Improved Taxiway Exit Identification System

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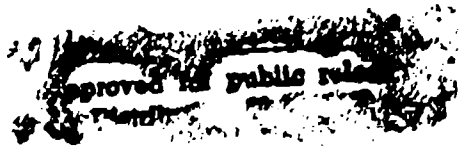

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16. Abstract

A prototype enhanced visual taxiway identification system, consisting of a segment of green lights imbedded within the conventional runway centerline lighting system, was developed and tested at the Federal Aviation Administration (FAA) Technical Center. Results of the combined developmental/evaluational effort indicated that the system may be expected to provide enhanced and effective identification of taxiway exit locations at minimum cost.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

EXECUTIVE SUMMARY

With the greatly increased complexity of airport runway and taxiway configurations and with the expanded variety of visual aids exposed to pilot view on airports, a requirement for enhanced identification of runway exits has arisen. This need is especially critical for assisting pilots attempting to locate the normal (other than high-speed) exits at night and during periods of low visibility.

A prototype enhanced visual taxiway exit identification system was developed and tested at the FAA Technical Center. The system consisted of a segment of green lights imbedded within the conventional runway centerline lighting system immediately prior to the exit taxiway location. The configuration was achieved by merely adding inexpensive "aviation green" filters to the appropriate centerline system in-pavement lighting fixtures.

The centerline lighting system serving the principal runway (13/31) at the Technical Center was modified, by the addition of filters, for evaluation by Center based air carrier and FAA test pilots. Additional evaluation, using a visual display of the prototype system programmed for testing under simulated reduced visibility weather conditions was also accomplished using the Boeing 727 Flight Simulator at the FAA Aeronautical Center in Oklahoma City.

Results of the developmental/evaluational effort indicated that the system may be expected to provide enhanced and effective identification of taxiway exit locations at minimum cost.

INTRODUCTION

BACKGROUND.

One of the most difficult tasks for a pilot, especially at night and during low visibility weather conditions, is that of identifying taxiway exits from the runway immediately after landing. The problem is especially critical at major airports, where there are numerous exits from each active runway and great emphasis placed on the need for reducing runway occupancy time. It becomes essential that pilots be able to identify exits in sufficient time to reduce their rollout speed to that which will permit vacating the runway as soon as possible.

Long radius (high speed) exits are provided with a continuous line of green in-pavement centerline lights from the runway centerline along the entire exit curve, and thus pose no exit identification problem. At present, however, normal taxiway exits are identified only by double (paired) blue taxiway elevated lights at the runway edge combined with signs denoting the taxiway designation. Even if taxiway green centerline lights are provided on the exit taxiway, they are not carried out into the runway surface so as to preclude the possibility of being mistaken for the long radius taxiway exit lighting system. In this respect, the FAA policy differs from the ICAO Annex 14 standard of providing for use of green taxiway centerline lighting from the runway centerline into all exits.

Normal short radius exits are therefore often most difficult to distinguish when identified only with low intensity lights and signs located at the runway edge where they easily blend into the myriad of other airport lighting systems. This is especially true when low visibility conditions prevail, and the pilot's attention is directed principally along the runway centerline while attempting to reduce rollout speed and maintain alignment straight ahead.

PURPOSE.

The purpose of this effort was to develop an enhanced visual taxiway exit identification device or system to provide pilots a positive early indication of normal short radius taxiway exit locations under nighttime and low visibility conditions.

OBJECTIVE.

This effort was directed specifically toward:

1. Developing a prototype enhanced taxiway exit identification system for normal exits.

2. Obtaining user pilot evaluational opinion as to the effectiveness of the developed system.

3. Determining the practicability of implementing the concept at commercial air-carrier airports.

DEVELOPMENT METHODOLOGY.

A visual system designed to satisfy the stated purpose must, at the least, satisfy the following requirements:

- It must provide, if at all possible, intuitive visual guidance information. In this case the purpose, identification of the taxiway exit location, should be immediately evident to the user through previous experience with systems of a similar nature.

- It must be sufficiently unique that there is no possibility of confusion with another airport lighting system located within the vicinity.

- It must be of such a nature that it can be located within the pilot's immediate area of concentration (field of view) so that there is no requirement for visual "searching". This requirement is particularly important if the system is to be used under low visibility, high-stress operational situations.

- It must be economically and technically practicable so that universal implementation is feasible.

In many instances, enhanced visual guidance may be provided by some alteration to, or modification of, an existing system with attendant reduced installation and maintenance costs. Providing that it does not jeopardize the integrity and usefulness of the "parent" system, the added guidance information will be provided at minimum cost. It was decided that this technique might provide the most reasonable approach for development of the prototype exit identification system.

Runway centerline lighting systems are provided on numerous runways at major airports for use under low-visibility (Category II and III) conditions. Further, these in-pavement lights constitute the primary source of guidance for pilots during the rollout maneuver subsequent to landing and during the time when the pilot is faced with the additional task of identifying the taxiway exit location. Since the pilot is already concentrating his attention upon this centerline system, it would seem reasonable that visual exit identification information might well be added within this area. A color variation within the predominately white (clear) runway centerline display could afford the necessary warning of available exit locations and, if sufficiently bold and distinct, allow the pilot to make a timely decision as to which exit to use.

