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Evaluation of Retroreflective Pavement Markers for Precision and Nonprecision Runways

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Final Report

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16. Abstract

This project involved the evaluation of retroreflective pavement markers installed to duplicate the patterns of runway centerline and touchdown zone lighting systems used for Category II runways. The purpose was to (1) determine whether the markers could enhance nighttime visual guidance and reduce minimums for Category I precision or nonprecision approaches and (2) determine if such guidance could provide increased safety of operations, particularly under wet runway conditions. Flight tests were conducted at two airports, one with a 150- by 6,144-foot runway and the other 100 by 2,950 feet. The shorter runway required a scaled down or abbreviated touchdown zone and color coded runway centerline. Visual contact height with the retroreflective pavement marker systems was not enhanced prior to reaching Minimum Descent Altitude (MDA) or Decision Height (DH) for nonprecision or Category I approaches, respectively; therefore, this system will not permit the reduction in approach minimums for Category I precision or nonprecision approaches. However, the test program demonstrated that, in the opinion of a widely diversified sample of user pilots, the system is effective in improving the safety of operation for final approach, flare, touchdown, landing, rollout, and for takeoffs. Under rainy, wet nighttime conditions, the subject pilots felt that the pavement retroreflectors significantly enhanced visual guidance; supplementing that which is provided by the standard runway edge lights and paint markings. The abbreviated touchdown zone and centerline markers were effective, acceptable to the pilots, and offer an improvement in the safety of operations for critically short runways.

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METRIC CONVERSION FACTORS

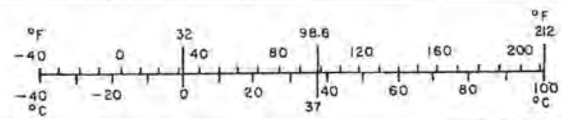
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

This project involved the evaluation of retroreflective pavement markers installed to duplicate the patterns of runway centerline and touchdown zone lighting systems used for Category II runways. The purpose of this evaluation was:

1. To determine whether runway pavement markers could enhance nighttime visual guidance and reduce minimums for nonprecision and Category I precision approaches.

2. To determine if such enhanced guidance could provide increased operational safety, particularly under wet runway conditions.

Under wet runway conditions the aircraft landing lights tend to reflect off the surface of the water instead of highlighting the white paint of the runway centerline and touchdown zone markings. It should be noted that the retroreflective markers are intended to supplement standard runway edge lights used for nonprecision and precision approach Category I runways and are not intended to replace touchdown zone and centerline lighting systems used for Category II runways.

An initial test phase was conducted at the Federal Aviation Administration (FAA) Technical Center's airport which was followed by an inservice test at Bader Field Airport, Atlantic City, New Jersey. Although an investigation was not initially planned, testing at Bader Field provided an opportunity to determine the suitability and pilot acceptance of a scaled down or abbreviated runway centerline and touchdown zone system suitable for short runways.

Flight tests to evaluate the retroreflective markers at both airports were conducted at night in visual flight rule (VFR) weather conditions and under reduced visibility conditions with rain and water accumulation on the pavement, using a cross section of pilot and aircraft types. The test runway at the Technical Center is a nonprecision approach runway, but with precision approach touchdown zone and centerline paint markings. A standard Visual Approach Slope Indicator (VASI), later replaced with a Precision Approach Path Indicator (PAPI) system, was used to provide a 3° visual glidepath on final approach. The Bader Field runway also has a nonprecision approach, but with standard nonprecision runway centerline paint markings (no touchdown zone paint markings). The lowest approved approach minimums are 700-foot ceiling and 1-mile visibility. Low clouds were frequently encountered at both airports during the low visibility and rain conditions. This limited the number of flights and the number of questionnaires in reduced visibility and rain conditions.

From the results of the visual contact height determination portion of the evaluation, it is concluded that installations of this type will not provide a basis for possible reduction of minimums for either Category I Precision or Nonprecision Approaches. Other flight evaluation results demonstrate that a diversified sample of pilots, flying a wide performance range of aircraft, rate the retroreflective pavement markers effective in VFR conditions at night. The markers also improve the safety of operations for the final approach, flare, touchdown, rollout, and takeoff maneuvers with visibilities greater than 1 mile and with standing rainwater obscurring the painted markings. It is further concluded that the markers can provide enhanced visual guidance to supplement that provided by standard runway edge lights. The marker system reduces the "black hole" effect by providing, under higher visibility (VFR) conditions, essentially the same visual cues as are obtained from the Category II in-pavement touchdown zone and centerline lighting systems. The retroreflective markers should not be considered as a suitable alternative or substitute for in-pavement lighting systems since the effectiveness of the markers is drastically reduced in the lower visibility (IFR) weather conditions.

It is further concluded that the scaled down or abbreviated touchdown zone and runway centerline pattern of retroreflective pavement markers for use on shorter runways were effective, acceptable to pilots, and offers an improvement in the safety of operations for shorter runways. Such runways may be near the critical length for many aircraft operating in reduced visibility and rain conditions. Acceptance of the shorter system of retroreflective markers could also provide the basis for adopting a reduced Category II lighting configuration standard for shorter length runways.

INTRODUCTION

The work described herein was accomplished in response to: (a) a request for Research, Development and Engineering (R,D&E) effort from the Associate Administrator for Aviation Standards and (b) a request for Engineering Support from the Airport Development Division, Systems Research and Development Service, now the Aircraft Safety and Airport Technology Division, Program Engineering and Maintenance Service. The latter office provided program direction and coordination under SRDS Program Number 071-500-01. The work was conducted under Technical Center Program Document Number 08-493, subprogram 081-502, project 520. The Project Manager was Guy S. Brown and the Technical Program Manager was Thomas H. Paprocki.

PURPOSE.

The project involved the evaluation of retroreflective pavement markers installed to duplicate the patterns of runway centerline and touchdown zone lighting systems used for Category II runways. The purpose of this evaluation was: (1) to determine whether runway pavement markers could enhance nighttime visual guidance and reduce minimums for Category I precision or nonprecision approaches, and (2) to determine if such enhanced guidance could provide increased operational safety, particularly under wet runway conditions.

It should be noted that the retroreflective markers are intended to supplement standard runway edge lights used for nonprecision and precision approach Category I runways and are not intended to replace touchdown zone and centerline lighting systems used for Category II runways.

BACKGROUND.

Runway paint markings in good condition provide visual daytime guidance even when the visibility is significantly less than 2400 feet runway visual range (RVR). At night, however, those same runway markings provide only minimal guidance and still less guidance when there is water standing on the runway. Under such wet runway conditions, the aircraft landing lights tend to reflect off the surface of the water instead of highlighting the white paint of the runway marking surfaces.

Retroreflective pavement markers have been successfully used on highways for a number of years, and a substantial increase in usage has been noted in the past few years. Guidance is greatly improved by use of such markers in adverse weather conditions of rain and fog, as well as in good weather.

Pavement markers have been evaluated previously at the Federal Aviation Administration (FAA) Technical Center for use on small or secondary airport runways under visual flight rule (VFR) conditions (references 1 and 2). Testing was not conducted under reduced visibility conditions or with rain or water on the runway. Also, the installations did not include retroreflective markers in the touchdown zone configuration.

It is noted that even though the use of clear and color coded runway centerline retroreflective markers has been approved for some time (references 3, 4, and 5), they have not been extensively used. Also, they have not been evaluated in conjunction with markers in the touchdown zone to be used as a system, as with inpavement lighting systems used for Category II runways.

DISCUSSION

TEST PROGRAM.

Tests were initially conducted at the FAA Technical Center's Atlantic City Airport, followed by an inservice test at Bader Field Airport, Atlantic City, New Jersey. Tests at the Technical Center utilized a full 3000-foot touchdown zone and runway centerline marker system as defined in the FAA Advisory Circulars for touchdown zone and runway centerline inpavement lighting and reflective markers for runway centerlines, see appendix A and reference 5. In addition to the flight test evaluation, this installation also provided the opportunity to observe maintenance considerations under normal usage and snow plowing operations.

The inservice tests at Bader Field served to determine the suitability and pilot acceptance of a scaled down or abbreviated centerline and touchdown zone system suitable for a short runway of about 3000-foot length. Such systems for shorter runways are not covered in the current Advisory Circulars. Although an investigation of shorter systems was not initially planned, pilot acceptance of such an installation could support a recommendation for such a standard to be included in appropriate future Advisory Circulars.

The installation, flight test evaluation, and test results will be described individually and combined as appropriate for the initial tests at the Technical Center and for the testing at Bader Field.

DESCRIPTION OF RETROREFLECTIVE MARKERS.

