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Marking and Lighting of Unpaved Runways - Inservice Testing

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

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16. Abstract

This document describes the results of inservice testing of an FAA developed unpaved runway airport marking and lighting system. Details of earlier work in connection with the development and preliminary testing of this system are contained in FAA Interim Report No. FAA-NA-76-159, "Visual Aids for Turf Runways at Utility Airports," dated June 1976, and FAA Technical Letter Report No. NA-78-34-LR, "Marking and Lighting of Unpaved Runways," dated May 1978.

Inservice testing of the prototype unpaved runway marking and lighting system was conducted at separate utility airports having essentially different evironmental conditions. User participating pilots were, in general, favorably impressed with the standardized system concept. They did, however, indicate several aspects of the system that could be improved or modified. This report details results of this inservice evaluation, and provides conclusions as to desirable changes that might enhance system effectiveness.

A complete resume of the total project effort would include this report, along with the two previously referenced reports of earlier work.

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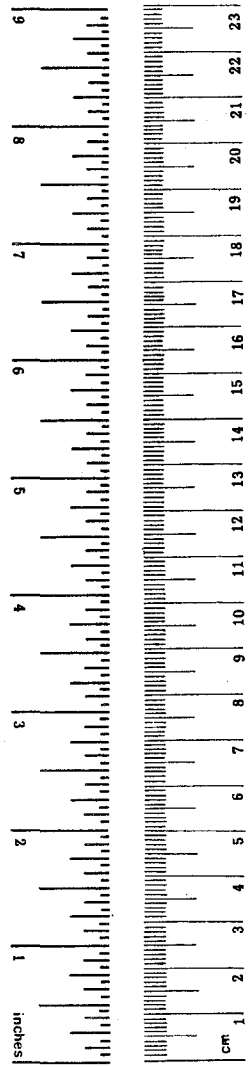
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

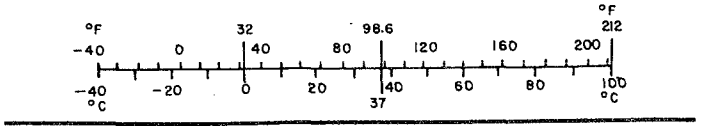
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	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



LIST OF ILLUSTRATIONS

EXECUTIVE SUMMARY

Numerous visual guidance systems and items of equipment have evolved over the years for use in providing visual flight rules (VFR) day and night approach, landing and takeoff guidance at smaller general aviation (GA) airports utilizing unpaved taxiway and runway surfaces. While these components and systems have, for the most part, provided adequate guidance, the very nature of the decentralized development effort has resulted in a lack of standardization and consequent confusion on the part of itinerant pilots using the systems for the first time. The principal purpose of this project was to define the visual guidance requirements for unpaved runway operations and, subsequently, to develop the most economical and efficient devices and systems for providing this guidance. Finally, it was necessary to perform inservice evaluations of the resultant systems with a view toward validating the results of the developmental effort.

In order to define the visual guidance requirements for safe unpaved runway operations, the Federal Aviation Administration (FAA) contracted with Mr. Robert F. Gates, an authority in the airport lighting and marking field, to conduct a study and to make a determination of the necessary elements for such an unpaved runway lighting and marking system. The results of this contract study are detailed in the previously published FAA Interim Report No. FAA-NA-76-159, "Visual Aids for Turf Runways at Utility Airports," dated June 1976.

Using the results and recommendations outlined in the above referenced interim report, the Visual Guidance Section at the FAA Technical Center (previously NAFEC) assembled various lighting and marking components and systems for installation and preliminary testing on a typical unpaved evaluation site at the Technical Center. By a process of elimination, using pilot input from FAA Center test pilots and employee pilots, best designs for various lighting and marking components were chosen to form a marking system for unpaved runway airports. A description of the developmental effort, along with construction and installation details for the evolved system components, are contained in FAA NAFEC Technical Letter Report NA-78-34-LR, "Marking and Lighting of Unpaved Runways," dated May 1978. This report also included a strong recommendation that the developed system be installed at a number of inservice test site airports for evaluation.

Inservice tests were conducted at six airports, each located in separate states, following development work and initial testing at the Technical Center and subsequent to a preliminary inservice test. The inservice test program was conducted to validate the overall system as well as individual components used for marking and lighting unpaved runways, and to provide feedback from users that might identify any problems, possible improvements, and verify user acceptance of the system.

As a result of inservice evaluation, it is concluded that the following modifications to the tested system should be incorporated to improve system effectiveness.

1. Airport Identifier - A unique, easily recognizable, two- or three-letter abbreviation of the name of the airport should be used as an identifier on the pyramid rather than the location identifier assigned by the FAA.

2. Runway Edge Markers - White cones with black tops with a minimum diameter of 36 inches should be considered as an alternative to the flat runway edge markers.

3. Go-Around Markers - These markers should not be used as a standard component of the system but could be considered as an option by the airport management.

4. Aiming Point Markers - These markers should not be used as a standard component of the system but could be considered as an option by the airport management.

5. Runway Edge Marker Separation - A separation distance of 400 feet between edge markers will probably provide adequate runway edge delineation.

6. Night Runway Lighting - It is possible that the proposed system using only runway threshold and end lights will not adequately define the lateral limits of the landing area. Incorporation of low intensity runway edge lights, at an extended spacing of 400 feet, with a minimum of three lights per side, should provide the required runway edge definition.

7. Aiming Point Lights - These lights should not be used as a standard component of the system, but could be considered as an option by the airport operator.

8. Poor Man's Optical Aid (POMOLA) - The POMOLA, in both day and night configurations, provides reliable visual glide slope guidance under all conditions, and should be included as a required part or component of any recommended unpaved runway lighting and marking system.

A complete resume of the total project effort would include this report, along with the two previously referenced reports of earlier work.

INTRODUCTION

PURPOSE.

The work described herein was performed under Subprogram T19-03, "Airport Lighting and Visual Aids," Project T19-03E, "Marking and Lighting for Unpaved (Turf) Runways." The project, for the development and testing of improved, economical marking and lighting systems for use on unpaved runways, was initiated at the request of officials of the State of New Jersey. The Director of Aeronautics, Bureau of Aviation, Department of Transportation of the State of New Jersey, requested that the Systems Research and Development Service (SRDS) in Washington, through the National Aviation Facilities Experimental Center (NAFEC) (now the Federal Aviation Administration (FAA) Technical Center), assist in solving visual guidance problems encountered with unpaved (turf) runway operations.

BACKGROUND.

Numerous visual guidance systems and items of equipment have evolved over the years for use in providing visual flight rules (VFR) day and night approach, landing and takeoff guidance at smaller General Aviation airports utilizing unpaved taxiway and runway surfaces. While these components and systems have, for the most part, provided adequate guidance, the very nature of the decentralized development effort has resulted in a lack of standardization and consequent confusion on the part of itinerant pilots using the systems for the first time. The principal purpose of this project was to define the visual guidance requirements for unpaved runway operations and, subsequently to develop the most economical and efficient devices and systems for providing this guidance. Finally, it was necessary to perform inservice evaluations of the resultant systems with a view toward validating the results of the developmental effort.

In order to define the visual guidance requirements for safe unpaved runway operations, the FAA contracted with Mr. Robert F. Gates, an authority in the airport lighting and marking field, to conduct a study and to make a determination of the necessary elements for such an unpaved runway lighting and marking system. Mr. Gates, with the help of an advisory group that included state aviation officials from New Jersey, Pennsylvania, Maryland and Delaware, FAA experts from various General Aviation District Offices (GADO's), and other noted aviation authorities, successfully accomplished this task. The results of this contract study are detailed in the previously published FAA interim report No. FAA-NA-76-159, "Visual Aids for Turf Runways at Utility Airports," dated June 1976.

Using the results and recommendations outlined in the above referenced interim report, the Visual Guidance Section at the FAA Technical Center (previously NAFEC) assembled various lighting and marking components and systems for installation and preliminary testing on a typical unpaved evaluation site at the Technical Center. By a process of elimination, using pilot input from FAA Center test pilots and employee pilots, best designs for various lighting and marking components were chosen to form, when assembled together, an economical, standardized lighting and marking system for unpaved runway airports. A description of the developmental effort, along with construction and installation details for the evolved system components, are contained in FAA NAFEC Technical Letter Report NA-78-34-LR, "Marking and Lighting of Unpaved Runways," dated May 1978 (reference 1). This report also included a strong recommendation that the developed system be installed at a number of inservice test site airports for evaluation.