Since the color "aviation green" has been standardized for use in taxiway centerline lighting applications, it would seem to be the most appropriate color to use in adding exit location identification information to the runway lighting system. The only other color found within the runway centerline lighting system configuration is "aviation red", which is used to designate the final segment of the system immediately before the runway end. This color is not likely to be confused with a green segment within the same system.

To retain its unique presentation as a continuous line of white lights, the runway centerline lighting system must not contain extensive segments of alternative color lights except, of course, for the red "end of runway" warning segment. Therefore, any green color-coding that might be added must be confined

to short segments only. Fortunately, relatively few green lights within the system will form a contrasting pattern and this presentation can be readily identifiable as a guidance signal.

Another attractive feature of the standard runway centerline lighting fixture, suiting it admirably for use in this application, is that they are manufactured with an integral mount for the red filters required to configure the "end of runway" warning system segment. Providing green light segments within the standard runway system would require only the installation of "aviation green" filters within existing fixtures.

It was thus concluded that a modification to the standard U.S. runway centerline lighting system, by adding short green color-coding at normal taxiway exit locations, showed promise for providing an effective, yet most economical, means of providing taxiway exit location information to pilots.

TEST METHODOLOGY.

As is the case with any evaluation of visual guidance systems, the effectiveness of the prototype system could only be determined by subjecting it to use in the field or in simulation. Accordingly, the following sequence of testing efforts was decided upon:

- Phase 1 - Actual taxi evaluation of the system by FAA test pilots and user air-carrier pilots at the Technical Center to "fine tune" system variables (light spacing, color, segment length, etc.).

- Phase 2 - Additional actual taxi evaluation of the system, with changes to the configuration resulting from phase 1 testing, at the Technical Center by FAA pilots.

- Phase 3 - Further simulator taxi evaluation of the system configuration using the FAA Boeing 727 flight simulator at the FAA Aeronautical Center (OKC). Volunteer air-carrier pilots, FAA test pilots, and FAA Boeing 727 instructors participated as subjects under simulated reduced visibility weather conditions.

During the conduct of phases 1 and 2, FAA subject pilots were briefed beforehand concerning the purpose of the evaluation, the general configuration of the system to be tested, and the operational procedures to be followed. They were also provided with the standard briefing sheet (figure 1) given to all participating pilots during these phases of testing. Immediately following each taxi test session, the pilots were asked to complete a detailed standard written evaluation questionnaire (figure 2).

Since some of the phase 1 testing was to be accomplished by air-carrier user pilots evaluating the system as it was observed and utilized during revenue flights, these subjects were provided with briefing and evaluation questionnaire sheets through airline company management channels. The questionnaires were returned for analysis whenever a significant number had been collected.

BRIEFING SHEET

IMPROVED TAXIWAY EXIT IDENTIFICATION

In order to assist pilots in identifying taxiway exits from the principle runway 13-31 at the Technical Center (ACY) airport, we have modified segments of the runway centerline lighting system. Sets of either three or five green filters have been installed within the normally white lights along the runway centerline at taxiway "A" and "I" intersection exits. The set of five green centerline lights at "A" taxiway exit will be visible to aircraft la ng in the runway 31 direction, and the set of three green centerline lights at "I" taxiway exit will be visible to aircraft landing in the runway 13 direction. It is hoped that these modifications will provide a measure of early warning to pilots intending to use either of these two exit locations. Simple questionnaire forms will be distributed at a later date after pilots have had sufficient opportunity to use the color-coded system, so that ACY based pilots will have a chance to express their opinions as to the usefulness of this concept.

FIGURE 1. SAMPLE STANDARD BRIEFING SHEET

IMPROVED TAXIWAY EXIT IDENTIFICATION

PILOT QUESTIONNAIRE

Name_____ Date _____Aircraft Type_____

Observed Visibility. (Mi) _____ VFR ___ or IFR ___

1. Did the green runway centerline lights provide significant assistance in positively identifying the exit taxiway location ?
   Yes_____ No_____

   Comments_____

   _____

   _____

2. In your opinion, would availability of color-coding such as this reduce the problem of identifying runway exits in low visibility weather conditions?
   Yes_____ No _____

   Comments_____

   _____

   _____

3. During the final approach, touchdown, or rollout, could the green runway centerline lights be misinterpreted as another airport lighting system or as an aircraft on the runway? Yes_____ No_____

   Comments_____

   _____

   _____

4. Which configuration of green runway centerline lights did you prefer?
   3 lights_____ 5 lights _____ No preference _____

   Comments_____

   _____

   _____

THANK YOU!

FIGURE 2. SAMPLE QUESTIONNAIRE

All pilots participating in the phase 3 simulator evaluation of the system were provided with detailed briefings before each session and completed detailed questionnaires afterwards.

During phase 1 testing, FAA test pilots and user air-carrier pilots evaluated the prototype system while encountering the lighting display during runway rollout after landings at Atlantic City International Airport. For phase 2 testing, FAA test pilots evaluated the system during high speed taxi simulations of the landing rollout conducted without actual airborne operations.

Aircraft types used by pilots participating in phases 1 and 2 of this evaluation included the Douglas DC-9 and Convair CV-580.

Pilots participating in phase 3 (simulation tests) were required to conduct Category I, II, and III approaches in the FAA Boeing 727 Flight Simulator to a landing. They then attempted to identify the indicated exit taxiway during rollout and completed the turnoff maneuver if possible. Simulated restricted visibilities of 1/2 mile, 1800-foot Runway Visual Range (RVR), 1200-foot RVR, and 300- to 400-foot RVR were used. Exit configurations were 90 degrees right, 90+ degrees left, and 90 degrees left.