A retroreflective pavement marker (figure 1) consists of an acrylic plastic shell fitted with a potting compound and having overall dimensions of 4 inches by 4 inches by 0.75 inch high. Two sides have sloping surfaces with one or two prismatic reflective faces, as required, to reflect incident light in single or dual directions. The area of each reflecting surface is 3.25 square inches. The unit

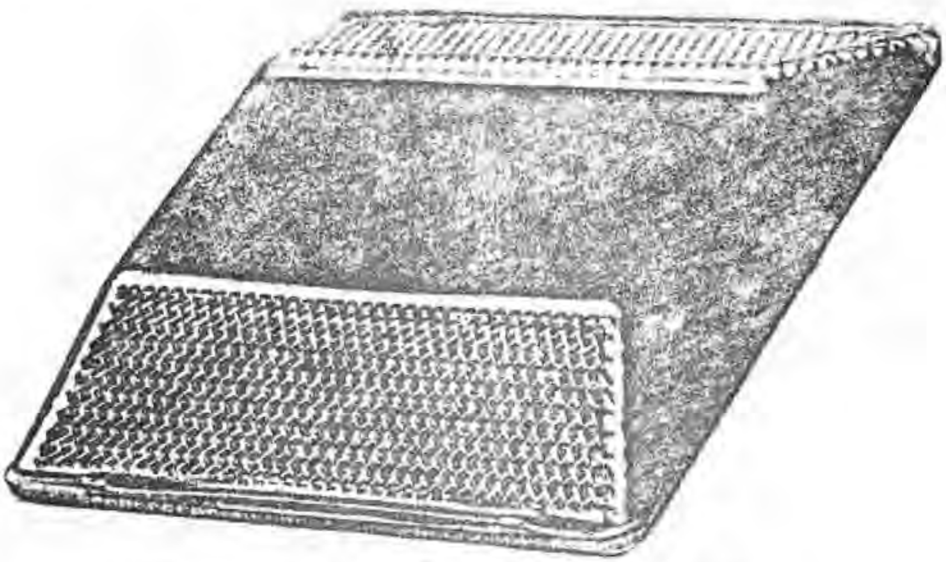

FIGURE 1. RETROREFLECTIVE PAVEMENT MARKER

used for this evaluation was the Stimsonite™ Model 911 Marker which is the basic Model 88 modified by the company to provide an improved abrasion resistant surface. Surface modification is accomplished by adding a thin layer of untempered glass bonded to the prismatic reflective face. The Model 88 retroflective marker is listed under Federal Aviation Administration (FAA) Approved Airport Lighting Equipment and Specification L-853 (references 3 and 4). The Model 911 has been approved recently and should be listed with the next revision.

INSTALLATION OF RETROREFLECTIVE MARKERS.

FAA TECHNICAL CENTER AIRPORT. The retroreflective markers were installed on runway 4-22 at the FAA Technical Center, Atlantic City Airport, New Jersey. The spacing and colors used were the same as those specified for runway centerline and touchdown zone lighting systems in accordance with FAA Advisory Circular Number 150/ 5340-4C, "Installation Details for Runway Centerline and Touchdown Zone Lighting Systems." See appendix A for description and layout details. Bidirectional markers were spaced at 50-foot intervals on the 6,144-foot runway centerline with color coding for distance information on the last 3,000 feet. In this 3,000-foot zone, the bidirectional markers were installed to provide alternate red and white markers for 2,000 feet and all red for the last 1,000 feet; the same pattern was used on the opposite end. Hence, white or clear markers were provided on the first 3,144 feet of the runway centerline and color coding was provided on the remaining 3,000 feet in both directions. This conforms to the standard as specified in FAA Advisory Circular, Number AC 150/5340-20, "Installation Details and Maintenance Standards for Retroreflective Markers for Airport Runway and Taxiway Centerline" (reference 5).

The retroreflective markers in the touchdown zone, the first 3,000 feet of runway 4, were unidirectional white or crystal and were installed so as to be visible only from the direction of approach and landing. Three markers spaced laterally 5 feet apart were located on each side of the runway, with the inboard markers 34 feet on each side of the centerline. The first set of three markers on each side of the centerline was located 100 feet from the runway threshold. Subsequent sets were located at 100-foot intervals for a total of 3,000 feet, thus providing rows of retroreflective markers on each side of the runway centerline, with a gauge of 68 feet between the inboard markers. The spacing or gauge of 68 feet is within the specification limits for both touchdown zone lighting and paint markings.

BADER FIELD AIRPORT. The retroreflective pavement markers were installed on runway 11-29, the only active runway during the test period at Bader Field Airport, Atlantic City, New Jersey. The touchdown zone and color-coded runway centerline systems, previously described, were scaled down or abbreviated to accomodate installation on the 100-by 2,950-foot runway.

The length of the touchdown zone was reduced to 1,000 feet, approximately one-third of the runway length. With a runway width of 100 feet, the lateral spacing or guage of the touchdown zone was reduced to 50 feet, i.e., 50 feet between the inboard markers. The standard 5-foot lateral spacing was maintained between the sets of three markers on each side of the runway centerline. These standards are shown in appendix A. Also, as prescribed in appendix A (AC 150/5340-4C), the first set of three markers on each side of the centerline was located 100 feet from the runway threshold and subsequent sets were located at 100-foot intervals, thus providing rows of retroreflective markers on each side of the runway centerline extending 1,000 feet from the runway threshold. These retroreflective markers were unidirectional white or crystal in color and were installed on each end of the runway so as to be seen only from the direction of approach and landing on runway 11 or 29. The standard or approved spacing and color coding of the runway centerline markers were maintained with one exception, the alternate red and white markers were installed from the midpoint of the runway to 1000 feet from the end. Thus, white or clear markers were provided on the first half of the runway centerline followed by alternate red and white markers and all red on the last 1000 feet as would be observed while operating in either direction.

FLIGHT TEST PROCEDURE.

FAA TECHNICAL CENTER AIRPORT. Flight tests to evaluate the retroreflective markers on runway 4 were conducted at night in VFR weather conditions and under reduced visibility conditions with rain and with water accumulation on the runway pavement. The test runway is a nonprecision approach runway with precision approach runway paint markings, including both centerline and touchdown zone markings. A standard Visual Approach Slope Indicator (VASI), later replaced with a Precision Approach Path Indicator (PAPI) system, was used to provide a 3° visual glidepath for final approach guidance.

The pilots participating in the evaluation consisted of a cross section of professional test pilots and general aviation pilots employed at the FAA Technical Center, plus volunteer professional and general aviation pilots, both locally based and transient. A cross section of aircraft ranging from small single engine to turbojet transport aircraft was included.

A total of 20 pilots participated in this phase of the evaluation, including one helicopter pilot. Of the 20 pilots, 6 were employed at the Technical Center; 4 as professional test pilots, and two were nonprofessional pilots with experience in the evaluation of visual aids. Of the remaining 14 pilots, 6 were classified as professional commuter or charter aircraft pilots.

BADER FIELD. The inservice flight tests to evaluate the retroreflective touchdown zone and color-coded runway centerline markers on runway 11-29 were conducted in VFR weather conditions and in reduced visibility conditions as low as 1 to 2 miles with rain and wet runway conditions.

The Bader Field runway was a nonprecision approach with standard nonprecision runway centerline paint markings (no touchdown zone paint markings), and the lowest approved approach minimums are 700 foot ceiling and 1-mile visibility. With the airport located near the ocean, low clouds were frequently encountered during the low visibility and rain conditions. This restricted the number of flight operations and, correspondingly, limited the number of responses to questionnaires under such weather conditions.

The pilots who participated at Bader Field were a cross section of volunteer professional commuter airline, charter and corporate pilots, and private general aviation pilots. The commuter airline and a few charter, corporate, and private pilots were based locally, while a majority were transient pilots. Four of the pilots were employed at the Technical Center, two as professional test pilots and two as nonprofessional pilots, all with previous experience in the evaluation of visual aids.

The total number of pilots participating is estimated at 65. A few pilots completed and returned multiple questionnaires for different weather conditions encountered, as was requested, resulting in 71 completed questionnaires.

VISUAL CONTACT HEIGHT DETERMINATION.

On final approach, the altitude at which the retroreflective markers were first seen by the FAA Technical Center pilots descending on a 3° glidepath was recorded. This data were not available from participating local and transient pilots. The small sample of data obtained does correspond, however, with that reported in previous test (reference 1). A listing of aircraft types which participated in the evaluation along with visual contact height data is shown in table 1 of the RESULTS section of this report.

POSTFLIGHT QUESTIONNAIRE RESPONSES.