This report, then, concludes the project with a description of the inservice evaluation portion of the effort, and provides not only evaluation results, but also conclusions as to desirable changes for a system that might be detailed in an FAA Advisory Circular on unpaved runway airport lighting and marking. A complete resume of the total project effort would include this report, along with the two previously referenced reports of earlier work.

SYSTEM DESCRIPTION.

Appendix A contains a complete description of the marking and lighting system as installed for day and night use at the inservice test sites. Figure 1 pictorially depicts the system components for quick reference while reading the report. Figures 2, 3, 4, and 5 are photographs depicting principal components of the daylight marking system.

DISCUSSION

PRELIMINARY INSERVICE TEST.

Preliminary flight tests, to evaluate the system and components and refine installation techniques, were conducted at Twin Pines Airport near Trenton, New Jersey. This was the first installation completed for inservice testing, and was accomplished in cooperation with the airport owner and the State of New Jersey, Division of Aeronautics. Only the day-marking portions of the system were installed for preliminary evaluation.

Questionnaires, along with an "Informational Package" were mailed to aviation user groups throughout the state by the New Jersey Division of Aeronautics. The informational package contained a sketch of the installation, as shown in figure 1, along with an explanation of the purpose and use of the various components of the experimental system. Pilots, as well as airport operators and owners, were encouraged to participate in the evaluation.

INSERVICE TEST AT SIX AIRPORTS.

Inservice tests were conducted at six airports, each located in separate states, following development work and initial testing at the Technical Center and subsequent to the preliminary inservice test. The inservice test program was conducted to validate the overall system as well as individual components used for marking and lighting unpaved runways, and to provide feedback from users that might identify any problems, possible improvements, and verify user acceptance of the system.

The test sites were selected in diverse parts of the country to test the system under different conditions of terrain and under varying weather conditions to include snow. The systems were installed as a cooperative effort with states and/or airport owners and operators.

These inservice tests were conducted over a 2- to 3-year period, subsequent to the preliminary tests previously discussed, at the following airports:

1. Twin Pine Airport, Trenton, New Jersey
2. Pleasant Valley Airport, Brodheadsville, Pennsylvania

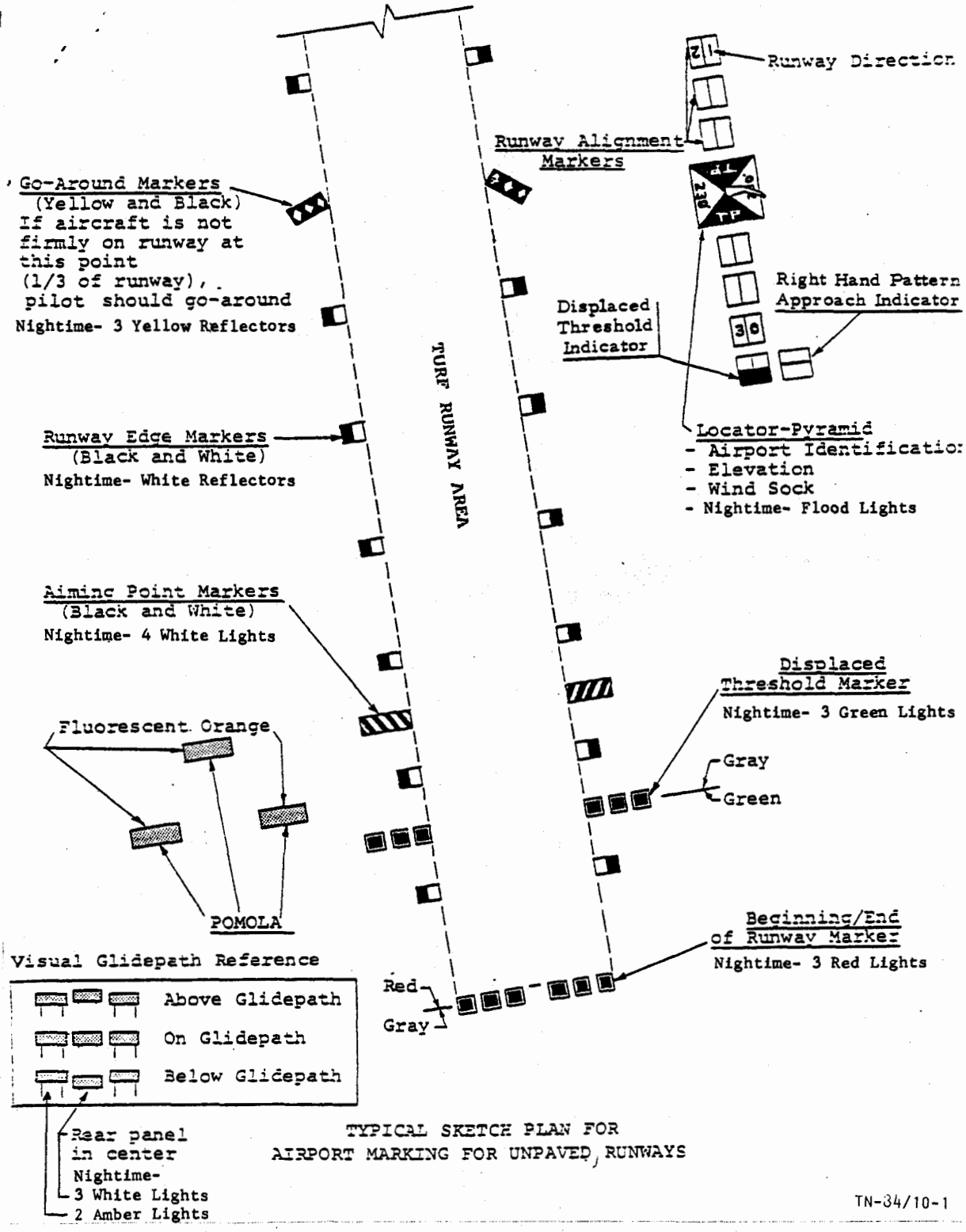


FIGURE 1. TYPICAL SKETCH PLAN FOR AIRPORT MARKING FOR UNPAVED RUNWAYS

FIGURE 2. LOCATOR PYRAMID WITH R/W ALIGNMENT MARKERS

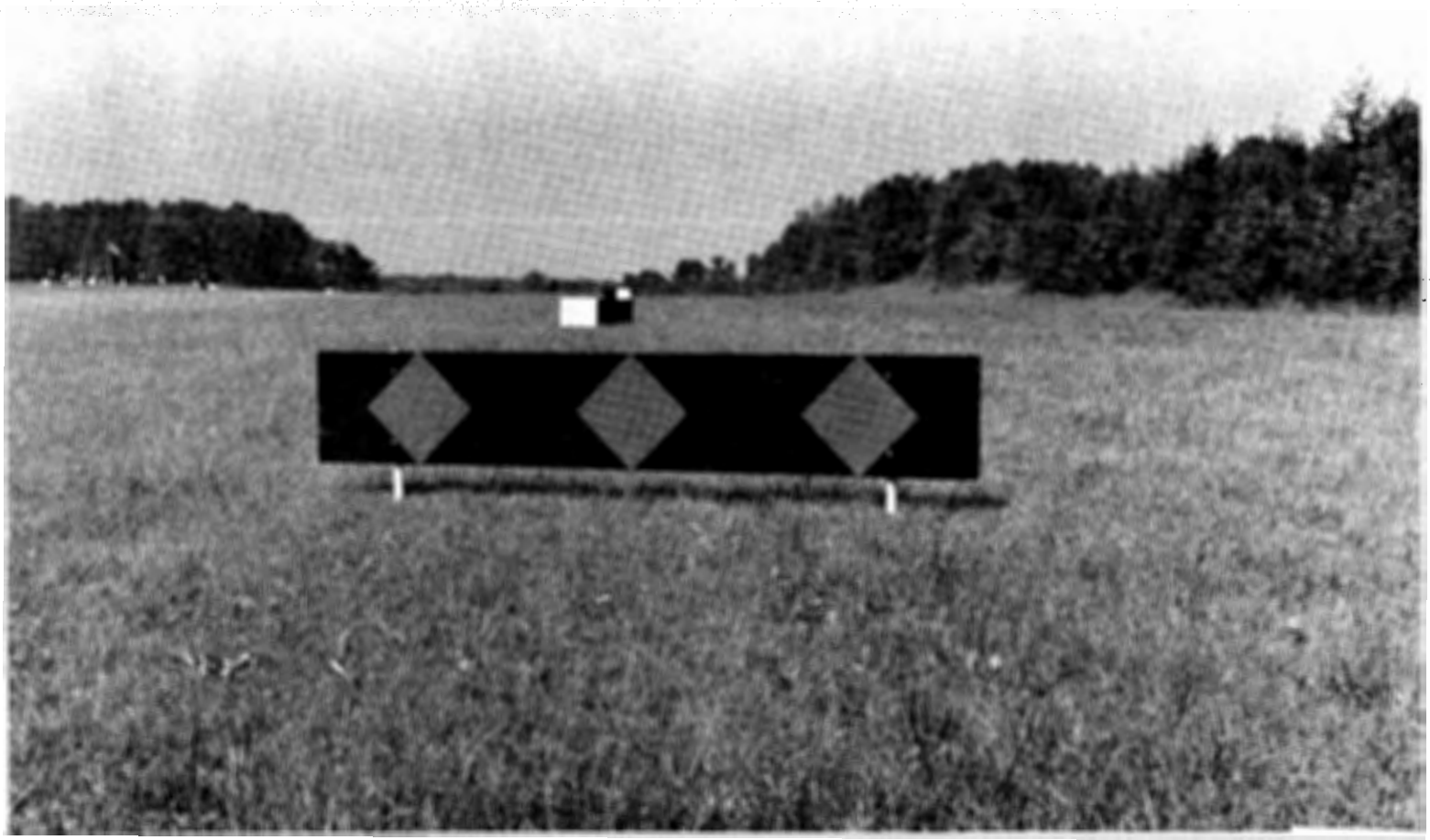


FIGURE 3. GO-AROUND MARKERS

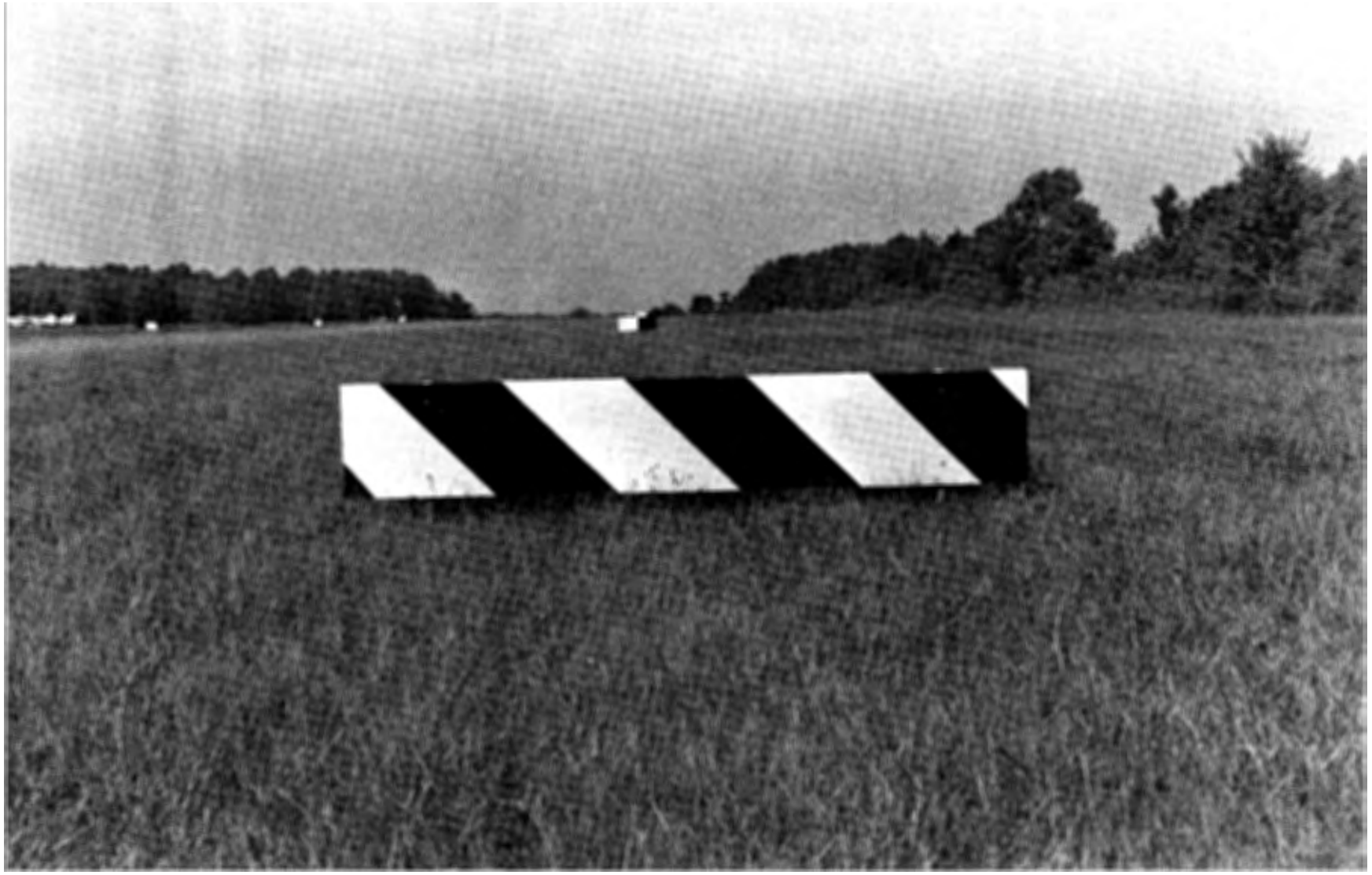


FIGURE 4. AIMING POINT MARKER

FIGURE 5. UNPAVED RUNWAY DAY MARKER SYSTEM

3. Gadabout Gaddis Airport, Bingham, Maine
4. Jennings Municipal Airport, Jennings, Louisiana (Day System Only)
5. Elliott Field, Clinton, Montana (Day System Only)
6. Columbus Municipal Airport, Columbus, North Dakota

Inservice test results were obtained through questionnaires (for sample, see appendix B) distributed to user pilots by the airport operators, and through written comments from pilots, owner/operators, and involved State aviation officials.

RESULTS

PRELIMINARY INSERVICE TEST.

The results from the preliminary inservice test, including pilot comments, are presented in this report, independent of the results obtained from the revised questionnaire which was used for the subsequent inservice evaluation at six airports. It was felt that the questions on the preliminary test questionnaire could not be directly equated to those used later on the revised questionnaire.

SUMMARY OF QUESTIONNAIRE RESPONSES. Eleven pilots responded to this initial questionnaire used for the preliminary evaluation. A summary of questionnaire responses, along with pilot comments received, follows:

Question 1. To what extent did the turf runway marking help you to identify this airport and the runway alignment?

	Responses
A. Significant	8
B. No Change	2
C. Confusing. How?	0
D. Other	1 (Only the pyramid helped)

Question 2. At what distance from the airport were you able to identify the airport through this marking system?

	Responses
A. 3 Miles or More	6
B. Entering pattern	3
C. Final Approach	0
D. Other	2 miles

Question 3. Did the Poor Mans Optical Aid (POMOLA) help establish and maintain a consistent approach slope on final approach?

	Responses
A. Yes	7
B. No	4 (was not below slope)

Comments:

1. I especially like the POMOLA. In strange territory, with obstacles, it's really great to have a visual indication for a safe glide.

2. Do not feel POMOLA is necessary with small aircraft.

Question 4. Was the POMOLA approach angle:

	Responses
A. Too High	3
B. Too Low	1
C. Just Right	6
D. Other	0

Comments:

1. Approach angle much too steep, should be same as any other VASI, 3 degrees.

2. It better be! I was depending on it! (Approach Angle)

3. A great aid in approach and glidepath, helpful in identifying airport. Would like to see more of these installations.

Question 5. Please identify the components of this turf marking installation from most beneficial to least beneficial in ascending numerical order. (No. 1 most beneficial.)

Order of Merit	
1	A. Pyramid
4	B. Runway Alignment Markers
5	C. POMOLA
2 (tie)	D. Runway Edge Markers
7	E. Displaced Threshold Markers
6	F. Runway End Markers
2	G. Aiming Point Markers
0	H. Go-Around Markers

Question 6. What percentage of your overall operations are at turf fields?

	Responses
A. 0% - 25%	4
B. 25% - 50%	2
C. 50% - 75%	3
D. 75% - 100%	2

Question 7. What type/model/make of aircraft did you use?

		Responses
Single engine, fixed gear:	Ercoupe	1
	Cessna 150	3
	Cessna 172	2
	Piper PA28	2
	Homebuilt	2
Twin engine, fixed gear:	Islander	1

Question 8. Is your aircraft based at this field?