SYSTEM DESIGN

Reconfiguration of the Technical Center's existing runway centerline lighting system to display the prototype taxiway exit identification presentation was relatively simple. It involved only the addition of "aviation green" color filters to selected in-pavement centerline lighting fixtures to provide the color-coded exit identification scheme depicted in figure 3. Two slightly different green segments were emplaced at runway 13/31 taxiway intersection exits to taxiways "A" and "I". In each instance, the color filters were installed to form a green segment of centerline lights commencing prior to the intersection and terminating at the taxiway and runway centerline intersection points. The segment at taxiway "A" consisted of five color-coded green lights on 50-foot centers for a total length of 200 feet, while the shorter segment at taxiway "I" consisted of only three color-coded green lights with a reduced length of 100 feet. The bidirectional centerline lights were only filtered to display the green signal in one direction, that from which the pilots making the turnoff would be expected to arrive. Since green dichroic filters were used, having a transmissivity of approximately 50 percent, it was realized that some reduction in light intensity would have to be accepted. It turned out that the difference in intensity between the white (clear) and green lights did not appear to significantly affect test results.

As a result of pilot comments and suggestions received during the phase 1 testing, the system configuration was adjusted somewhat to that depicted in figure 4 for subsequent phase 2 and 3 evaluations. A standard system length of 200 feet (five green lights on 50-foot centers) was adopted. Also, the termination point for each segment was displaced, in the approach direction, so that each segment ended at the point where the painted yellow taxiway turnoff line indicated the beginning of the exit turn.

EVALUATION RESULTS

PHASE 1 TESTING.

Air-Carrier Pilot Results. A total of eight Atlantic City based air-carrier pilots returned completed questionnaire sheets after having identified and used the prototype exit identification lighting system during revenue flights. Six of the associated landings were conducted under Visual Flight Rule (VFR) conditions of better than 3-mile visibility, while the remaining two landings were conducted under Instrument Flight Rule (IFR) conditions of approximately 1/2- and 2-mile visibilities.