FAA TECHNICAL CENTER AIRPORT. After each flight, the subject pilot completed a questionnaire and made comments on his evaluation of the guidance provided by the marker system. Also recorded on the questionnaire were the type aircraft, prevailing weather, and runway conditions (appendix B). Of the local and transient pilots, it is estimated that about 40 percent were briefed to some extent prior to their flight. The remaining pilots were not briefed and probably were not aware of the markers and evaluation until after their arrival when they were given a copy of the questionnaire.

Six responses to the questionnaire were received for operations in rain and wet runway conditions with visibility conditions as low as 1 to 2 miles. Of the six responses, four were from professional FAA test pilots operating an Aero Commander and a Cessna 172 aircraft. The remaining two responses were from professional commuter and charter pilots operating a Piper Cheyenne turbo-prop and a DC-9 jet transport aircraft. The relatively low number of responses in rain conditions can be attributed to instrument weather conditions with clouds below published minimums, forcing the use of the ILS-equipped runway. An evaluation in visibility conditions as low as one-half mile would require use of a runway having a precision approach ILS system.

BADER FIELD. Questionnaires, along with a description of the touchdown zone and runway centerline systems and the overall purpose of the evaluation, were made available to all pilots by the airport commission and the local airport operator. The Allegheny Commuter Airline (operating De Havilland Twin Otter aircraft) also cooperated, and these pilots provided a preponderence of the completed questionnaires for operation in rain and wet runway conditions.

The questionnaire used for the Bader Field tests was essentially the same as that used for the tests at the Technical Center, allowing pooling of the test results. The 71 responses from Bader Field are shown in appendix C, and the pooled responses, from the Technical Center and Bader Field, are shown in appendix D.

As with the local and transient pilots who responded to the questionnaire at the Technical Center, it is estimated that about 40 percent of the pilots at Bader Field were briefed to some extent about the installation and evaluation prior to their flight. The remaining pilots were not briefed and generally were not aware of the markers and evaluation until seeing them on approach to the runway.

Thirteen responses to the questionnaire were made for operations in rain and wet runway conditions with visibility ranging from 1 to 2 miles. These conditions were about the same as encountered in the previous tests at the Technical Center. Of the Bader Field responses, six were from professional commuter airline pilots, three from charter pilots, and four from others. The preponderence of Bader Field operations were with De Havilland DHC-6 Twin Otter, Cessna 402, and other aircraft having wing-mounted landing lights and nose- or nosewheel-mounted taxi lights. The effect of the location and aiming of landing/taxi lights will be discussed under the test results.

The relatively small number of responses in rain conditions, as with the tests at the Technical Center, is attributed to instrument weather conditions with clouds or visibility below the published minimums for nonprecision approaches resulting in diversion of traffic to another airport. As previously mentioned, an evaluation with visibility conditions as low as one-half mile would require the use of a runway having a precision approach ILS system.

RESULTS

VISUAL CONTACT HEIGHT DETERMINATION.

Recorded heights at which pilots were able to first obtain meaningful guidance from the installed retroreflectors are shown in table 1. For the total of 31 recorded observations, an average contact height of 199.9 feet was calculated. Assuming a nominal glidepath angle of 3°, the aiming angle of the VASI system installed to provide vertical guidance to the participating pilots, the average distance from threshold, at which the pilots first sighted the retroreflector systems, was calculated to be just slightly less than one-half nautical mile (0.46 nmi).

All of the participating aircraft were equipped with nose- or nosewheel-mounted landing lights, which resulted in optimum light return from the retroreflectors to the pilot's eye. For aircraft also equipped with wing-mounted landing lights, the wing-mounted lights were used independently to determine the effectiveness of the retroreflectors. In each instance, the retroreflectors were not perceived by the pilot until the aircraft was over or past the runway threshold. This is because the design of the retroreflector is such that the reflected light is returned to or near the light source. The quantity of light returned toward the pilots eye is a function of the distance between the location of the light source and the pilot's eye. This distance is much greater in the case of the wing-mounted landing light than for that of the nose-mounted light, and accounts for the greatly reduced effectiveness of the retroreflector system under such conditions. Prototype retroreflector designs intended for use with wing-mounted landing lights have been tested, but have proven to be virtually useless for use with aircraft equipped with nose-mounted lights. These retroreflectors are not presently available in quantity.

As shown in table 1, the average visual contact height obtained during testing was 199.9 feet, the range of the observed and recorded contact heights varied from a minimum of 50 feet to a maximum of 275 feet. This was due to variations in pilot technique, wind, and resultant crab angles required to maintain runway centerline

TABLE 1. PARTICIPATING AIRCRAFT AND VISUAL CONTACT HEIGHT VALUES

TYPE AIRCRAFT	AVERAGE VISUAL CONTACT HEIGHT (Feet)	NUMBER OF OBSERVATIONS
Single Engine-Propeller		
Beech V35 Bonanza	N/R*	
Cessna 172	200*/***	4
Cessna 177	N/R***	
Cessna 182	N/R*/***	
Cessna 210	215*	7
Navion	N/R****	
Piper PA-28 series	145*	3
Piper PA-32 Saratoga/Six	N/R*	
Piper PA-38 Tomahawk	N/R*	
Twin Engine-Propeller		
Aero Commander 680	201*	10
Beech 55 Baron	233**	6
Bech B65 Queen Air	N/R**	
Beech King Air	50**	1
Cessna 402	N/R**	
De Havilland Twin Otter	N/R**	
De Havilland Dash 7	N/R**	
EMB-110	N/R**	
Mitsubishi MU-2	N/R**	
Piper PA-23 Aztec	N/R*	
Piper PA-31 Navajo	N/R*	
Piper PA-42 Cheyenne	N/R**	
Piper PA-44 Seminole	N/R*	
Multi-Engine Jet		
Boeing 727	N/R**	
Douglas DC-9-30	N/R**	
Helicopter		
H-52	N/R*	
All Recorded Aircraft	199.9	31

Average visual contact height data given only for aircraft flown by FAA pilots and for which height observations at contact height were recorded.

N/R - Transient A/C, Questionnaire Completed, Height not Recorded.

* Nose/nose gear mounted lights
** Wing and nose mounted lights
*** Wing mounted lights only
**** Main gear mounted lights

position, location of nose-mounted landing light and, finally, aiming of the landing light itself. Subject pilots were requested prior to the evaluation flights, to attempt to maneuver the aircraft so as to maintain the landing light illumination upon the runway whenever possible. Pilots in routine flight operations will probably not make this conscious effort to insure the most effective use of the retroreflector system, and, consequently, the visual contact heights achieved will probably be somewhat lower than those reported herein.

POSTFLIGHT QUESTIONNAIRE RESPONSES.

FAA TECHNICAL CENTER AND BADER FIELD AIRPORTS. The postflight questionnaire covered five specific topics:

1. The effectiveness of the markers during the approach, flare and touchdown, landing rollout, and during the takeoff.

2. The ability to decrab sufficiently early during the approach to illuminate the pavement markers with crosswind conditions.

3. The usefulness of the red/white and all red coded centerline markers in determining distance remaining on the runway.

4. Rating of the landing lights on the aircraft as to illumination/brightness and aiming.

5. The safety of operations with additional guidance provided by the retroreflective pavement markers during takeoff, approach, flare and touchdown, and landing rollout.

The results of the responses and pilot comments are summarized in appendix B and shown in tables 2 through 6. As noted in appendix B, there were 20 responses at the Technical Center under all of the weather conditions encountered. Of these, there were only six responses for operations in rain and wet runway conditions. There were 71 responses from Bader Field for all conditions and 13 in rain and wet runway conditions as shown in appendix C and the tables previously mentioned.

Combining the questionnaires from the Technical Center and Bader Field airports provides 91 responses under all of the various weather conditions encountered and 19 responses in reduced visibility conditions with rain and wet runway conditions. Summaries of these pooled responses from both airports are shown in the following tables (2 through 6), expressed in percentage of total responses as indicated. The question concerning rating of the aircraft landing/taxi lights was omitted in the Bader Field questionnaire; consequently, the results presented are from the Technical Center evaluation only.

The first question asked pilots to rate the operational effectiveness of the retroreflective markers (touchdown zone and runway centerline) during certain flight conditions. A summary of all responses is shown in table 2.

TABLE 2. OPERATIONAL EFFECTIVENESS

Flight Conditions	Responses With Rain Conditions		Responses Under All Conditions	
	Excellent to Good (percent)	Fair to Poor (percent)	Excellent to Good (percent)	Fair to Poor (percent)
Approach	58	42	69	31
Flare and Touchdown	89	11	89	11
Landing Rollout	100	0	95	5
Takeoff	100	0	98	2

For the approach phase, there were fewer "excellent to good" responses than for other phases of this question on the operational effectiveness of the markers. The lower response can be attributed to several factors, but primarily due to poorly aimed aircraft lights as indicated in the pilots' comments. The pilots' ability to recognize and to decrab the aircraft in crosswind conditions is another factor, as will be shown in the responses to the next question.

