out of 14 (64 percent) pilots answered "yes." The numbers differ because one pilot was able to correct to centerline at 300 feet RVR but did not feel that the guidance was adequate. Seven out of fourteen pilots, to include the four subjects previously unable to accomplish successful rollout completion with the standard TDZ system, were able to achieve successful lower visual range performance with the modified TDZ lighting system. Four of these pilots were able to reduce their successful performance RVR value by as much as 200 feet with the modified system. With the modified system all pilots were able to achieve adequate centerline orientation at or below 300 feet RVR. Thirteen of the 14 pilots said that the modified TDZ system provided the additional guidance needed to determine the direction of the runway centerline. Pilots commented that they could regain centerline position more rapidly and with greater confidence using the modified system. The only time pilots thought that either lighting system induced any measure of confusion was when they were used under the lower visibility conditions for which they were judged inadequate.

CONCLUSION

From the results of this simulator evaluation it is concluded that, given a true reduced visibility condition of 300 to 500 feet RVR and with an auto-land system malfunction which delivered the aircraft to a touchdown point immediately over the TDZ lighting system, a pilot would not have sufficient lateral guidance to insure recapture of the runway centerline during rollout. A condition of any less than 300 feet RVR would require that the aircraft be equipped with a functioning "fail-operational" rollout guidance system, of course, and so the lack of sufficient lateral visual guidance would not be critical. For RVR conditions greater than 500 feet, the standard TDZ, centerline, and edge lighting systems would, as revealed by the simulator tests, provide adequate visual clues to allow the pilot to complete his rollout manually by regaining the runway centerline visually.

Therefore, we can see that a problem of insufficient visual guidance for very low visibility landing and rollout operations would only be encountered if the following two critical conditions prevailed at the same time:

1. Failure or malfunction of the auto-land/rollout system so drastic as to cause the aircraft to touch down more than 40 feet to the right or left of runway centerline.

2. Occurrence of a restricted visibility weather condition resulting in a reported runway RVR value within the 300- to 500-foot range.

Considering the high reliability specified for installed auto-land and rollout guidance systems and the relatively rare occurrences of very low visibility weather conditions within a narrow (200-foot) RVR bracket, it would seem that the probability of the above situation existing would be extremely remote.

Installation or retrofit of the TDZ lighting system modification as developed and tested would provide the necessary supplemental guidance, i.e., direction to centerline, to insure successful completion of the rollout maneuver under even these most stringent and unlikely conditions. Modification of the standard TDZ lighting system, to the suggested configuration, would entail no additional cost for a new airport or new runway installation. Retrofitting the modification to an existing serviceable TDZ system would, however, be extremely expensive, since it entails re-installation of a total of 60 in-pavement, semi-flush lighting fixtures and the attendant rewiring of the system power cables.

Certainly, a carefully calculated cost/benefit study would have to be conducted before any consideration could be given to requiring that the modification to the standard TDZ configuration be adopted. Accomplishment of such a study is beyond the capability of this reporting organization.