IMPROVED TAXIWAY EXIT IDENTIFICATION

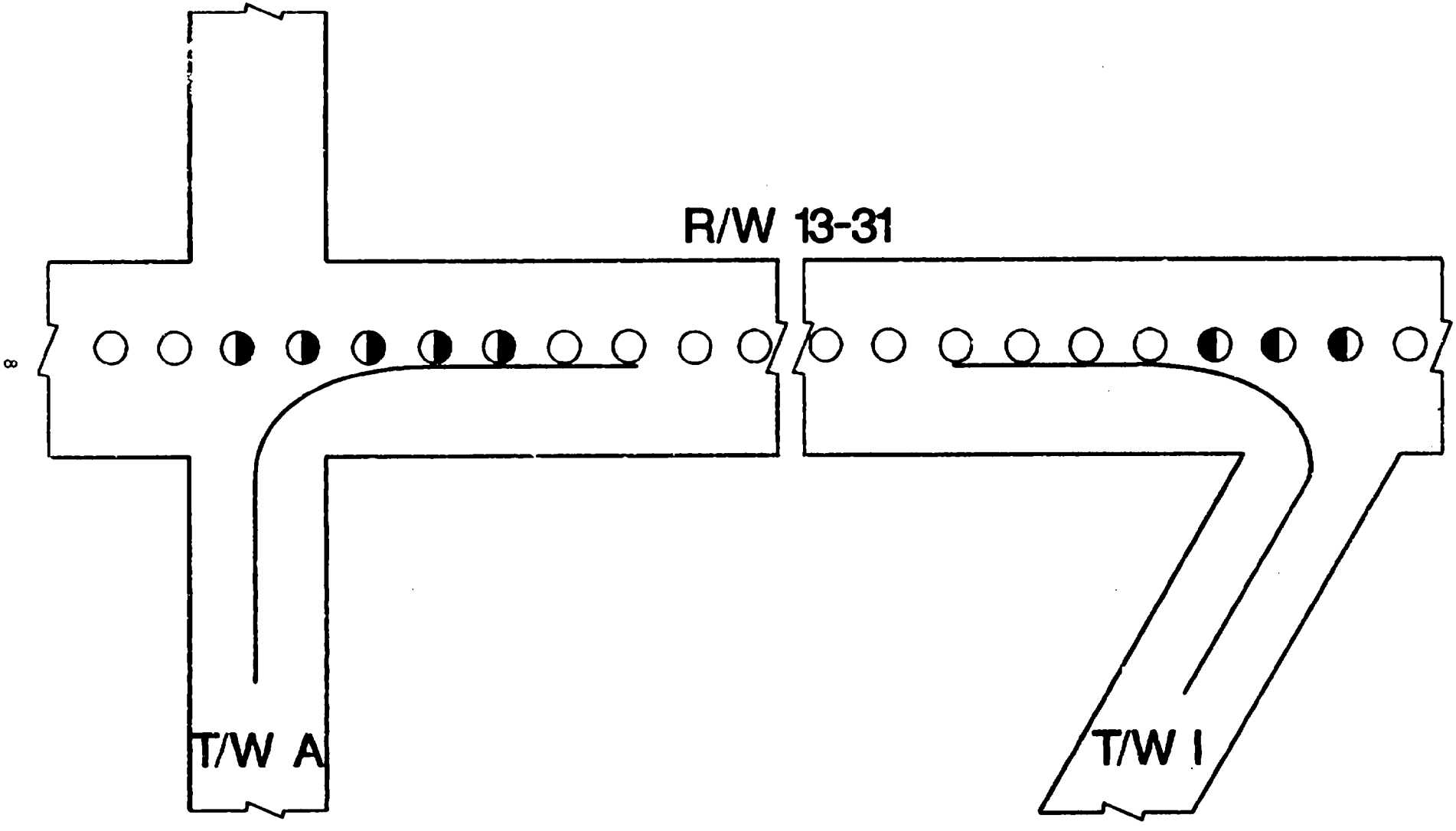

FIGURE 3. INITIAL SYSTEM CONFIGURATION

IMPROVED TAXIWAY EXIT IDENTIFICATION

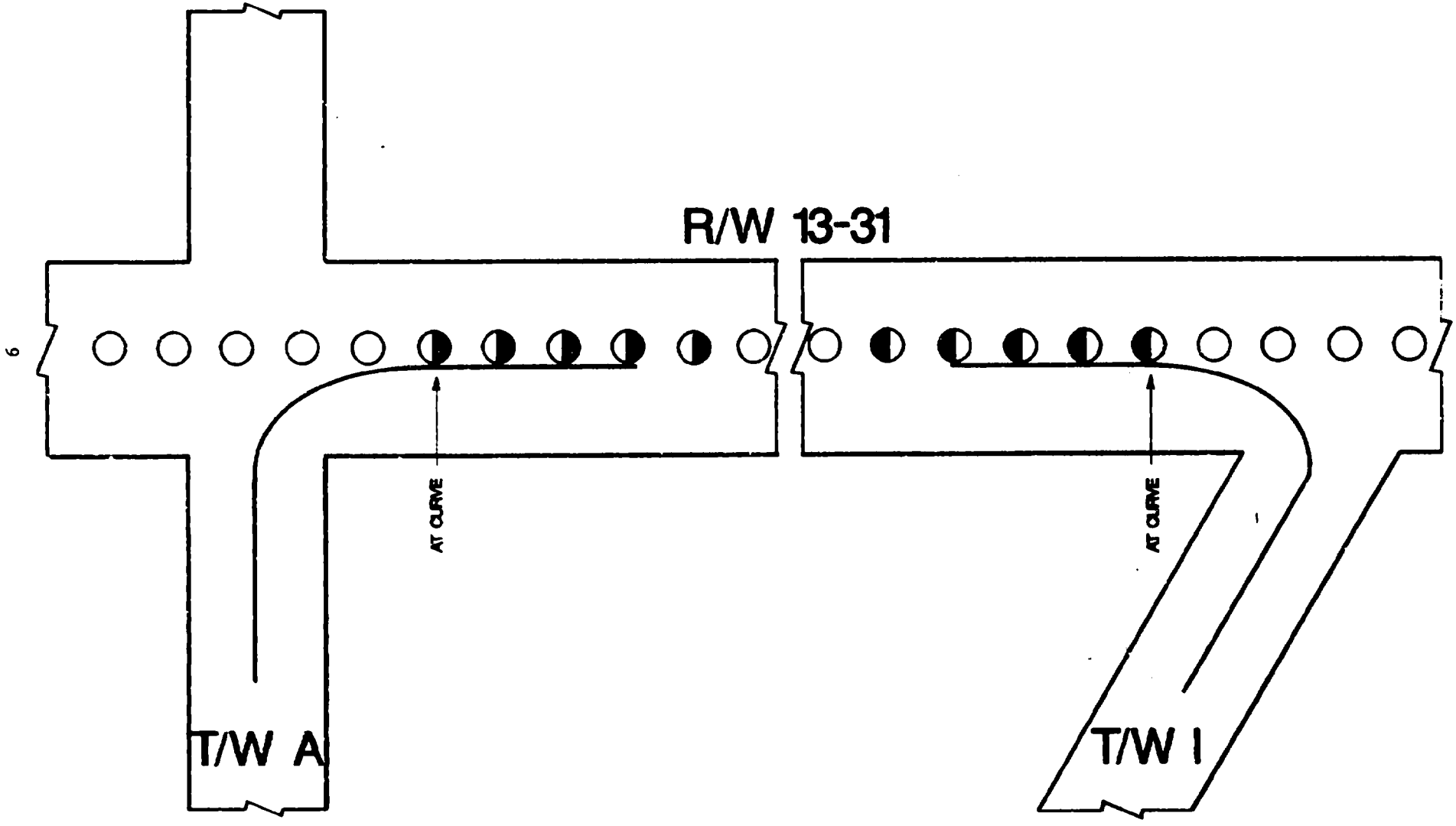

FIGURE 4. MODIFIED SYSTEM CONFIGURATION

Pilot questionnaire responses are summarized in figure 5 and revealed virtually a unanimously favorable opinion as to the usefulness and desirability of the prototype system. Seven pilots expressed a preference for the 5-light configuration, and the remaining pilot expressed no definite preference.