For the flare, touchdown and landing rollout, and takeoff phases of the flight, the responses were quite favorable, and, again, would be rated higher with better aiming of the lights on some aircraft. For the takeoff phase, most of the "no responses" noted in appendices B and C, can be attributed to those pilots who completed the questionnaire on arrival and had not experienced the takeoff situation. In summary on this aspect of the evaluation, the pilots found the markers to be very effective in providing useful visual guidance overall and, in particular, under the rain and wet runway conditions.

The second question asked the pilot whether, under the existing wind conditions, he was able to decrab the aircraft sufficiently early in the approach so as to illuminate the pavement markers with the aircraft landing lights. The responses are shown below in table 3.

TABLE 3. CROSSWIND OPERATIONS

REPORTED AT THE FAA TECHNICAL CENTER (ACY) AND BADER FIELD (AIY)

	Responses With Rain Conditions (percent)		Responses Under All Conditions (percent)	
	Yes	No	Yes	No
Ability To Decrab In Time	100	0	83	17

Some of the pilots could not respond to this question, since many landings did not have a crosswind condition which required a decrab maneuver. However, the majority of the pilots who experienced crosswind conditions responded positively. One pilot commented — "had to decrab much earlier than normal." This shows that, in crosswind conditions, pilots must learn to decrab by maneuvering the aircraft into a wing-down slip condition much earlier than normal in order to aim the lights toward the runway and illuminate the markers.

The third question asked the pilots whether they felt that the color-coded centerline markers on the last 3,000 feet of the runway at the Technical Center and on the last half of the runway at Bader Field provided significant guidance relative to runway distance remaining. The responses are shown in table 4.

TABLE 4. OPERATION WITH COLOR-CODED CENTERLINE

REPORTED AT THE FAA TECHNICAL CENTER (ACY) AND BADER FIELD (AIY)

	Responses With Rain Conditions (percent)		Responses Under All Conditions (percent)	
	Yes	No	Yes	No
Provided Guidance	100	0	90	10

Of the pilots who did not respond to the questionnaire, gave comments to indicate most were able to land and turnoff the runway before encountering the color-coded markers. When considering the "yes" responses from the larger aircraft using more than half of the runway, it is clearly shown that pilots consider the coding quite useful. This corresponds to data obtained in an earlier evaluation of the centerline system (reference 1).

The fourth question asked the pilots to rate the landing/taxi lights on his aircraft as to illumination or brightness and aiming. The responses are shown in table 5.

TABLE 5. RATING OF AIRCRAFT LIGHTS

REPORTED AT THE FAA TECHNICAL CENTER (ONLY)

	Responses With Rain Conditions		Responses Under All Conditions	
	Excellent to Good (percent)	Fair to Poor (percent)	Excellent to Good (percent)	Fair to Poor (percent)
Illumination/ Brightness	67	33	75	25
Aiming	83	17	79	21

As noted in the pilots' comments (appendix E), several pilots indicated that their lights were aimed low. As noted in reference 1, the effectiveness of the markers, in addition to proper aiming, is a function of the intensity and location of the light relative to the pilot's line of vision. The further the light is displaced from the pilot's line of vision, the less light is reflected to the pilot's eyes. Consequently, aircraft lights mounted on the wing, some 15 to 20 feet from the pilot's eye, are ineffective. It is believed that few aircraft are equipped with wing lights alone, and that most later model aircraft have lights mounted in the nose, on the nose wheel, or on the wing root. The location of the lights of the participating aircraft is shown in table 1.

The fifth and final question asked whether the additional guidance provided by the retroreflective markers, considering the weather conditions encountered, improved the safety of operations during certain flight conditions; responses are listed in table 6.

TABLE 6. IMPROVED SAFETY OF OPERATIONS

REPORTED AT THE TECHNICAL CENTER (ACY) AND BADER FIELD (AIY)

Flight Condition	Responses With Rain Conditions (percent)		Responses Under All Conditions (percent)	
	Yes	No	Yes	No
Takeoff	89	11	92	8
Approach	63	37	81	19
Flare & Touchdown	89	11	94	5
Landing Rollout	100	0	99	1

With respect to the question on improving safety on takeoff, it is noted again that several pilots did not respond to this question, as shown in the appendices, since they completed the questionnaire on arrival without exposure to the takeoff situation. Nevertheless, a significant majority of the pilots who responded said that the additional guidance provided by the markers improved the safety of operations during takeoff.

For the approach, the previously noted problems with respect to aircraft lights and pilots' techniques, resulted in poor illumination of the markers on final approach and fewer positive responses. The fewer positive responses, particularly during rain and water on the runway, are attributed to the type aircraft operating in these conditions. Many of these responses came from pilots operating aircraft, such as the commuter airline Twin Otter, with wing-mounted landing lights and a nose- or nose-strut-mounted taxi light. As previously mentioned, wing-mounted lights are ineffective and the taxi light is adversely aimed due to the pitch attitude of these aircraft on final approach and during the flare and touchdown. Even considering these aircraft, almost two-thirds of the pilots who provided responses in rain and wet runway conditions felt that the markers improved the safety of operations during the approach.

For the critical flight conditions of flare and touchdown and landing rollout, a significant majority of the pilots said that the safety of operations was improved.

Obviously, the helicopter pilot did not respond to the question on landing rollout and did not flare and touchdown on the runway, but airtaxied, commenting that the retroreflective markers were "great on the taxiway."

INSTALLATION AND MAINTENANCE DETAILS.

Installation of the individual markers is relatively easy. For example, a team of five persons measured and marked the 3000-foot Bader Field runway in less than 4 hours in spite of frequent traffic interruptions. The individual markers were then installed at night, with the runway closed, in about 5 hours. Installation during the day would, of course, take less time. The markers were bonded to the pavement with a two-part epoxy applied to the pavement surface. Use of the cardboard pan having a marker template, furnished with the epoxy, facilitated mixing and application of the adhesive. The markers were aimed by eye so as to be parallel to the runway centerline. Curing time for the epoxy is dependent on ambient temperature and ranges from about 45 minutes at higher temperatures to two hours at a minimum permissable installation temperature of 58°.

Maintenance of the markers is dependent on the type of user aircraft and number of operations, and was considered minimal for the test runways. Heavier aircraft, which leave rubber tire marks or deposits on the pavement on touchdown and during heavy braking, will also leave deposits on the top of the markers and, to some extent, on the retroreflective face. Small aircraft leave few, if any, rubber deposits. Other damage consisted of a few markers that separated from the pavement for reasons unknown, but possibly due to poor bonding or having been struck by airport equipment not having rubber tires or wheels.

Rubber deposits were removed from the markers on the Technical Center runway in about 2 manhours. The rubber deposits were, for the most part, confined to the centerline markers in the touchdown area and near the end of the runway. This accumulation resulted from approximately 2 years' use, with most of the accumulation occurring during a period of 6 months while the runway was not restricted to aircraft under 12,500 pounds. The abrasive-resistant glass face covering the retroreflective surface greatly facilitated removal of the rubber deposits. The rubber was readily removed with either a razor blade or by use of a wire brush powered by an electric drill. No chemicals were found that would readily dissolve the rubber, particularly when the deposits were heavy.

Even though the markers evaluated were not designed to be resistant to snowplows, the runway at the Technical Center was plowed with equipment having rubber ground contact edges on the blades. Little, if any, damage was done by the rubber-tipped blades. However, some plows incorporate steel dolly wheels mounted behind the blade, from which damage resulted. Of the total 475 installed markers, 36 were replaced. About the same number, though damaged, did not require replacement since the damage was not on the retroreflective surface. (It has been reported that some highways on Long Island, New York, are fitted with this type marker, and that plowing with rubber blades has been successful for several seasons.) Snow-plowing without appropriate rubber-tip blades will remove markers from the pavement and, with blacktop pavement, 1/8- to 1/4-inch of the pavement may adhere to the epoxy base upon separation.

Testing of snowplow-resistant retroreflective markers, designed for installation with special protective steel sideguards, was not conducted and may be considered later, depending upon whether or not the use of markers appears sufficiently advantageous to justify the expense. In addition to the cost of the metal guard, the installation is more expensive, since a cutout must be made in the pavement to accommodate the guard containing the reflector. Markers designed to allow snowplow blades to ride over the units without damaging either blades or markers have been extensively tested and successfully used on highways in several states for a number of years. The specifications for snowplowable markers to be used for runways and taxiways are contained in reference 4.