	Responses
A. Yes	1
B. No	10

Question 9. Operational Data

	Responses
A. Landing Direction:	East 5, West 7
B. Time of Day:	Various to include 5 p.m. and dusk
C. Visibility:	Clear 9, Hazy 3

SUMMARY OF COMMENTS.

1. Very functional system.

2. It was like landing in a hostile pasture surrounded by sheep. Markers are too high.

3. Very large improvement over normal markings or lack thereof at other turf fields.

4. Too many signs.

5. Spotted fluorescent orange POMOLA long before the pyramid, which should be painted orange. Runway markers were an extreme hazard. If you have them, at the very least, have them laying flat so you can run over them. I am really enthusiastic about this system and hope these improvements will be considered. I especially like the POMOLA.

6. Runway markers too close - will damage low wing or biplanes if struck. Hard to see from behind radial engine; move them back!

7. The myriad of markers was confusing. Although a few were quite nice, the majority were found to be unnecessary.

8. Bigger wind sock is needed.

9. Two letters were received by the Director of Aeronautics, State of New Jersey, from pilots who probably did not complete a questionnaire. Both pilots fly "tail-draggers," one having a large radial engine with poor visibility. Both pilots felt strongly that the 100-foot width of the runway markers is so narrow as to constitute a safety hazard. As one pilot expressed, "inviting accidents by particular types of aircraft."

SUMMARY OF PRELIMINARY INSERVICE TEST RESULTS.

Responses to the 11 preliminary questionnaires and comments from these pilots, plus comments from two pilots who wrote letters, are summarized as follows:

Eight of the pilots said that the turf runway markings helped to identify the airport and runway alignment (question 1) to a significant degree.

The most beneficial component (question 5) was judged to be the pyramid. The runway edge markers and the aiming point markers were tied in score as the second most beneficial. As noted under pilot comments, four pilots said that the edge markers were either; too high, too close together (limiting runway width), or confusing with the majority of markers being unnecessary. Two of these pilots, plus two who commented by letter, said or inferred that the edge markers were hazardous. Of these pilots, three flew "taildraggers" which, for the most part, have poor forward visibility when the tail wheel is on or near the ground.

The go-around markers were judged to be the least beneficial, while the other markers were ranked as shown in question 5.

Seven pilots said that the POMOLA helped establish and maintain a consistent glidepath while four responded in the negative. Six pilots said the approach angle (5°) was about right while three said it was too high and one said too low. The pilots comments were positive except for one pilot's comment that it was much too steep and should be the same as other VASI's, at 3°.

The results of this preliminary evaluation confirmed, in general, those results obtained during the developmental stage of the project at the Technical Center. This will be discussed further in the results section of this report for the inservice testing effort.

INSERVICE TEST AT SIX AIRPORTS.

The results of pilot responses to the questionnaire for daytime operations, with the totals combined for the six participating airports, are presented, along with pilot comments concerning the particular question or system component. Comments by airport owner/operators and by state organizations are included and referred to as "Other Comments." Comments of a general nature or those which cannot be directly related to a specific question are also presented and discussed.

Results of testing of the nighttime systems, conducted at only four of the six airports as previously mentioned, are presented following the results section devoted to daytime operations. As with the daytime inservice test, results data for the nighttime tests were obtained through questionnaires distributed to the user pilots by airport operators and from written comments from pilots, owner/operators, and from state aviation officials.

INSERVICE TEST RESULTS - DAY SYSTEM.

During the inservice test, 124 pilots completed questionnaires and provided comments concerning the effectiveness of the daytime marker system. A summary of questionnaire responses, along with user comments received, follows:

Question 1. Does the pyramid with runway alignment markers help you locate the airport in VFR conditions?

Yes	No
114	10

Comments:

1. The function of the pyramid was unclear - confusing.

Other Comments:

One state commented that a fluorescent windsock, in combination with a properly maintained segmented circle, is much more visible and recognizable than the pyramid. Another state commented that the pyramid is a good airport locator and windsock placement.

An owner/operator commented that the pyramid has been the most commented on aspect of the system and has made the identification of a turf runway much easier for pilots. Several pilots landed successfully in bad weather conditions after they spotted his airport and, he felt, that two pilots were saved from possible accidents because they could wait out the weather on the ground. Also, two Medevac flights located the airport easily when forced to sit out bad weather. He recommended that the pyramid be installed at all unpaved runway airports and that information describing the system should be presented to all pilots as a safety factor.

SUMMARY OF RESPONSES AND COMMENTS. A significant majority of the pilots said "Yes" to the question "Does the pyramid with runway alignment markers help locate the airport in VFR conditions?" Also, the majority of comments, considering those on the system in general, are quite favorable.

Question 2. Does the airport identifier and airport altitude painted on the pyramid (airport locator) provide any useful information to you?

Yes	No
116	7

Comments:

1. Must overfly the airport to see the runway direction and airport identifier - suggest larger numbers.

2. Identifier and elevation numbers were confusing.

3. Altitude (field elevation) was particularly helpful.

Other Comments:

One state commented that the three-character identifier painted on the pyramid is useless and confusing to nearly all pilots.

Three other state officials said that the identifier and altitude (field elevation) provided useful information.

An owner/operator commented that, with the elevation painted on the pyramid, pilots have immediate information without checking charts.

SUMMARY OF RESPONSES AND COMMENTS. Again a significant majority of the pilots responded "Yes" to the question, "Does the airport identifier and airport altitude painted on the pyramid provide any useful information?"

The majority of the comments were also quite favorable.

Question 3. Do you find the combination of pyramid with windsock on top, runway alignment markers, and runway direction numbers to provide adequate information for selection of proper runway for landing and circling guidance?

Yes	No
115	9

Comments:

1. Three pilots commented that the windsock was hard to see (one said "with white background").

2. Windsock should be larger.

3. The windsock (mounted) on the pyramid is very useful and ends hunting for it.

4. Runway alignment markers are not essential, especially with more than one runway.

5. The right traffic indicator did not provide enough info, maybe one more block (section) would help identification.

Other Comments:

No specific comments were received from states or owner/operators. However, the windsock was raised in height in some installations to alleviate interference from the pyramid. An owner/operator increased the spacing between the runway alignment markers to accomodate the width of his mowing machine. Others have raised the markers (cinder blocks) to alleviate moisture accumulation problems, and some have used roofing material or tar paper around the markers to keep grass/weed growth down and to accomodate mowing.

SUMMARY OF RESPONSES AND COMMENTS. Again, a significant number of the pilots responded "Yes" to the question concerning the windsock, runway alignment markers, and runway direction numbers.

There were no specific comments from state or owner/operators, but, in general, the overall system was favorable to the majority.

Question 4. Do the runway edge markers provide adequate lateral guidance on final approach?

Yes	No
119	4

Comments:

1. Probably don't need as many black and white runway markers.

2. Edge markers are obstructions.

3. Airport is overmarked and may be considered confusing.

4. Runway markers too tall.

5. Runway markings are a big improvement over most unpaved strips - especially for first timers.

6. Edge markers provide good approach guidance.

7. Markings are the best I have ever seen at a grass strip; easier to pick out airport and runways than with grass runways.

8. Very good system.

9. Highly recommend it.

10. Marking system is quite useful and width is more than adequate.

11. Great runway.

12. Edge markers provide positive identification on the limits of the landing turf and are superior to tires, cones, or lights.

13. A letter from a pilot said the marking system is good but could be improved by adding fluorescent paint to the black and white edge markers. Five specific suggestions were made, with drawings, to provide more contrast, particularly in snow conditions.

Other Comments:

One state commented that the edge markers, while quite visible on approach, are not visible from above or either side of the runway. Also, the state questioned whether the edge markers would withstand snowplowing (heavy and frequent snow fall). Fiberglass cone markers have been used for nearly 20 years and they conclude that the 36-inch cone is a superior marking system, from both the cost standpoint and for installation and ongoing maintenance. (Additional details were given which will be discussed later.)

Another state said that runway markers made from wood or metal are rather hazardous and would rather see all markers made of plastic.

Two other states commented that black and white panels are always distinguishable or conspicious regardless of the ambient light or color of the background.

One owner/operator commented that the unpaved marking system, tested for over 3 years, has been more than adequate for its purpose, to aid pilots in locating and landing on turf runways.

Another owner/operator commented that the edge markers provided adequate guidance for final approach; however, when on downwind leg, they are almost impossible to see. Also, pilots have expressed concern about damage if the edge markers were hit.

SUMMARY OF RESPONSES AND COMMENTS. In response to the question "Do the runway edge markers provide adequate lateral guidance on final approach?" a significant majority of the pilots said "Yes."