These particular pilots, being relatively inexperienced in formal evaluation of airport visual aids, appeared to have been somewhat reluctant to make comments. Those few comments received, however, were universally favorable and may be typified with the following:

- "It is a good system, being in your limited field of view. It is unambiguous, and I like it."
- "Adds to identifying exit areas."
- "All runways should be lighted with green lights to help in identifying the taxiway (exits)."

FAA Test Pilot Results. A total of fifteen FAA pilots from the Technical Center Flight Test Branch participated in the phase 1 evaluation and completed post flight questionnaires. Nine of the simulated rollout and exit maneuvers were conducted under VFR conditions of better than 3-mile visibility, while the remainder, a total of six, were conducted under IFR conditions of approximately 1/4- to 3-mile visibilities.

FAA pilot questionnaire responses are summarized in figure 6 and showed an extremely favorable opinion with regard to the prototype system. Eleven of the pilots expressed a preference, sometimes strongly, for the 5-light configuration, and only two favored having only three. Two pilots checked "no preference", but one of them indicated that the 3-light grouping might be perceived as only a "gap" or "outage" in the runway centerline lighting array. With regard to the possibility of misinterpretation or confusion with other airport lights, only three out of fifteen pilots expressed concern. One individual felt that there might be some confusion between the green lights and the red "end-of-runway" color-coding. The other two pilots did not include any comments as to why, or for what, they might misinterpret the green signal.

As might be expected of evaluation-oriented individuals, the FAA Test Pilot group offered copious comments on various system characteristics and on the basic concept itself. These comments, for the most part not unfavorable, but suggesting possible enhancements are provided on page 13. While not necessarily direct quotes, they reflect the general nature of the originals.

IMPROVED TAXIWAY EXIT IDENTIFICATION

PILOT QUESTIONNAIRE

Name Air Carrier Pilots Date _____ Aircraft Type DC-9

Observed Visibility. (Mi) 1/2 to 5 VFR 6 or IFR 2

1. Did the green runway centerline lights provide significant assistance in positively identifying the exit taxiway location ?
   Yes 8 No 0

   Comments See Text

2. In your opinion, would availability of color-coding such as this reduce the problem of identifying runway exits in low-visibility weather conditions?
   Yes 8 No 0

   Comments See Text

3. During the final approach, touchdown, or rollout, could the green runway centerline lights be misinterpreted as another airport lighting system or as an aircraft on the runway?
   Yes 0 No 8

   Comments See Text

4. Which configuration of green runway centerline lights did you prefer?
   3 lights 0 5 lights 7 No preference 1

   Comments See Text

THANK YOU!

FIGURE 5. PHASE 1 AIR-CARRIER PILOT RESPONSES

IMPROVED TAXIWAY EXIT IDENTIFICATION

PILOT QUESTIONNAIRE

Name FAA Pilots Date _____ Aircraft Type Convair 500

Observed Visibility. (Mi) 1/4 to 10 VFR 9 or IFR 6

1. Did the green runway centerline lights provide significant assistance in positively identifying the exit taxiway location ?
   Yes 14 No 1

   Comments See Text

2. In your opinion, would availability of color-coding such as this reduce the problem of identifying runway exits in low visibility weather conditions?
   Yes 15 No 0

   Comments See Text

3. During the final approach, touchdown, or rollout, could the green runway centerline lights be misinterpreted as another airport lighting system or as an aircraft on the runway? Yes 3 No 12

   Comments See Text

4. Which configuration of green runway centerline lights did you prefer?
   3 lights 2 5 lights 11 No preference 2

   Comments See Text

THANK YOU!

FIGURE 6. PHASE 1 FAA TEST PILOT RESPONSES

- The 5-light configuration was seen from 3 NM on the glide slope, positively identified at 2 NM, but blended in with the r/w centerline lights after descent below 100 feet AGL prior to touchdown. The green lights reappeared when about 1,000 foot away during rollout after landing.

- I prefer the 5-light over the 3-light system. Also, the turnoff to India (taxiway) is more than 90 degrees, and probably should have more than a 3-light warning.

- With step 4 intensity - green lights are difficult to find when lined up with the centerline lights.

- Unusable at steps 1 and 2. I feel that the 3-light system is unacceptable.

- At or above intensity step 3 the green lights helped.

- Five, rather than three, lights seemed better for initial acquisition. Also, "last" light's location with respect to the taxiway is important for judging the turn.

- The extra two lights (of the 5-light configuration) give you a little extra space for recognition.

- The system is particularly helpful when the runway is wet and yellow painted taxi lines are hard to identify.

- Did not like three lights at all. Must have five lights, with the last light at the beginning of the turnoff taxiway.

- I suggest positioning the lights so that the last green light is at the (beginning of the) yellow taxi off line.

- Would like more than five lights, and the last light should end at (start of) turnoff, not at runway/taxiway centerline intersection.

- Need to eliminate imbalance in intensity of white and green lights.

- I liked the 5-light group, and felt that the 3-light group was too short, especially for the 120 degree turn from the runway into taxiway India.

As mentioned previously, and as a result of comments received during phase 1 testing, the prototype system configuration was changed (figure 4) as follows:

1. The 5-light configuration was standardized with 50-foot spacing between green lights for a total segment length of 200 feet.

2. The entire segment was shifted toward the approach direction so that the last green light was located at the beginning of the exit curve rather than at the runway/taxiway centerline intersection.

This modified configuration was retained unchanged for the remainder of the evaluation (phases 2 and 3).