CONCLUSIONS

Results of the visual contact height determination portion of the evaluation effort indicate that pilots will not, with any degree of reliability, be afforded significant guidance from the runway retroreflector systems prior to or upon reaching the minimum descent altitudes (MDA) associated with nonprecision approach instrument flight operations (250 feet above ground level (AGL) or more). Likewise, the retroreflector system will not afford any significant visual guidance to the majority of pilots conducting a Category I Instrument Landing System (ILS) instrument approach before they have reached the minimum decision height (DH) of 200 feet AGL. In fact, the reduced visibility weather conditions of one-half nautical mile that may be encountered during Category I instrument approach will considerably reduce the ranges at which the retroreflector systems can be expected to be effective from those values attained during the conduct of this evaluation. It is concluded, therefore, that installations of this type of retroreflective system will not provide a basis for possible reduction in either Category I precision or other nonprecision approach minimums.

Even though instrument approach minimums may not be reduced, the results of this evaluation demonstrate that a diversified sample of pilots, flying widely different aircraft, and using a 6,000-foot runway and a shorter 3,000-foot runway, rate retroreflective runway pavement markers effective in improving the safety of the operations for final approach, flare and touchdown, landing rollout, and for takeoff. The most critical visual guidance condition at nighttime may be one with rainwater on the runway tending to obscure the paint markings. For rain conditions with visibilities above 1 mile, as well as for better nighttime visibility conditions, it is concluded that the retroreflective markers on the pavement can provide enhanced visual guidance to supplement that provided by standard runway edge lights. The marker system reduces the "black hole" effect by providing, under higher visibility (VFR) conditions, essentially the same visual cues as are obtained from the Category II in-pavement touchdown zone and centerline lighting systems. The retroreflective markers should not be considered as a suitable alternative or substitute for in-pavement lighting systems, however, since the effectiveness of the markers is drastically reduced in the lower visibility (IFR) weather conditions.

It is further concluded that the scaled down abbreviated touchdown zone and runway centerline systems of retreflective pavement markers for use on shorter runways was effective, and, in the opinion of the user pilots, offers an improvement in the safety of operations for shorter runways. Such runways may be near the critical length for many of the aircraft operating under reduced visibility and rain conditions. The favorable results obtained using of the abbreviated system for runway centerline and touchdown zone markers could also provide the basis for adopting a reduced lighting configuration standard for shorter length Catefory II runways.

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1. Twichell, N. H. and Phillips, C. P., Testing of Reflective Markers for Indicating the Threshold and Centerline of Runways for Small Airports, Report No. FAA-RD-66-71, NAFEC, FAA/DOT, September, 1966.

2. Brown, G. S., Evaluation of Retroreflective Taxiway Edge Markers, Report No. NA-79-44-LR, NAFEC, FAA/DOT, July 1979.

3. FAA/DOT, Advisory Circular No. AC: 150/5345-1F, Approved Airport Lighting Equipment, FAA/DOT, January 16, 1981.

4. FAA/DOT, Advisory Ciruclar No. AC: 150/5345-39B, FAA Specification L-853, Runway and Taxiway Retroreflective Markers, December 9, 1980.

5. FAA/DOT, Advisory Circular No. AC: 150/5340-20, Installation Details and Maintenance Standards for Reflective Markers, February 17, 1969.

APPENDIX A

Excerpts From Advisory Circular No. 150/5340-4C, dated May 6, 1982

"INSTALLATION DETAILS FOR RUNWAY CENTERLINE AND TOUCHDOWN ZONE LIGHTING SYSTEMS"

"1. INTRODUCTION. The runway centerline and touchdown zone lighting systems are designed to facilitate landings, rollouts, and takeoffs. The touchdown zone lights are primarily a landing aid, while the centerline lights are intended to provide after-touchdown rollout and takeoff guidance.

"2. BACKGROUND. These lighting systems were developed to be used in conjunction with electronic precision approach aids and the standard approach lighting systems under limited visibility conditions. Installation techniques described here can be applied to similar semiflush lighting installations.

"3. CONFIGURATION.

a. Runway Centerline Lighting. (See Figure 1 for general layout)

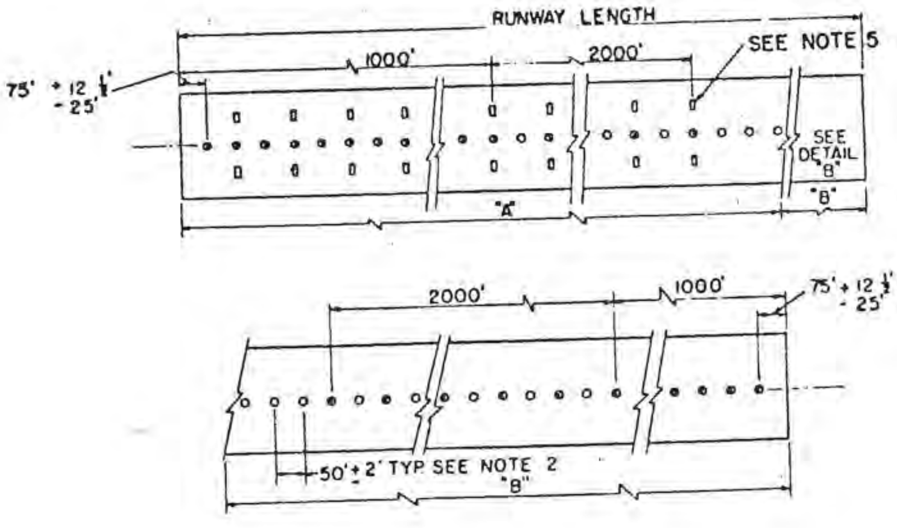
(1) Spacing. Install the single lights along the runway centerline in a straight line. Space the light fixtures at 50-foot intervals. Locate the first centerline light 75 feet from the landing threshold. Extend these lights to a similar point at the opposite end of the runway. Offset the line of lights 2 feet (maximum) to the right or left of the designed centerline to avoid the painted stripe. The offset should be to the opposite side of the centerline from the major taxiway turnoffs.

(2) Color Coding. Use color coding on the end 3,000-foot portions of the runway centerline lights as shown on Figure 1. Provide alternate red and white lights as seen from the 3,000-foot to the 1,000-foot points, and all red lights for the last 1,000-foot portion of the runway centerline lighting system.

b. Touchdown Zone Lighting. (See Figure 2 for general layout)

(1) Longitudinal Spacing. Provide the runway touchdown zone lighting system with rows of transverse light bars located symmetrically about the runway centerline. Each light bar consists of three unidirectional lights facing the threshold. Extend the system for a distance of 3,000 feet along the runway. Reduce this basic length to one-half the runway length for those runways less than 6,000 feet. Locate the first pair of light bars 100 feet from the landing threshold, followed by each succeeding pair at 100-foot intervals to the end of the system.

(2) Lateral Spacing. See Figure 2."



DETAIL "B"