Even though the response to this specific question was in the affirmative, the question elicited numerous comments from pilots as well as from state aviation officials and from owner/operators. Six out of 14 comments from the pilots were negative, as were several comments during the preliminary inservice test. Also, some of the states and owner/operators had negative comments.

The concern about too many markers and clutter of the runway will be discussed in connection with the last two questions. As to the use of plywood, it is noted under "Recommendations" in reference 1, that other materials such as plastic, vinyl, or fiberglass could be used which may prove to be more frangible and cause less damage if accidently struck.

Also, an alternative to panels would be the use of 36-inch diameter white plastic/vinyl cones with a black top for runway edge markers. Tests were conducted with one type of cone and it was found that the colors (except black and white) faded after exposure to ultraviolet rays from the sun. Black and white plastic flat panels were also tested; however, some of them warped badly. One state advised they are looking at plastic panels from another manufacturer. It is felt that, in time, manufacturers will have materials available to overcome these problems.

Question 5. Does the POMOLA provide adequate vertical guidance, glidepath guidance, and obstruction clearance on final approach?

Yes	No
110	8

Comments:

1. POMOLA hard to see until close final. (Trees have been reported as obscuring POMOLA at some locations until aligned on final approach.)

2. POMOLA is perfect for teaching soft field landings.

3. POMOLA worked excellent.

4. POMOLA is particularly useful, especially on runway 33 approach. Suggest handout sheets mailed to pilots to explain meaning of markers.

5. POMOLA markers provide good approach guidance.

Other Comments:

One state commented that one of the major benefits of the system is the value of POMOLA as a landing aid to assist in determining final approach angle and stressed the need for POMOLA or other visual aid, particularly for the transient pilot.

Another state commented that the POMOLA has the most promise of any part of the system, in as much as it is relatively simple and does provide adequate vertical guidance on approach. The state feels, however, that international orange may not be the best color, and they also suggest that a substantial amount of publicity and educating of the flying public would be necessary for its eventual acceptance.

Another state commented that the POMOLA gives good accuracy for landing in the touchdown zone and the 15:1 approach criteria should be clarified with FAA airspace people who still use 20:1 as standard.

SUMMARY OF RESPONSES AND COMMENTS. Again a significant majority of the pilots answered "yes" to the question "Does the POMOLA provide adequate vertical glidepath guidance and obstruction clearance on final approach." In response to a similar question during the preliminary inservice test, a majority of the pilots responded in the affirmative and said that the glidepath angle of 5 degrees was "just right."

Comments from the pilots, state officials, and owner/operators were all positive with the exception of two comments made during the preliminary test. One pilot commented that the POMOLA was not necessary with small aircraft and another said the approach angle was too steep.

These results show that the low-cost POMOLA (references 4 and 5), used where the cost of a standard red/white VASI cannot be justified, will provide adequate daytime vertical guidance for obstruction clearance and confirms previous tests results (reference 2). The inservice tests also confirm that a 5-degree approach angle is optimum for small general aviation aircraft using turf runways less than 3000 feet in length. Previous tests at the Technical Center (references 2 and 6) and tests by NASA, (reference 7) also concluded that a 5-degree approach angle is most commonly used by such aircraft on shorter runways.

Question 6. Do the aiming point markers and threshold or displaced threshold markers provide proper indication for touchdown guidance?

Yes	No
117	7

Comments:

1. The displaced threshold and runway end markers are confusing on the first landing.

2. Threshold markers provide guidance; aiming point does not.

Other Comments:

One state commented that the displaced threshold must be an integral component of the system as it is one of the key elements (when considering obstacle clearance and approach slope protection). Another state commented on the location of displaced thresholds and this subject will be discussed later.

A third state said that the marking for a displaced threshold is very useful and is a good design.

An owner/operator commented that threshold markers provide an adequate indication for touchdown guidance and that aiming point markers were not needed.

SUMMARY OF RESPONSES AND COMMENTS. In response to the question, "Do aiming point markers and threshold or displaced threshold markers provide proper indication for touchdown guidance?" again, a significant majority of the pilots said "Yes."

Some pilots commented that the markers are confusing, which shows again that they must be educated as to the meaning and use of the many parts of the system. Three states and an owner/operator commented on the need for, and the usefulness of, the displaced threshold markers, as noted above, while others commented that the aiming point markers were not needed.

Based on total responses and comments, including those from the preliminary inservice test, both the threshold and displaced threshold markers were judged to provide adequate and useful guidance.

Question 7. Do you consider the aiming point markers useful?

Yes	No
107	11

Comments:

1. Aiming point markers are very useful.

2. Aiming point markers provide good approach guidance.

3. Touchdown markers are very useful.

4. My aiming point is runway end and I believe your end markers may serve this purpose.

5. Aiming point markers are of limited usefulness.

Other Comments:

One state commented that the aiming point and go-around markers are too confusing and may not be needed.

Another state commented that the purpose of aiming point markers is not well understood and that they are, in their opinion, unnecessary.

As noted under the previous question, an owner/operator said that threshold markers provide adequate indication for touchdown guidance and that aiming point markers were not needed. Another owner/operator commented that aiming point and decision markers are used by pilots once they are familiar with the system.

SUMMARY OF RESPONSES AND COMMENTS. Even though a majority of the pilots responding were in favor of the aiming point markers, consideration should be given to the adverse comments, including those concerning clutter on the runway with too many markers as previously noted. An argument was made by some pilots that the back panel of the POMOLA serves as an aiming point. Others feel that the glidepath signal will be disregarded at some point after clearance of obstructions. The pilot will then aim for a point near the threshold and will probably "duck-under" the glidepath in an attempt to touch down near the threshold and prior to the glidepath intercept point. Others contend that the final aiming point should be left to the individual, taking into consideration his particular aircraft, wind, and other conditions, and that threshold and edge markers provide adequate guidance.

Question 8. Do the "go-around" markers perform a useful function?

Yes	No
96	17

Comments:

1. Go-around markers are too close to touchdown and leave too much usable runway. Markers must be a "positive go-around," otherwise, no one will respond to them.

2. Go-around markers are too close to threshold but otherwise are very useful.

3. They do not serve a useful function.

Other Comments:

One state questioned the real value of go-around markers and said they, (and aiming point markers) are too confusing and may not be needed.

An official from another state said he did not see any value in the go-around markers; thinks they could be eliminated. Some of the comments he addressed were regarding the number of panels that mark the runway. Some have no apparent meaning, and the system seems very cluttered.

Another state commented that the go-around markers are not understood and it is questionable whether any education effort would change this substantially.

One owner/operator said that we should not dictate to the pilot when he should or should not go-around on an approach. Weather and wind conditions, aircraft type and configuration, runway length, and pilot proficiency are all factors that must be taken into consideration. He said that, in his opinion, these markers merely clutter the side of the runway. Another owner/operator said the decision and aiming point markers are used by pilots once they are familiar with the system.

SUMMARY OF RESPONSES AND COMMENTS. Again, a majority of the pilots responded "Yes" to the question, "Do the go-around markers perform a useful function?" Of the

total responses, fewer pilots responded to this question than to any other question and a greater precentage of pilots responded negatively. The go-around markers were also judged to be the least beneficial of the markers in the system during the preliminary inservice test.

INSERVICE TEST RESULTS - NIGHT SYSTEM.

The nighttime system, consisting of lights and retroreflective runway edge markers, were installed for inservice testing at four locations:

1. Twin Pine Airport, near Trenton, New Jersey,

2. Pleasant Valley Airport, Brodheadsville, Pennsylvania,

3. Gadabout Gaddis Airport, Bingham, Maine, and

4. Columbus Municipal Airport, Columbus, North Dakota.

As with the daytime inservice tests, data for nighttime operations were obtained through questionnaires distributed to pilots by the airport operators and by written comments from user pilots, airport owner/operators and from state aviation officials.

The total number of questionnaires received for nighttime test of the system was limited, with only 27 pilots responding. As we have learned, pilots are reluctant to complete questionnaires unless there is a personal contact to encourage response. This need for personal contact has been a problem throughout the inservice testing since some of the airports are unattended or attended part-time. Accordingly, there were relatively few questionnaire responses from pilots concerning the nighttime system, and few comments were received from state aviation officials and owners/operators.

A summary of questionnaire responses, along with pilot comments received, follows:

Question 1. Is the beacon, in combination with lighted pyramid with runway alignment markers, adequate for locating the airport at night?