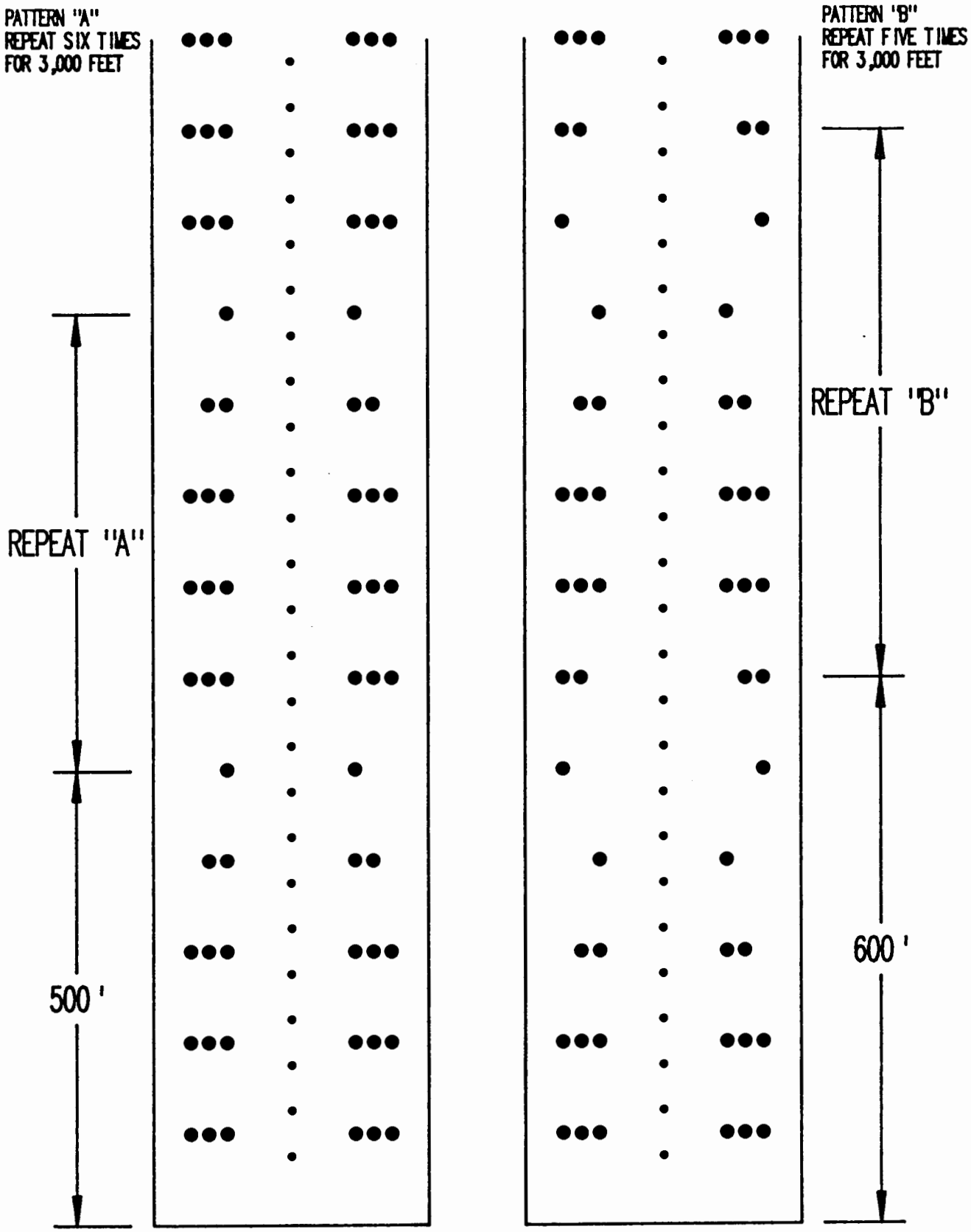

FIGURE 1. PRELIMINARY TEST PATTERNS

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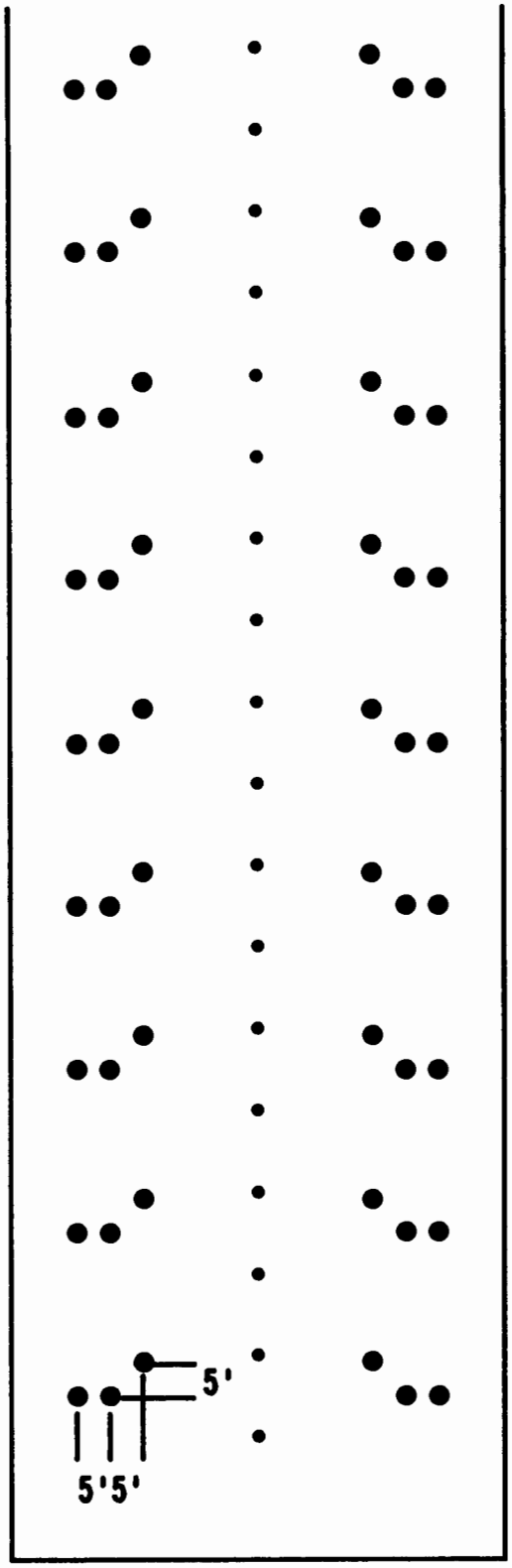