SYMBOLS

▯ — Unidirectional touchdown zone light bar, 3 lights per bar

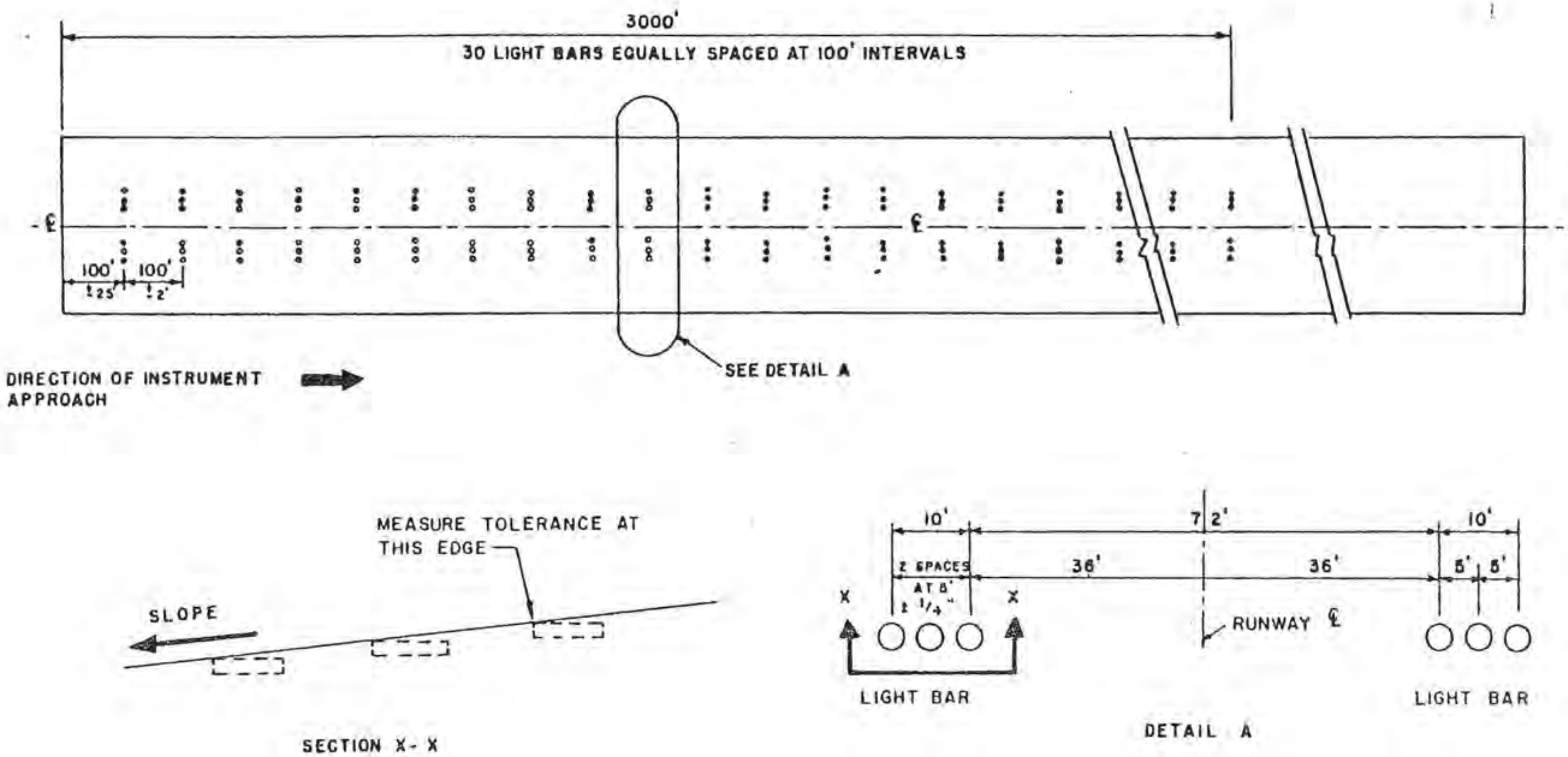
o — Bidirectional runway centerline light white both directions

r ⊙ w — Centerline lights white (w) one direction and red (r) opposite direction.

NOTES

1. Centerline lights may be offset 2' to the right or left of the runway centerline to avoid the centerline paint markings.
2. The centerline lights may have a longitudinal tolerance of ± 2', a lateral tolerance of ± 1/4".
3. The last 3000 - foot to 1000 - foot section of the runway centerline displays an alternate red and white light signal.
4. The last 1000 - foot section of the runway centerline displays an all red signal.
5. The touchdown zone light bars are not required to be located at the same stations as the centerline lights. See figure 2 for configuration.

FIGURE A-1. RUNWAY CENTERLINE LIGHTING LAYOUT



NOTES

1. THE LONGITUDINAL INSTALLATION TOLERANCE IN LOCATING THE PAIRS OF TRANSVERSE LIGHT BARS SHOULD NOT EXCEED 2 FEET. LATERAL TOLERANCE OF LIGHTS IN A BAR IS $\pm \frac{1}{4}$"

2. THE SPACING BETWEEN THE INNERMOST TOUCHDOWN ZONE LIGHT FIXTURES SHOULD BE UNIFORM THROUGHOUT THE LENGTH OF THE SYSTEM. THIS SPACING IS 72 FEET EXCEPT WHERE CONSTRUCTION PROBLEMS PREVENT THIS SEPARATION. IN THIS CASE, THE UNIFORM SPACING IS REDUCED TO NOT LESS THAN 65 FEET.

FIGURE A-2. TOUCHDOWN ZONE LIGHTING LAYOUT

APPENDIX B

PILOT BRIEFING
EVALUATION OF RETROREFLECTIVE PAVEMENT MARKERS
FOR PRECISION AND NONPRECISION RUNWAYS
PROJECT 081-502-520

The objective is to determine if retroreflective pavement markers, installed to duplicate runway centerline and touchdown lighting, will enhance nighttime visual guidance to provide increased safety of operations and possible reductions in Category I and nonprecision approach minimums, particularly under wet runway conditions.

Flights will be conducted in VFR and reduced visibility conditions as low as 1/2 mile, if practicable, with rain, fog, and/or wet runway conditions and with crosswinds ranging from minimum to maximum, to the extent possible.

From the threshold or takeoff position on runway 4, the distance or number of retroreflective markers and the number of paint marking stripes that can be observed when illuminated by the aircraft lights will be recorded with the aircraft:

(a) Aligned with the runway centerline (C/L); and

(b) Aligned midway between the C/L and TDZ (touchdown zone) markers.

After takeoff, four approaches and landings will be made, weather and other conditions permitting. The first approach with a touch-and-go landing should be made with the aircraft aligned with the runway C/L; the second and third to the left/right of C/L; and the fourth, a full stop aligned with the C/L and roll-out to the end of the runway. For comparison purposes, a takeoff and landing can be made on a runway without markers.

The first three approaches will be made on a 3-degree glide slope using a "Two Box PAPI" visual glidepath system. As with the standard VASI, a red and a white signal is "on glidepath;" two red signals indicate "low;" and two white signals indicate "high" on the glidepath. The system will be turned off for the fourth and final approach to allow you to make a steeper approach path if desire.

On each approach, you will be asked to call-out when you have the green threshold lights in sight with the altitude (above field level). Another call-out with altitude when you first see the retroreflective markers on the pavement and, when operating in a crosswind, when the aircraft is decrabbed, and the lights are aimed toward the runway. The retroreflective markers cannot be seen, of course, unless they are illuminated.

You will be asked to judge the quality of visual guidance obtained from the visual aids and to complete a post-flight questionnaire after each flight. Please review these questions before each flight. If possible, we would like to have each pilot make additional flights in the same type with different weather conditions.

Attention: All Pilots

EVALUATION OF RETROREFLECTIVE RUNWAY PAVEMENT MARKERS

Runway 4/22, Atlantic City Airport (ACY)

Retroreflective runway pavement markers, similar to those used on highways, have been installed on Runway 4/22 for evaluation by the FAA Technical Center's Airport Technology Division.

The evaluation is to determine whether the retroreflective markers provide improved visual guidance to aid the pilot and improve the safety of nighttime operations, particularly during reduced visibilities with rain, fog and wet runway conditions.

Taxiway Exit Markers. Installed on Runway 4 as an aid in identifying the exit at Taxiway Bravo and on Runway 22 as an aid in identifying Taxiways Bravo and Delta.

Runway Centerline and Touchdown Zone Markers. Installed on Runway 4 (to duplicate the standard runway centerline and touchdown zone lighting configuration used for runways approved for Category II operations), as an aid for takeoff, approach, landing and rollout on the runway.

Completion of the attached questionnaires would be gratefully appreciated. Please return to the box located on the Operations Desk.

Thank you for your cooperation.

Summary of All Responses

EVALUATION OF RETROREFLECTIVE RUNWAY PAVEMENT MARKERS

Runway 4/22, Atlantic City Airport (ACY)

Type and Model Aircraft ________________ Date ________________

Location of Taxi/Landing Lights Used: Wind CALM to 010/15G22

Nose 14 only Wing 0 only Both 6 Other ______ Pavement: Wet 6 Dry 14

Visibility:

<1 Mile ___ 1 to 2 Miles ___ 2 to 3 Miles ___ >3 Miles 20

Precipitation/Visibility Restrictions:

Rain 6 Snow ___ Fog ___ Haze or Smoke ___ None 14

Exit Taxiway Retroreflectors

~~Runway Used: Taxiway Used to Exit Runway:~~

~~Rwy. 4 ___ Rwy. 22 ___ T/W Bravo ___ T/W Delta ___~~

~~How much help were the reflective markers in finding the exit taxiway?~~

~~No Help ___ Some Help ___ Great Help ___~~

Centerline and Touchdown Zone Retroreflectors

For the type aircraft and weather conditions experienced, please answer the following questions.

1. Please rate the effectiveness of the markers during the:

a. Approache Excellent 5 Good 8 Fair 4 Poor 3
b. Flare & Touchdown Excellent 14 Good 4 Fair 2 Poor 0
c. Landing Rollout Excellent 15 Good 4 Fair 1 Poor 0
d. Takeoff Excellent 12 Good 4 Fair 0 Poor 0 NoResp. 4

Comments:

2. During crosswind conditions, were you able to decrab sufficiently early during the approach to illuminate the pavement markers?

a. Yes 10 No 1 No Response 9
Comments:

Continued on next page.

3. Did you find the red/white and all red coded centerline markers useful in determining distance remaining on the runway?