Yes	No
27	0

Comments:

1. Beacon extremely bright and somewhat distracting (located too close to r/w).

2. Without rotating beacon, could not find airport or adjust pattern.

3. Beacon was overpowering - move airport beacon.

4. Beacon too close to runway - high brightness interferes with alignment on flare and touchdown.

5. Lights do not provide enough illumination on runway alignment markers.

6. Need more light on runway alignment markers.

Other Comments:

One owner/operator said that the Medivac (helicopter) pilots can see our beacon when they lift off from the hospital; a distance of 25 miles. Another said that their beacon could not be seen more than a few miles at lower altitudes. It was suggested that aiming of the lights should be checked against the manufacturers specifications. Another owner/operator said they planned to add additional lights on the pyramid to better light the alignment markers.

SUMMARY OF RESPONSES AND COMMENTS. All pilots said yes to the question, "Is the beacon in combination with the lighted pyramid with runway alignment markers adequate for locating the airport at night?" Based on these and comments of a general nature, these components of the system appear to be adequate for nighttime operations. There was common agreement that one particular beacon, adjacent to the pyramid, was located much too close to the edge of the runway.

Question 2. Is nighttime lighting adequate to identify airport and obtain wind information (from windsock on top of pyramid) and runway landing direction?

Yes	No
22	4

Comments:

None.

Other Comments:

See comment to previous question regarding plans to better illuminate the runway alignment markers.

SUMMARY OF RESPONSES AND COMMENTS. A great majority of the pilots responded in the affirmative to the above question. The general comments concerning the overall system were favorable and these lighting components of the system appear adequate for night operations.

Question 3. Do the runway end lights provide adequate circling guidance and lateral alignment on final approach?

Yes	No
21	6

Comments:

1. Must learn system for runway alignment.

2. Increase intensity of red lights at far end of runway to aid in lining-up.

3. If lights are installed on runway, they should include the full length of runway.

Other Comments:

No specific comments were made by states or owner/operators about this part of the system. It is known, however, that one owner/operator explains the system to pilots operating at night from his airport.

SUMMARY OF RESPONSES AND COMMENTS. A majority of the pilots said "Yes" to the above question; however, a greater percentage of pilots responded "No" to this question than to the other questions. When considering the design of the system and the comments that were made, the need for pilots to learn and understand the system is further amplified.

Question 4. Does the nighttime POMOLA provide adequate vertical glidepath guidance and obstruction clearance on final approach?

Yes	No
23	2

Comments:

1. POMOLA gives good guidance for obstacle clearance, especially for night fog conditions.

2. Must learn system for use of POMOLA.

3. Makes night landings much easier.

Other Comments:

One state commented that one of the major benefits from the project is the value of the POMOLA as a landing aid to assist in determining final approach glide angle, particularly for the transient pilot. If the POMOLA, or other visual aid, is utilized at night, it must be lighted. Other states commented on the approach slope and obstruction clearance criteria which will be discussed under Vertical Approach Guidance and Obstruction Clearance. One owner/operator would prefer a low cost VASI, due to limited space for the POMOLA. Another said pilots had learned to align POMOLA lights.

SUMMARY OF RESPONSES AND COMMENTS. A majority of the pilots said "Yes" to the above question and there were no adverse comments from the states and owner/operators. Based on the test results and comments, the lighted POMOLA provides adequate guidance, but pilots must learn to use the system, since it is not a commonly used standard such as the red/white VASI.

Question 5. Do the retroreflective runway edge markers provide sufficient delineation of the runway during the latter portion of the final approach, flare, landing, and taxiing?

Yes	No
25	2

Comments:

1. Retroreflective markers are surprisingly bright.

2. Reflectors are really bright.

Other Comments:

One state said that the use of reflectors on panels for runway edge and taxiway guidance was a major benefit for night operations and that the 200-foot spacing and 100-foot width is perfectly acceptable.

Other than overall comments about the system, other state officials made no specific comments concerning the retroreflective markers. One owner/ operator said that most pilots are amazed by the effectiveness of the retroreflectors. Another said they provided good guidance and other pilots reported they were adequate when picked up with the landing light.

SUMMARY OF RESPONSES AND COMMENTS. A large majority of the pilots said "Yes" that the retroreflective runway edge markers provide sufficient delineation of the runway. All comments were favorable. Based on the results of the inservice and previous tests, the retroreflective runway edge markers will provide adequate guidance for those pilots who understand the system and are operating aircraft with landing lights located on or near the nose of the aircraft. Wing-mounted lights will not be as effective due to the large angle between the light source, the retroreflectors, and the pilot's eyes.

Question 6. Do the white aiming point lights and threshold or displaced threshold lights provide proper indication for touchdown guidance?

Yes	No
22	4

Comments:

1. Suggest three aiming point lights, as two are not enough and four are overpowering.

Other Comments:

The states and owner/operators made no specific comments about the aiming point, threshold, or displaced threshold lights. One state commented, however, that the displaced threshold indication must be an integral component of the system as it is one of the key elements.

SUMMARY OF RESPONSES AND COMMENTS. A majority of the pilots said "Yes" to the question "Do the white aiming point lights and threshold or displaced threshold lights provide proper indication for touchdown guidance?" The lack of comments does not help in identifying dissatisfaction with any of the system components. As noted in the test results of the daytime system, the threshold and displaced threshold markers were well received, while the usefulness of the aiming point markers was questioned. It was suggested that the rear panel of the POMOLA, located adjacent to the runway, could serve as an aiming point, and the same logic

could be applied to POMOLA lights located on the back panel. The threshold and displaced threshold lights are considered satisfactory and they conform to FAA standards.

Question 7. Do the yellow "go-around" retroreflective markers perform a useful function?

Yes	No
19	6

Comments:

None specific to the question.

Other Comments:

None specific to the question.

SUMMARY OF RESPONSES AND COMMENTS. A majority of the pilots said "Yes" to the above question, while six, or 24 percent said "No." No comments were received that related specifically to the retroreflective go-around markers. Individual pilots are able to determine an appropriate go-around point, if they wish, dependent on the field length, the type of aircraft, and other factors previously discussed.

COMMENTS ON VERTICAL APPROACH ANGLE

In addition to the results of the questionnaire and comments on the POMOLA 5° approach slope (question 5), the following comments were received that pertained to the approach slope and the ratio used for obstruction clearance.

One state said the POMOLA has the most promise of any part of the system in as much as it is relatively simple and does provide adequate vertical guidance on approach. Also, they suggested that a substantial amount of publicity and education of the flying public would be necessary for its eventual acceptance.

Another state official said he liked the (POMOLA) system, but that the 15:1 approach criteria should be clarified with FAA airspace people who still use 20:1 as standard. An owner/operator said they were using a 5° glide slope with clear zones of 15:1 (and) for large twin engine aircraft using a grass runway, and that this might have to be altered to better meet their needs. Another owner/operator was satisfied with a 5° approach and a 6° approach in the opposite direction. The 6° slope was necessary to provide sufficient runway landing length after clearing a ridge near the end of the runway.

A third state said one of the major benefits of the program is the value of the POMOLA as a landing aid to assist in determining final approach glidepath angle, particularly for the transient pilot. Also, it was established factually and operationally that the 15 to 1 approach slope protection is not only feasible, but practical and effective for the lower performance general aviation aircraft that would normally operate from unpaved runways. This 15 to 1 slope protection ratio permits the unrestricted, safe use of runways by such aircraft. It was further

stated that final approach angles of 5° to 6° are, in fact, those commonly flown by smaller aircraft; even though 3° to 4° approach slope angles are currently believed to be the norm.

A fourth state said that approach clearance ratios such as used on this project (15:1) were adequate for the type of aircraft that use unpaved airports. The 15:1 approach clearance ratio, they said, is acceptable and appropriate for the 5° to 6° approach angles used by small, general aviation aircraft. Therefore, this could be accepted as a standard approach clearance ratio for small general aviation airports. The state further said that it recommends adopting this same criterion for displaced thresholds, that is, to locate the displaced threshold at the point on the runway where a clear 15:1 approach ratio can be achieved.

SUMMARY OF COMMENTS ON VERTICAL APPROACH GUIDANCE AND OBSTRUCTION CLEARANCE.

Four state aviation officials and two owner/operators commented favorably on the vertical approach guidance of the 5° POMOLA and the approach slope obstruction clearance ratio of 15 to 1 for small, single engine, general aviation aircraft that would use short unpaved runways. One state said the ratio could be a standard adopted by the FAA for small, general aviation airports. As previously noted, such recommendations were made following tests at the Technical Center (references 1 and 2.)

GENERAL COMMENTS ON SYSTEM CONCEPT.

General comments are those received which could not be directly related to the system components referred to in the questionnaire.

One state commented favorably on the system and said that it is extremely important to translate the project results into an Advisory Circular to achieve standardization and reduce aircraft accident potential from this source.