The pilot questionnaire was modified to eliminate question 4, which dealt with the subject's preference for either a 3- or 5-light configuration.

PHASE 2 TESTING.

A total of five FAA pilots from the Technical Center Flight Test Branch participated in the phase 2 evaluation which was primarily concerned with validating the improvements to the configuration. The FAA pilots evaluated the modified system during high-speed taxi simulations of the landing rollout maneuver conducted without actual airborne approaches. One of the simulated rollout and exit maneuvers was conducted under VFR conditions of better than 12-mile visibility, while the remainder, a total of four, were conducted under IFR conditions of 600- to 800-foot RVR.

Referencing the summarized pilot questionnaire responses (figure 7), it would appear that the modifications made to the initial system configuration were most successful in eliminating pilot perceived deficiencies. All five subject pilots were unanimous in expressing favorable opinion as to the usefulness and desirability of the system as shown by their responses to questions 1 and 2. They also indicated that, through responses to question 3, the danger of confusion and/or misinterpretation of the system presentation was not a consideration.

Pilot comments, as expressed on the questionnaire sheets, were not nearly so profuse during this phase of testing. They may be summarized as follows:

- I liked the positioning of the lights. I saw them 1,000 to 1,500 feet out from (before) the taxiway, and I appreciated the last light coinciding with the turnoff point.

IMPROVED TAXIWAY EXIT IDENTIFICATION

PILOT QUESTIONNAIRE

Name FAA Pilots Date _____ Aircraft Type Convair 580

Observed Visibility. (Mi) 600'RVR to 12 Mi VFR 1 or IFR 4

1. Did the green runway centerline lights provide significant assistance in positively identifying the exit taxiway location?
   Yes 5 No 0

   Comments See Text

2. In your opinion, would availability of color-coding such as this reduce the problem of identifying runway exits in low-visibility weather conditions?
   Yes 5 No 0

   Comments See Text

3. During the final approach, touchdown, or rollout, could the green runway centerline lights be misinterpreted as another airport lighting system or as an aircraft on the runway?
   Yes 0 No 5

   Comments See Text

THANK YOU!

FIGURE 7. PHASE 2 PILOT RESPONSES

- These lights are too low on touchdown and rollout to be mistaken for another aircraft, and there is no recognizable pattern to misinterpret on final.

- Lights were seen clearly before the taxiway turn stripe was seen, giving adequate warning of impending turn.

- RVR (800 feet) was such that the green coded segment helped significantly in locating the runway exit.

- Last green light was positioned ideally at the beginning of the yellow painted turn stripe.

- Much better, maybe a couple of extra lights would help, but definitely an improvement from the previous pattern.

- Provides excellent lead-in to taxiway entrance - turns were certainly facilitated using this configuration.

- Excellent - position allowed a normal turnoff from the runway onto the centerline of the taxiway. Much better than the original runs.

PHASE 3 TESTING.

Since only a small portion of the evaluation conducted during phases 1 and 2 had been accomplished under actual low visibility weather conditions, a decision was made to continue evaluation of the taxiway exit identification system using the FAA Aeronautical Center Flight Simulator in Oklahoma City. The prototype configuration, as modified after phase 1 testing, was programmed into the flight simulator visual display to identify three separate exit situations (figure 8) as follows:

- Exit 1 - 90 degree turnoff to the right.

- Exit 2 - greater than 90 degree turnoff to the left.

- Exit 3 - 90 degree turnoff to the left.

Subject pilots were once again fully briefed prior to the testing sessions and required to complete an evaluation questionnaire after each series of simulator exercises. The basic questionnaire form was again modified to include two additional questions concerning the adequacy of the simulator visual depiction of the green light segments and the impact of using the Heads-Up Display (H.U.D) during approaches in the lowest visibility condition (300-foot RVR).

Each pilot accomplished twelve simulated approaches with subsequent landings, rollouts on the runway, and attempts to exit at one of the three identified exits per instructions from the simulator operator. Simulated weather conditions of 1/2 mile, 1800-foot RVR, 1200-foot RVR, and 300- to 400-foot RVR visibilities were programmed into the simulator visual display, with all three exit situations presented to the subject pilots under each visibility condition.