Comments: Yes 14 No 0 No Response 6

4. How would you rate the landing lights on your aircraft as to:

a. Illumination/ Brightness — Excellent 7 Good 8 Fair 5 Poor 0

b. Aiming — Excellent 7 Good 8 Fair 1 Poor 3 NoRep 1

5. Considering the weather conditions encountered, do you feel that the additional guidance provided by the retroreflective markers improved the safety of operations during:

	Yes	No	No Response
a. Takeoff?	13	1	6
b. Approach?	11	6	3
c. Flare & Touchdown	19	0	1
d. Landing Rollout?	18	0	2

Comments:

Please include any additional comments or remarks:

Name ______________________

(Optional)*
Organization* ______________________

*Name and Organization will not be used when test results and comments are reported.

Summary of Responses With Rain/Wet Runway Conditions

EVALUATION OF RETROREFLECTIVE RUNWAY PAVEMENT MARKERS

Runway 4/22, Atlantic City Airport (ACY)

Type and Model Aircraft ______ Date ______

Location of Taxi/Landing Lights Used: Wind ______

Nose 4 only Wing 0 only Both 2 Other 0 Pavement: Wet 6 Dry ___

Visibility:

<1 Mile ___ 1 to 2 Miles ___ 2 to 3 Miles ___ >3 Miles 6

Precipitation/Visibility Restrictions:

Rain 6 Snow ___ Fog ___ Haze or Smoke ___ None ___

Exit Taxiway Retroreflectors

~~Runway Used:~~ ~~Taxiway Used to Exit Runway:~~

~~Rwy. 4 ___ Rwy. 22 ___ T/W Bravo ___ T/W Delta ___~~

~~How much help were the reflective markers in finding the exit taxiway?~~

~~No Help ___ Some Help ___ Great Help ___~~

Centerline and Touchdown Zone Retroreflectors

For the type aircraft and weather conditions experienced, please answer the following questions.

1. Please rate the effectiveness of the markers during the:

a. Approach	Excellent 2	Good 3	Fair 1	Poor 0
b. Flare & Touchdown	Excellent 4	Good 2	Fair 0	Poor 0
c. Landing Rollout	Excellent 5	Good 1	Fair 0	Poor 0
d. Takeoff	Excellent 3	Good 3	Fair 0	Poor 0 No Resp. 4

Comments:

2. During crosswind conditions, were you able to decrab sufficiently early during the approach to illuminate the pavement markers?

a. Yes 4 No 0 No Response 2

Comments:

Continued on next page.

3. Did you find the red/white and all red coded centerline markers useful in determining distance remaining on the runway?

Comments: Yes 6 No 0 No Response 0

4. How would you rate the landing lights on your aircraft as to:

		Excellent	Good	Fair	Poor	No Resp.
a.	Illumination/ Brightness	2	2	2	0	0
b.	Aiming	2	3	1	0	0

5. Considering the weather conditions encountered, do you feel that the additional guidance provided by the retroreflective markers improved the safety of operations during:

		Yes	No	No Response
a.	Takeoff?	6	0	0
b.	Approach?	4	2	0
c.	Flare & Touchdown	6	0	0
d.	Landing Rollout?	6	0	0

Comments:

Please include any additional comments or remarks:

Name______________________________

(Optional)*
Organization* ________________________

*Name and Organization will not be used when test results and comments are reported.

BADER FIELD AIRPORT

ATLANTIC CITY, NEW JERSEY

SUBJECT: Operational Evaluation of Approach and Landing Visual Aids - Runway 11-29

TO: All Pilots Operating From Bader Field

Bader Field is cooperating with the FAA Technical Center in an operational evaluation of visual aids designed to provide improved visual guidance for pilots, particularly at night and during wet runway conditions. The following systems are being evaluated:

Precision Approach Path Indicator (PAPI) System, a variation of the standard VASI system, will be installed to serve runway 11 in early June. The system, consisting of four light sources at the touchdown point and to the left of the runway, will display a two-white, two-red light indication to pilots flying the desired 3 degree glide slope path. A higher than 3 degree glide path angle will result in either three or four white lights being visable. Conversely, flight below the 3 degree glide slope angle will result in a display of three or four red lights. A one degree safety clearance above obstacles is assurred whenever at least one white light is visable. Four lights are visable at all times, being either red or white depending upon the glide path angle being flown.

Retroreflective Runway Pavement Markers, similar to those used on highways, have been installed on runway 11-29 to provide additional guidance during approach, landing and takeoff operations. White markers to the right and left of centerline define the touchdown zone in the first 1,000 feet of each end of the runway. Markers at 50 foot intervals along the length of the runway define the centerline, and are color-coded alternating and solid red to indicate the last half of each runway. Additional reflective markers, in a combination green-yellow pattern, define each of the useable taxiway exits from the runway.

Summary of All Responses

BADER FIELD AIRPORT

Atlantic City, New Jersey

EVALUATION OF RETROREFLECTIVE RUNWAY PAVEMENT MARKERS

Runway Centerline and Touchdown Zone

An operational evaluation of retroreflective pavement markers, installed on the centerline and touchdown zones of runway 11-29, is being conducted in cooperation with the FAA Technical Center. The evaluation is to determine whether the retroreflective markers will provide improved visual guidance and safety of nighttime operations, particularly during rain, fog, and wet runway conditions.

Please fill out a questionnaire after each flight in different weather conditions, i.e., light or heavy rain, drizzle, etc. Your views are considered vital to the results of this evaluation. Please return the questionnaires to the operations desk.

Pilot Questionnaire

Date/Time of Arrival ________ ____________ Aircraft Type ____________

Weather: VFR __ IFR __ Visibility ______ Wind D ___ V ___ Please Circle Rain: R+ R R- D None

Location of Landing/Taxi Lights Used: Nose 50 ONLY Wing 3 ONLY Both 17 Other 1

Note: Retroreflective markers will be marginally effective when illuminated by wing mounted lights.

1. Please rate the effectiveness of the retroreflective markers during the:

a. Approach	Excellent 27	Good 19	Fair 15	Poor 5	No Response 5
b. Flare & Touchdown	Excellent 42	Good 18	Fair 7	Poor 1	3
c. Landing Rollout	Excellent 51	Good 14	Fair 3	Poor 0	3
d. Takeoff	Excellent 39	Good 7	Fair 1	Poor 0	24

Please comment:

2. During crosswind conditions, were you able to decrab sufficiently early during the approach to illuminate the pavement markers?

   Yes 30 No 7 Please Comment: No Response 34

3. Did you find the red/white and all red coded centerline markers useful in determining distance remaining on the runway?

   Yes 59 No 8 Please Comment: No Response 4

4. Considering the weather conditions encountered, do you feel that the additional guidance provided by the retroreflective markers improved the safety of operations during:

			No Resp.				No Resp.
a. Takeoff?	Yes 42	No 4	25	c. Flare & Touchdown?	Yes 61	No 5	5
b. Approach?	Yes 57	No 10	4	d. Landing Rollout?	Yes 66	No 1	4

Please add further comments on back of page. Thank you.

Summary of Responses With Rain/Wet Runway Conditions

BADER FIELD AIRPORT

Atlantic City, New Jersey

EVALUATION OF RETROREFLECTIVE RUNWAY PAVEMENT MARKERS

Runway Centerline and Touchdown Zone

An operational evaluation of retroreflective pavement markers, installed on the centerline and touchdown zones of runway 11-29, is being conducted in cooperation with the FAA Technical Center. The evaluation is to determine whether the retroreflective markers will provide improved visual guidance and safety of nighttime operations, particularly during rain, fog, and wet runway conditions.

Please fill out a questionnaire after each flight in different weather conditions, i.e., light or heavy rain, drizzle, etc. Your views are considered vital to the results of this evaluation. Please return the questionnaires to the operations desk.

Pilot Questionnaire

Date/Time of Arrival ____ ________ Aircraft Type ________

Weather: VFR__ IFR__ Visibility____ Wind D ___ V ___ Please Circle Rain: R+ R R- D None

Location of Landing/Taxi Lights Used: Nose Only 4 Wing Only 0 Both 9 Other 0

Note: Retroreflective markers will be marginally effective when illuminated by wing mounted lights.

1. Please rate the effectiveness of the retroreflective markers during the:

	Excellent	Good	Fair	Poor	No Response
a. Approach	2	4	5	2	0
b. Flare & Touchdown	7	4	1	1	0
c. Landing Rollout	8	5	0	0	0
d. Takeoff	7	4	0	0	2

Please comment:

2. During crosswind conditions, were you able to decrab sufficiently early during the approach to illuminate the pavement markers?

   Yes 7 No 3 Please Comment: No Response 3

3. Did you find the red/white and all red coded centerline markers useful in determining distance remaining on the runway?