An official from a second state commented that, in reviewing the system, he feels personally that a standard turf runway marking system is needed. This system is financially cheaper than systems used in the past, and is equally efficient and, in addition, provides night capability. The system requires a lot of time to install but creates summer jobs for youths in the community. Another official from this state said he would like to see all markers made of plastic rather than wood, as it would entail less maintenance. He feels this is a good system and would like to see more installed. He foresees that his state agency will promote its use on unmarked turf strips.

A fourth state commented that they found the fabrication of the marking system components and the installation work to be extremely labor intensive, and expensive by comparison with other marking systems in use. Because of soil conditions, installation of the pipe receptacles required driving them into the ground using a special driving tool together with a tractor mounted postdriver. Eighteen employee-days were spent installing the system, cone markers can be installed to mark an entire runway in one day by two workers. This airport was built on glacial stone making it difficult to insert pipes for markers. The cones used are 36-inch diameter cones and were affixed to the ground by driving four 12-inch spikes at four points along the edge. The state said, in summarizing, that they feel the experimental system has met with very little acceptance by the flying public. They have used white fiberglass cone markers for nearly 20 years and conclude that they

are a superior marking system from both the installed cost standpoint and the ongoing maintenance requirements, not to mention better visibility overall. They also said that, although the foregoing lends very little support to the experimental marking system, they feel it is important that it was given a fair test in the field, rather than being dismissed out-of-hand without evaluation.

An owner/operator commented that the system tested for the last three years has been more than adequate for its purpose, to aid pilots in locating and landing on turf runways. The maintenance has been minimal and marking unpaved runways will make flying safer.

Another owner/operator commented, as stated under question 4, that the plywood markers provide adequate guidance on final approach. However, when on downwind leg, they are almost impossible to see. Also, pilots expressed concern about damage if the edge markers were hit. He has used, and suggests, five gallon plastic buckets where snow is not a factor. A third owner/operator expressed satisfaction with the system and said it was well received by visiting pilots.

SUMMARY OF GENERAL COMMENTS.

There were three comments concerning the need to achieve standardization. The substitution of cones, plastic buckets, or other materials for runway markers, with a size approximating that provided by the panels, should provide a degree of flexibility which results in a standardized pattern that pilots will recognize. One state said they foresee that their agency will promote use of the system, while another said that it was extremely important to translate the results of these tests into an Advisory Circular to achieve standardization and reduce aircraft accident potential.

CONCLUSIONS

Questionnaire data from the daytime system tests, including comments from user pilots, airport owner/operators, and from state aviation officials, appear to be adequate to make reasonable conclusions relative to the value of various components of the system. However, the data for the nighttime system represented a relatively small sample (27) with relatively few comments. This required some interpolation, from the daytime system and previous test experience, resulting in conclusions which are considered reasonable for marking and lighting unpaved runways for nighttime use.

For the most part, the marking and lighting system developed at the Technical Center was found acceptable during the 2- to 3-year inservice test period. The few changes resulting from the inservice tests should improve the system and provide a basis for an Advisory Circular governing marking and lighting of unpaved runways. This Advisory Circular could be used by local governments as a criteria for their certification of unpaved runway airports. Also, it would encourage standardization among states.

While we recognize that many of the negative comments resulted from the lack of education relative to details of this new system, we must realize that this, in itself, is a significant problem. Educating the pilot population to a new system,

or to components of a system, is a slow process, particularly when deviating considerably from previous standards. However, we should not let this deter us from making changes where safety can be significantly improved.

Based upon the results of the inservice test program, it is concluded that the following changes should be made to the system which is described in Appendix A and Letter Report NA-78-34-LR:

1. Airport Identifier - A unique, easily recognizable, two- or three-letter abbreviation of the name of the airport should be used as an identifier on the pyramid rather than the location identifier assigned by the FAA.

The concept of using the standard FAA assigned location identifier would be a good approach if all airports were so labeled on the sectional charts and were commonly known as such. However, pilots (particularly VFR only pilots) are often confused by these official identifiers which are frequently meaningless to them. Participating pilots were much more receptive to common abreviations, such as P.V. for Pleasant Valley Airport and T.P. for Twin Pine Airport, which were used by two airports in the program instead of their FAA assigned location identifiers.

2. Runway Edge Markers - White cones with black tops and a minimum diameter of 36 inches should be considered as an alternative to flat runway edge markers.

One of the complaints about the flat edge markers was that they could not be seen from the side. However, the runway alignment markers were incorporated to provide circling guidance to compensate for this deficiency. The runway edge markers are primarily to provide lateral guidance on final approach and departure, for which they are well suited. The use of cones of adequate size will, of course, assist in circling guidance since they can be seen from the side and top as well. The commonly used 24-inch or less in diameter cone does not present enough surface viewing area to accomplish the above purpose. The minimum size cone that will adequately perform this function is the white/black cone of 36-inch diameter or larger, which has slightly less frontal area than the recommended flat edge marker. The 36-inch diameter cone may be more expensive, however, maintenance could be less with improved materials.

3. Go-Around Markers - These markers should not be used as a standard component of the system but could be considered as an option by the airport management.

According to the questionnaire results, this component was considered the least important and received the most negative comments. While most pilots who were familiar with its meaning considered it useful, many pilots were opposed to use of the go-around markers, indicating that there were too many variables to the proper location of the marker and that it only contributed to the "clutter" of many panels.

4. Aiming Point Markers - These markers should not be used as a standard component of the system but could be considered as an option by the airport management.

This component of the system received the second most negative comments. While the majority of the pilots considered the aiming-point-markers useful, they felt that they did contribute to the "clutter" of too many markers and were considered superfluous by many pilots who considered the threshold (or displaced threshold markers) adequate. In addition, the rear panel of the daylight POMOLA system, while some

distance from the runway edge, can also be condsidered as an aming point marker. Indeed, if the six panel POMOLA is used, two of the rear panels of this unit do replace the aiming-point-markers.

5. Runway Edge Marker Separation - A separation distance of 400 feet between edge markers should provide adequate runway edge delineation.

Considerable comment concerning the number of edge panels and their possible hazard to aircraft exiting the runway area was received. The 200 foot spacing between edge markers specified for the evaluation was proposed and derived from the distance usually chosen for placement of conventional runway edge lights. Considering the larger physical size of the daylight markers, it is probable that a greater spacing, as concluded above, will reduce the physical hazard and still provide adequate definition of the runway edge location. A spacing of 400 feet between markers was not evaluated during the inservice test, but could be accomplished with a minumum of effort should it become necessary.

6. Night Runway Lighting - The proposed system of runway threshold and end lights only will probably not adequately define the lateral limits of the landing area. Incorporation of low intensity runway edge lights, at an extended spacing of 400 feet should provide the required runway edge definition.

While the participating pilots judged the nighttime system marginally adequate, the low number of questionnaire responses was not sufficient to insure a firm determination of system effectiveness. In particular, concern was expressed over the reduced effectiveness of the edge panel mounted retroreflectors under crosswind landing conditions. With a strong crosswind, many pilots will use the "crab" technique for maintaining runway alignment during the approach. In this situation, the landing lights on the aircraft will be aligned to one side or the other of the runway, rendering the reflectors totally ineffective. Hence the need for supplemental runway edge lights to provide additional guidance under all conditions.

7. Aiming Point Lights - These lights should not be used as a standard component of the system, but could be considered as an option by the airport operator.

The aiming point lights, when serving as the rear component of the nighttime POMOLA system, must be used, but only since they form a portion of that system in providing visual glide slope guidance.

8. POMOLA - The POMOLA, in both day and night configurations, provides reliable visual glide slope guidance under all conditions, and should be included as a required part or component of any recommended unpaved runway lighting and marking system.

The POMOLA system proved to be very effective and was extremely well received by the user pilot group participating in this inservice test. Questionnaire responses indicated almost universal acceptance of the system, with the pilots judging it to be one of the most desirable components of the proposed lighting and marking system.

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APPENDIX A

MARKING AND LIGHTING OF UNPAVED RUNWAYS
OPERATIONAL DESCRIPTION OF SYSTEM
AS INSTALLED FOR INSERVICE TESTING

PURPOSE.

The marking and lighting system for unpaved runways was developed to provide a low cost, economical system that will provide improved safety of operations at small, unpaved general aviation airports utilized by single engine and light twin aircraft. The marking and lighting system was developed to satisfy the following functional requirements:

1. Airport Location
2. Airport Identification
3. Runway Selection for Landing
4. Circling Guidance
5. Final Approach Guidance
6. Touchdown and Rollout Guidance
7. Exit Identification
8. Taxiing Guidance

Items 7 and 8 are of lesser importance and may or may not be included in the system.