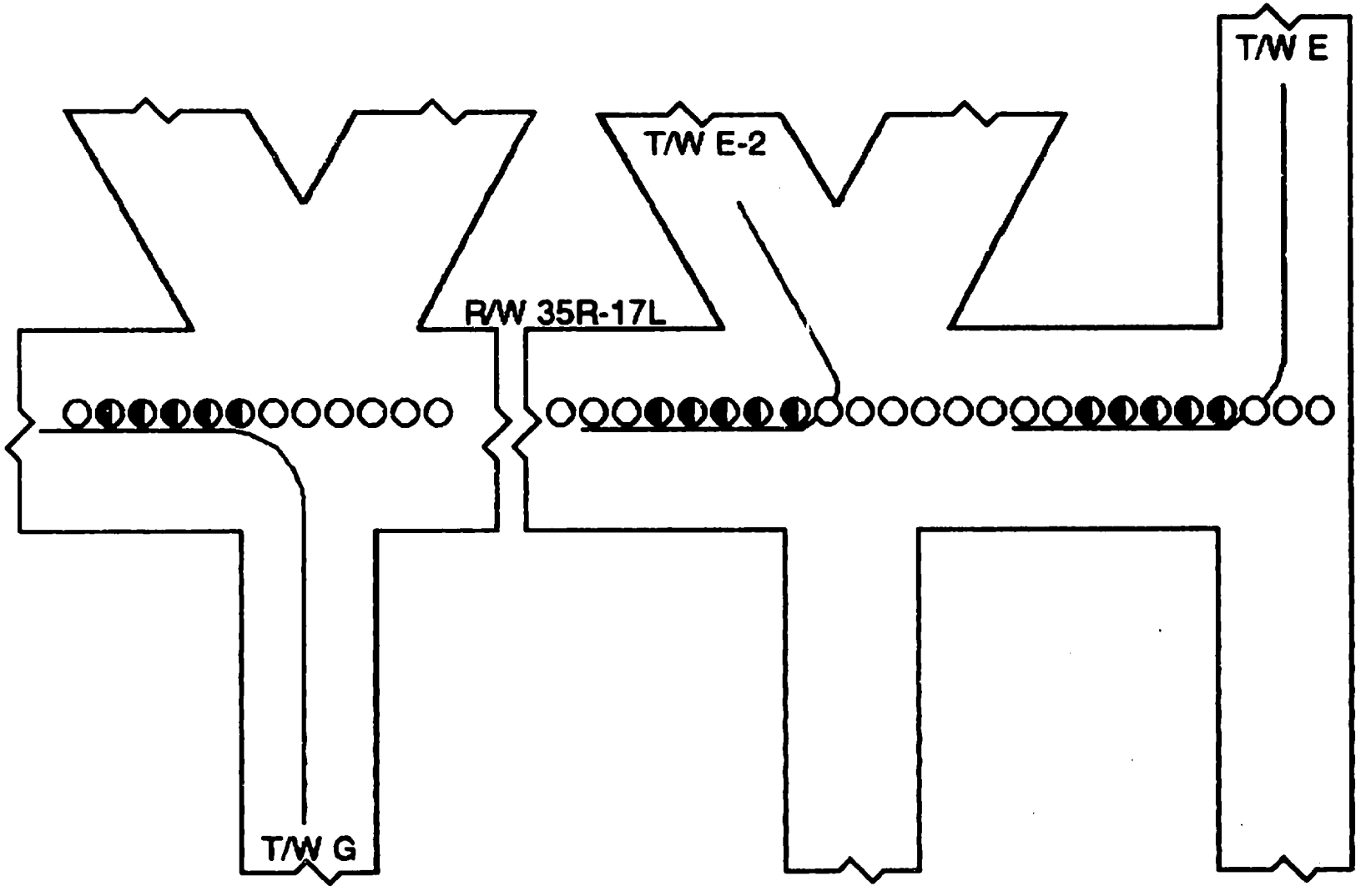

FIGURE 8. B-727 SIMULATOR CONFIGURATION

Pilot performance in executing the exit turnoffs in an acceptable manner was monitored and notations made on a test matrix recording sheet as to whether the exit was, or was not, successfully accomplished.

A total of eight subject pilots (five FAA test pilots, one airline captain, and two instructors) participated in this phase of testing.

Reference to the summarized questionnaire response sheet (figure 9) reveals that these pilots were unanimous in judging the exit identification system to be effective in providing warning of exit location (questions 1 and 2). They also indicated that they felt that there should be little or no concern over the possibility of confusing this green light configuration with other lights or visual devices on the airport (question 3).

With regard to the adequacy, or realistic appearance, of the green light simulation (question 4), there is some concern evidenced that the green color was not portrayed vividly enough and that this may have diminished the effectiveness of the presentation. The summary of pilot comments speaks to this issue.

It is apparent that the majority of pilots (five out of seven) felt strongly that the H.U.D. presentation, or rather the appearance of visual system lights as viewed through it, leaves something to be desired (question 5). Here again, pilot comments elaborate on the problem.

As mentioned previously, pilot performance in successfully accomplishing the three different turnoff situations under varying levels of visibility restriction was recorded and is presented on the Test Matrix Record Sheet Summary (figure 10).

The objective pilot performance data correlates quite well with the subjective pilot questionnaire response data, in that only three instances of pilot failure to successfully identify the exit and execute the turnoff maneuver occurred. Each of these "failure" events was encountered at the lowest visibility condition presented to the subject pilots (300-foot RVR).

IMPROVED TAXIWAY EXIT IDENTIFICATION

PILOT QUESTIONNAIRE

Name FAA & Carrier Pilots Date _____ Aircraft Type OKC B-727 Simulator

Observed Visibility. (Mi) 300'RVR to 1/2 Mi VFR ___ or IFR 8

1. Did the green runway centerline lights provide significant assistance in positively identifying the exit taxiway location ?
   Yes 8 No 0

   Comments See Text

2. In your opinion, would availability of color-coding such as this reduce the problem of identifying runway exits in low-visibility weather conditions? Yes 8 No 0

   Comments See Text

3. During the final approach, touchdown, or rollout, could the green runway centerline lights be misinterpreted as another airport lighting system or as an aircraft on the runway? Yes 0 No 8