   Yes 13 No 0 Please Comment: No Response 0

4. Considering the weather conditions encountered, do you feel that the additional guidance provided by the retroreflective markers improved the safety of operations during:

   a. Takeoff? Yes 10 No 2 No Resp. 1 c. Flare & Touchdown? Yes 11 No 2 No Resp. 0
   b. Approach? Yes 8 No 5 No Resp. 0 d. Landing Rollout? Yes 13 No 0 No Resp. 0

Please add further comments on back of page. Thank you.

APPENDIX D

All Responses Pooled

FAA Technical Center and Bader Field Airports

EVALUATION OF RETROREFLECTIVE RUNWAY PAVEMENT MARKERS

Runway Centerline and Touchdown Zone

~~An operational evaluation of retroreflective pavement markers, installed on the centerline and touchdown zones of runway 11-29, is being conducted in cooperation with the FAA Technical Center. The evaluation is to determine whether the retroreflective markers will provide improved visual guidance and safety of nighttime operations, particularly during rain, fog, and wet runway conditions.~~

~~Please fill out a questionnaire after each flight in different weather conditions, i.e., light or heavy rain, drizzle, etc. Your views are considered vital to the results of this evaluation. Please return the questionnaires to the operations desk.~~

Pilot Questionnaire

Date/Time of Arrival ______ ______ Aircraft Type ______

Weather: VFR___ IFR___ Visibility______ Wind D ___ V ___ Please Circle Rain: R+ R R- D None

Location of Landing/Taxi Lights Used: Nose Only 64 Wing Only 3 Both 23 Other 1

Note: Retroreflective markers will be marginally effective when illuminated by wing mounted lights.

1. Please rate the effectiveness of the retroreflective markers during the:

a. Approach	Excellent 32	Good 27	Fair 20	Poor 8	No Response 5
b. Flare & Touchdown	Excellent 56	Good 22	Fair 9	Poor 1	3
c. Landing Rollout	Excellent 66	Good 18	Fair 4	Poor 0	3
d. Takeoff	Excellent 51	Good 11	Fair 1	Poor 0	28

Please comment:

2. During crosswind conditions, were you able to decrab sufficiently early during the approach to illuminate the pavement markers?

   Yes 40 No 8 Please Comment: No Response 43

3. Did you find the red/white and all red coded centerline markers useful in determining distance remaining on the runway?

   Yes 73 No 8 Please Comment: No Response 10

4. Considering the weather conditions encountered, do you feel that the additional guidance provided by the retroreflective markers improved the safety of operations during:

	Yes	No	No Resp.		Yes	No	No Resp.
a. Takeoff?	55	5	31	c. Flare & Touchdown?	80	5	6
b. Approach?	68	16	7	d. Landing Rollout?	84	1	6

Please add further comments on back of page. Thank you.

APPENDIX D

Pooled Responses With Rain/ Wet Runway Conditions

FAA Technical Center and Bader Field Airports

EVALUATION OF RETROREFLECTIVE RUNWAY PAVEMENT MARKERS

Runway Centerline and Touchdown Zone

An operational evaluation of retroreflective pavement markers, installed on the centerline and touchdown zones of runway 11-29, is being conducted in cooperation with the FAA Technical Center. The evaluation is to determine whether the retroreflective markers will provide improved visual guidance and safety of nighttime operations, particularly during rain, fog, and wet runway conditions.

Please fill out a questionnaire after each flight in different weather conditions, i.e., light or heavy rain, drizzle, etc. Your views are considered vital to the results of this evaluation. Please return the questionnaires to the operations desk.

Pilot Questionnaire

Date/Time of Arrival ____ ____ Aircraft Type ____

Weather: VFR __ IFR __ Visibility ____ Wind D __ V __ Please Circle Rain: R+ R R- D None

Location of Landing/Taxi Lights Used: Nose Only 8 Wing Only 0 Both 11 Other 0

Note: Retroreflective markers will be marginally effective when illuminated by wing mounted lights.

1. Please rate the effectiveness of the retroreflective markers during the:

	Excellent	Good	Fair	Poor	No Response
a. Approach	4	7	6	2	0
b. Flare & Touchdown	11	6	1	1	0
c. Landing Rollout	13	6	0	0	0
d. Takeoff	10	7	0	0	2

Please comment:

2. During crosswind conditions, were you able to decrab sufficiently early during the approach to illuminate the pavement markers?

   Yes 11 No 3 Please Comment: No Response 5

3. Did you find the red/white and all red coded centerline markers useful in determining distance remaining on the runway?

   Yes 19 No 0 Please Comment: No Response 0

4. Considering the weather conditions encountered, do you feel that the additional guidance provided by the retroreflective markers improved the safety of operations during:

	Yes	No	No Resp.
a. Takeoff?	16	2	1
b. Approach?	12	7	0
c. Flare & Touchdown?	17	2	0
d. Landing Rollout?	19	0	0

Please add further comments on back of page. Thank you.

APPENDIX E

SUMMARY OF PILOT COMMENTS

GENERAL COMMENTS.

Boeing 727-100 - An excellent addition in terms of centerline guidance. They would be a welcome addition to small airports and alternate runways at large airports.

Cessna 172 - Didn't really see touchdown zone (markers) until about 100 feet, mainly due to the way the A/C's landing light was positioned.

Cessna 172 - For the conditions experienced (light to moderate rain) the system is completely satisfactory, as effective as lights. The lights were very effective from 200 feet.

Cessna 177RG - They don't seem to angle high enough. A great idea, Teterboro (airport) desperately needs them.

Douglas DC-9-30 - Evaluation is based on several flights; both conditions, dry and rain. Would like to see this equipment at all airports where lighting is presently not available.

Embraer EMB-110 - Centerline reflectors not too visible until close in. Reflectors better than nothing but inferior to imbedded lighting.

Piper PA-28 - Good close in.

Piper PA-28 - They are good to use to keep you lined up with center of runway.

Piper PA-28 - Even when lights were not on the touchdown zone retroreflectors, you could still spot them peripherally to provide additional roll guidance and help alleviate the "black hole." The centerline lights (markers) were very bright.

Piper PA-28R - Light is presently aimed much too low. It illuminates bare ground short of the threshold during the approach rather than the runway surface.

Piper PA-44 - Believe it helped on flare height.

De Havilland Twin Otter - Centerline and side of TDZ markers always visible in flare.

Aero Commander - Relatively flat approach aimed lights too high until power reduced and nose dropped on short final.

Aero Commander - Runway painted markings were not visible until late in approach (80' altitude) due to water on the runway surface. Reflectors were evident at about 180' point in the approach, providing good texture information within the touchdown area. Reflectors were more effective than painted markings, especially at lower viewing angles (final, flare and touchdown - takeoff) with landing/taxi lights reflecting off the water layer on runway.

PA-32 - Centerline reflectors would be very nice for taxiways.

De Havilland Dash 7 - Very good in poor visibility and wet surface.

Beech King Air - First observed reflectors approximately 300 feet and 1/4 mile.

De Havilland Dash 7 - Good last 100 feet (on approach) better (with) wet runway conditions.

Cessna 402 - I think they're great, would like to see them installed at FLR.

Beech Bonanza - Markers initially seem to distort depth perception, however I believe this system after a few landings will be much safer for approach and landing.

Aero Commander - Saw centerline reflectors at 300 feet, touchdown zone at 250 feet, no crab.

Cessna 172 - Markers appear to be in-runway lighting.

Beech Queen Air - Retroreflectors only as good as landing light system on aircraft.

Beech Baron - Put them on all runways at airports where it is feasible.

Miscellaneous Aircraft - Great, very nice, help a lot, really nice, beats nothing.

CROSSWIND COMMENTS.

Aero Commander-680 - Yes, (able to decrab) but pilot has to decrab much earlier than normal.

PA-28 - No problem with crab angle.

De Havilland Twin Otter - Reflectors are only effective when aircraft lights are directed on them.

PA-31 - Effective in shallow crab.

Miscellaneous Aircraft - No crosswind, no significant crosswind. (Responses from several pilots.)

CENTERLINE COLOR CODING COMMENTS.

Cessna 177RG - Did not use enough runway (to evaluate).

H-52 Helicopter - Didn't notice (color coded centerline) - great on taxiway (to helipad).

De Havilland Dash 7 - Very good in low visibility.

De Havilland Twin Otter - More (useful) on landing than on takeoff.

De Havilland Twin Otter - Effectiveness is determined too much by position of aircraft lights.

Aero Commander - Very helpful to have runway distance remaining information when using most of wet runway for rollout.

PA-31 - Yes (useful) both landing and takeoff.

PA-32 - Useful to me because I am familiar with the meaning of this type lighting.

PA-28 - Landed long, very useful.

Beech Baron - Very helpful with a multi-engine aircraft.

Aero Commander - Excellent guidance for decision to stop or go on short runway.