FIGURE 2. LONGITUDINALLY MODIFIED TOUCHDOWN ZONE SYSTEM

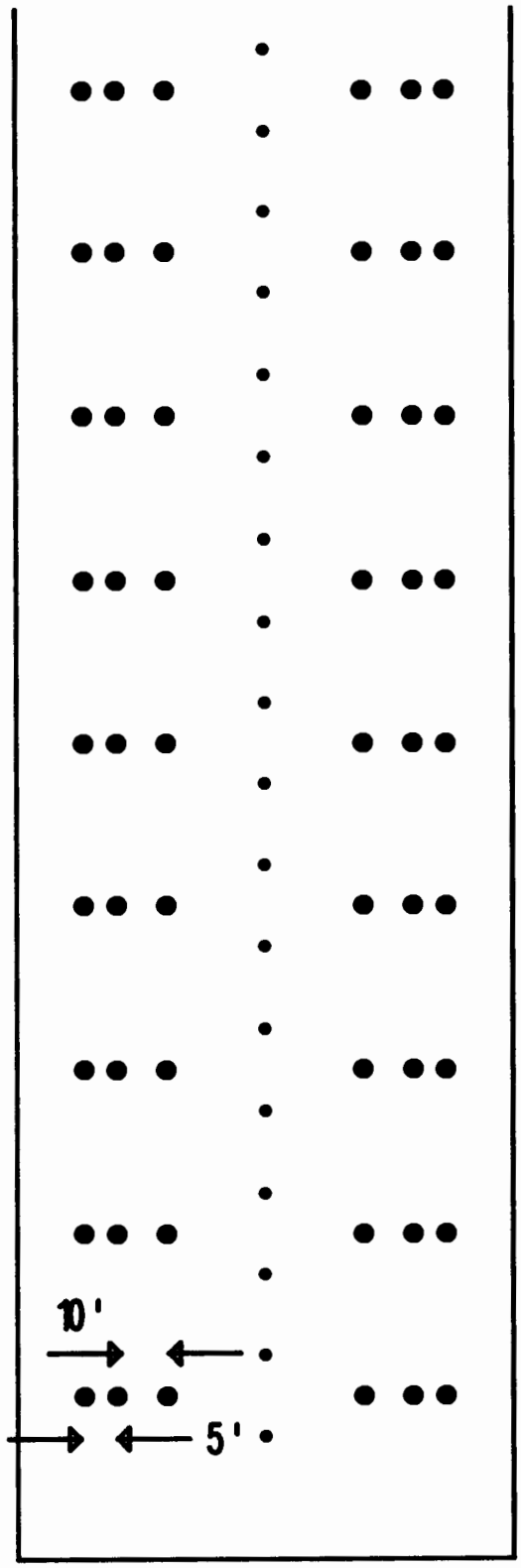

FIGURE 3. LATERALLY MODIFIED TOUCHDOWN ZONE SYSTEM

Run Number	Configuration	Visibility (ft) RVR	Offset (ft)
1	Standard	500	40 right
2	Standard	400	40 left
3	Standard	300	40 right
4	Standard	200	40 right
5	Standard	100	40 left
6	Modified	500	40 right
7	Modified	400	40 left
8	Modified	300	40 left
9	Modified	200	40 right
10	Modified	100	40 left

FIGURE 4. TEST MATRIX

TOUCHDOWN ZONE LIGHTING

QUESTIONNAIRE

NAME:_____ DATE:_____

ESTIMATED FLIGHT HOURS:_____ AIRCRAFT: B-727 SIMULATOR

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1. At what minimum visibility conditions were you able to determine the direction of the runway centerline with the Standard TDZ Lighting System?

   _____ Visual Range

2. Was the Standard TDZ Lighting system adequate down to 300 ft. visual range?

   _____ Yes _____ No

3. At what minimum visibility conditions were you able to determine the direction of the runway centerline with the Modified TDZ Lighting System?

   _____ Visual Range

4. Did the Modified TDZ provide any additional guidance to help determine the direction of the runway centerline?

   _____ Yes _____ No

COMMENTS: _____

_____

_____

5. At anytime did either system provide any confusing signals?

   _____ Yes _____ No, Which one?_____

COMMENTS:_____

_____

Thank you

FIGURE 5. TEST QUESTIONNAIRE.

SUMMARY SHEET

TOUCHDOWN ZONE LIGHTING

QUESTIONNAIRE

NAME: (14 Pilots) DATE: _____

ESTIMATED FLIGHT HOURS: _____ AIRCRAFT: B-727 SIMULATOR

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1. At what minimum visibility conditions were you able to determine the direction of the runway centerline with the Standard TDZ Lighting System?

   2 Pilots @ 500'
   2 Pilots @ 400'
   8 Pilots @ 300'
   2 Pilots @ 200'
   — Visual Range

2. Was the Standard TDZ Lighting system adequate down to 300 ft. visual range?

   9 Yes 5 No

3. At what minimum visibility conditions were you able to determine the direction of the runway centerline with the Modified TDZ Lighting System?

   6 Pilots @ 300'
   8 Pilots @ 200'
   — Visual Range

4. Did the Modified TDZ provide any additional guidance to help determine the direction of the runway centerline?

   13 Yes 0 No 1 No answer

COMMENTS: Much easier to determine your position. Felt very comfortable with modified system. System provided - extra visual cues - quicker resolution - instantaneous direction. Vastly superior system.

5. At anytime did either system provide any confusing signals?

   11 Yes 3 No, Which one? 1 - Modified 10 - Standard

COMMENTS: Under the lower visibility conditions there were insufficient visual cues to determine your location.

FIGURE 6. QUESTIONNAIRE SUMMARY