   Comments See Text

4. Are the simulated green lights adequate for testing purposes?
   Yes 6 No 2

   Comments See Text

5. Did the H.U.D. have any impact on the effectiveness of the green lights?
   Yes 5 No 2

   Comments See Text

FIGURE 9. PHASE 3 PILOT RESPONSES

IMPROVED TAXIWAY EXIT IDENTIFICATION

PILOT PERFORMANCE TEST MATRIX

PILOT VIS.	EXIT TYPE	1	2	3	4	5	6	7	8
1/2 MILE	90 R	YES	YES	YES	YES	YES	YES	YES	YES
1/2 MILE	90+L	YES	YES	YES	YES	YES	YES	YES	YES
1/2 MILE	90 L	YES	YES	YES	YES	YES	YES	YES	YES
1800' RVR	90 R	YES	YES	YES	YES	YES	YES	YES	YES
1800' RVR	90+L	YES	YES	YES	YES	YES	YES	YES	YES
1800' RVR	90 L	YES	YES	YES	YES	YES	YES	YES	YES
1200' RVR	90 R	YES	YES	YES	YES	YES	YES	YES	YES
1200' RVR	90+L	YES	YES	YES	YES	YES	YES	YES	YES
1200' RVR	90 L	YES	YES	YES	YES	YES	YES	YES	YES
300'* RVR	90 R	YES	YES	NO	YES	NO	NO	YES	YES
300'* RVR	90+L	YES	YES	YES	YES	YES	YES	YES	YES
300'* RVR	90 L	YES	YES	YES	YES	YES	YES	YES	YES

90 R - 90 Degree Turnoff to the Right
90+L - Greater than 90 Degree Turnoff to the Left
90 L - 90 Degree Turnoff to the Left

YES - Exit Identified and Turnoff Successful
NO - Exit Not Identified and No Turnoff Accomplished

* - 400' RVR Programmed for Pilots 1 and 2 only

FIGURE 10. TEST MATRIX RECORD SHEET SUMMARY

Since, in this phase of testing, five of the eight subjects were experienced FAA test pilot evaluators, written questionnaire comments were profuse. As before, the comments provided below are not necessarily direct quotations but do retain the essential content of the originals:

- The green lights definitely help, but there will have to be some indication on an approach plate that the lights are available (i.e., need for pilot education).

- The color-coding at the end of the runway (all red with green exit lights) was extremely effective. Even at the lowest visibility the contrasting colors were apparent for exit guidance.

- Very effective at higher visibilities, i.e., at 1/2 mile and 1800 RVR, but effectiveness diminishes gradually with lowering visibility. At 300 RVR, the painted line was more effective than the green lights.

- The lights were very helpful in giving advance indication of the turnoff.

- No real help at 1/2 mile, but very good from there on in the lower visibilities.

- Maybe one red light before the start of the green lights would be helpful, for better contrast in low visibilities.

- Of significant assistance down to 1800 RVR but less effective at 1200 and 300 RVR with H.U.D. use.

- Green light simulation adequate, except for the 300' RVR condition. It appears that the step-b selection is not representative of real fog conditions.

- Green lights very hard to pick out at 300' RVR while using the H.U.D.

- The green phosphors of the H.U.D. apparently affect the eye's response to the "quasi-green" exit lights, making them virtually undetectable.

DISCUSSION

Results of the three phases of testing are relatively straight forward and lead reasonably to the reported conclusions. Some issues, however, surfaced during the conduct of the development and evaluation effort that deserve mention and possible consideration in the event that the system concept is implemented.

Concern that there was a deficiency in contrast between the green lights of the exit identification system and the white (clear) lights of the normal runway centerline system was expressed on more than one occasion by subject pilots. There is no doubt that the green filters, even though of a dichroic type with a relatively high (50 percent) transmissivity value, reduce the actual intensity of that portion of the centerline visual presentation and have an adverse effect

on the visual acquisition range. On the other hand, and in spite of this apparent deficiency, the subject pilots almost unanimously judged the system to be most useful. The problem appears to be relatively minor and may well be corrected with a selection of more suitable (deeper hue) green filters.

Since the system tested was configured merely by installation of green filters in existing runway centerline fixtures, it would appear to have a somewhat limited application only on those Category II and III runways with already installed centerline systems. It would, in fact, be most economically emplaced on such runways, but the concept of green centerline segments for exit identification might also be applied to runways without centerline lights. Some caution should be exercised before committing to this additional application since a possibility exists that pilots might mistake these isolated green exit lights for position lights of an aircraft on the runway. Limited testing could establish whether such confusion should be anticipated.

Retrofitting short segments of green lights, by core drilling for shallow-base taxiway inset light fixtures and carrying the low voltage secondary power cables in saw cuts to transformers at the runway edge, should not prove unduly expensive nor necessitate extensive runway downtime. The prospect of using the green segments alone, and not in visual competition with a high intensity runway centerline lighting system, is particularly attractive in that the "contrast" problem mentioned earlier would no longer pertain.

CONCLUSIONS

Based on the results of this evaluation effort, it is concluded that:

1. The prototype enhanced taxiway exit identification system for normal exits was successfully developed and tested.

2. Air-carrier and FAA test pilot evaluational comments and simulator performance verified that the prototype system, as modified during the course of testing, was highly effective in providing advance identification of taxiway exit locations under nighttime and reduced visibility conditions.

3. Incorporation of the system concept on runways having existing centerline lighting systems would be extremely economical since it would require only the installation of inexpensive filters within selected centerline in-pavement fixtures.

4. If a determination that no possibility for user pilot confusion exists, the system could also be implemented on runways not equipped with centerline lights by installing segments of green in-pavement lights along the runway centerline as required.