It should be understood that this system is designed for short unpaved runways where the runway length is usually in the order of 1,600 to 3,000 feet long, with the majority in the neighborhood of 2,000 to 2,600 feet in length. Most of the aircraft being flown into these airports are light single engine aircraft with slow approach speeds from 50 mile per hour (mi/h) to 90 mi/h, with the majority in the upper 60 mi/h to low 70 mi/h range. The aircraft circling approach is generally in the range from 1/4 mi to 1 1/4 mi, with the median at 3/4 mi from the runway. These light aircraft normally execute relatively steep approaches ranging from 4° to 6° with a median of 5°. In general, the shorter the runway, the steeper the approach angle to insure maximizing runway length for landing and slow approaches (full flaps) to minimize landing distance.

DAYTIME MARKER SYSTEM.

Locating an airport with unpaved runways (figure 1) can be difficult unless there are many parked aircraft, since otherwise the airport usually blends into the surrounding terrain. In order to enhance the ability to visually locate the airport, a black and white pyramid locator with adjacent runway alignment markers is placed in a central location of the airport to provide a unique structure such that it can be readily differentiated from the surrounding structures and terrain. The pyramid locator can generally be seen within 3 miles or the minimum VFR visibility. It is expected that aircraft will utilize normal navigation such as pilotage, dead reckoning, VOR, or other techniques, to come within the 3-mile visual acquisition area.

After visual acquisition of the pyramid locator, the pilot can verify that he is approaching the correct airport by reading the airport identifier white letters on the black side of the pyramid.

While overflying the pyramid, other required information becomes available i.e., the windsock on top of the pyramid provides guidance for landing (runway direction) and the runway magnetic bearing (first two digits — i.e., 12 for 120°) is visible

on top of the third runway alignment marker located on each side of the pyramid. The runway alignment markers are always parallel to the runway. Therefore, this provides the necessary information to determine runway selection for landing.

The combination of pyramid and runway alignment markers, parallel to the runway, provides a visual reference for circling guidance to the appropriate runway. If the runway requires right-hand patterns, an additional runway alignment marker is placed 90° from the normal alignment markers to provide that indication. Additionally, on the white sides of the pyramid parallel to the runway, the runway elevation is imprinted in black lettering to provide information for proper circling approach altitude and altimeter setting when on the ground. In addition, if a displaced threshold is required on one or both ends of the runway, a fourth runway alignment marker is placed on the displaced threshold end with the outer half painted red to indicate the potential danger of a displaced threshold. While flying the downwind portion of the approach, the pilot will generally not be able to see most of the edge markers and must depend upon the runway alignment markers adjacent to the pyramid for guidance (these markers are always parallel to the runway).

When on base leg of an approach, the pilot will begin to see the edge markers and the panels of the POMOLA. As the pilot approaches the final approach area, he will see the edge markers for providing lateral guidance, and the POMOLA panels for vertical guidance, as shown in figure A-1. The edge markers are black and white in order to provide maximum visibility contrast with the background and within the two components of the marker. When approaching "down sun" (sun on your back) reflection of light from the white portion of the panel can be seen at a considerable distance with the black portion also generally visible but not nearly as prominent. When approaching "up sun" (facing the direction of the sun), the white portion of the edge markers will generally not be visible; however, the black portion of the marker will be in evidence. The distance that these markers are visible will vary as a function of the sun location, brightness, cloudiness, background colors, and other environmental conditions. However, they will generally be visible for 1 to 1 1/4 miles under minimum VFR visibility conditions (3-mile visibility) such as to provide appropriate lateral final approach guidance. (Note: circling guidance and final approach for most small general aviation airports is 1/4 to 1 1/4 miles with the median of about 3/4 mile.)

The POMOLA panels will also be visible on final approach to provide vertical guidance and obstruction clearance. These panels are painted fluorescent orange and are generally very visible. (Note: Under many conditions, fluorescent orange is more visible than black and white; however, the paint is expensive and needs to be repainted about every 6 months; therefore, this color was limited to the POMOLA.) The POMOLA can be seen adequately for vertical guidance out to a distance of about 1 1/4 miles under good conditions and less under poor visibility conditions. However, under most conditions, it can be used from 3/4 mile down to near threshold, which is adequate for unpaved runway operations. The approach slope is generally set at 5° with a buffer of about 1.2° from an obstruction slope of 15:1 (3.81°), to provide a safe approach over obstructions in the approach zone.

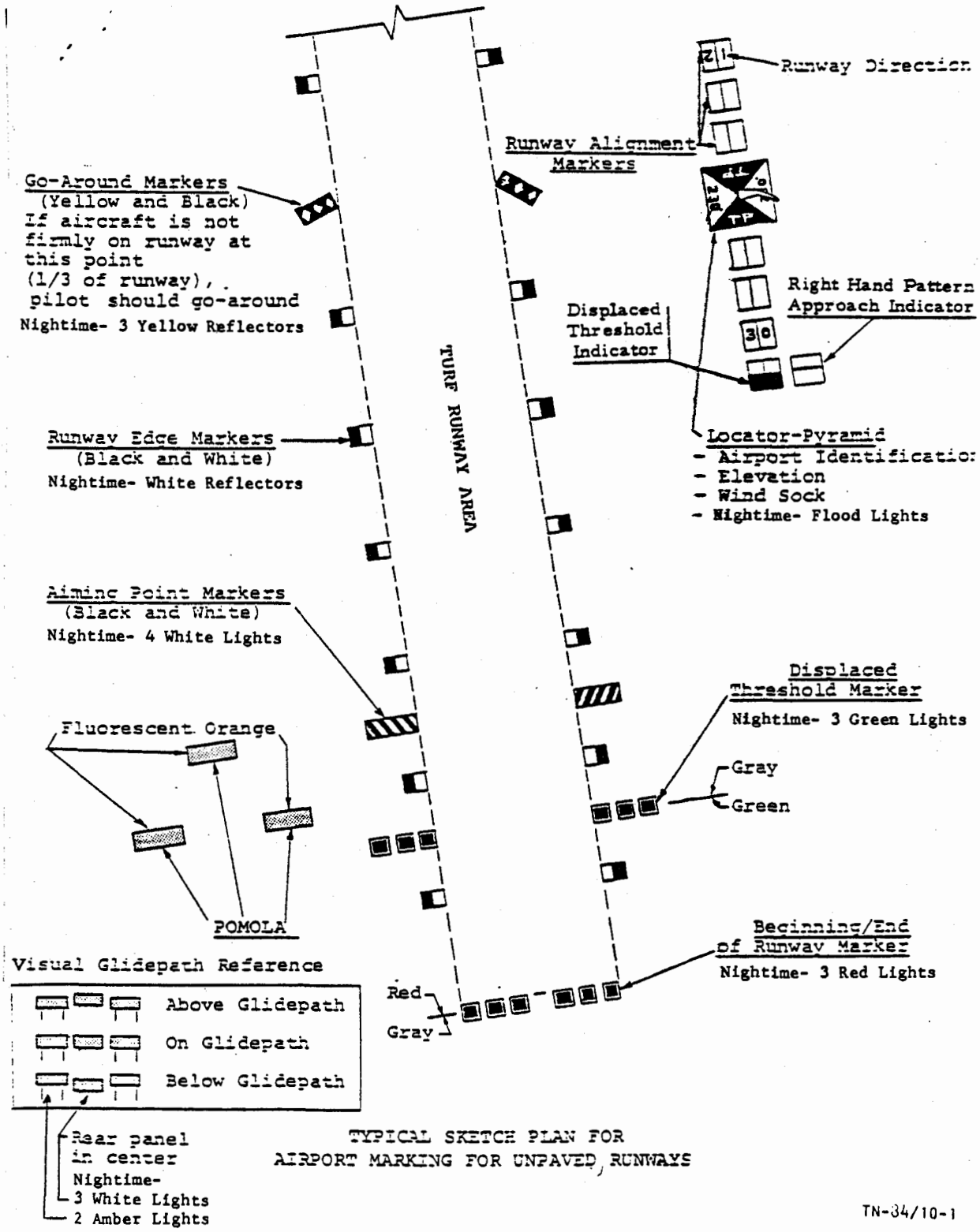

FIGURE A-1. TYPICAL SKETCH PLAN FOR AIRPORT MARKING FOR UNPAVED RUNWAYS

As final approach is being accomplished, a black and white diagonal stripped aiming point marker on each side should be used as an intercept point to which the landing will be attempted. This tends to provide a fixation point to which the pilot can aim the aircraft approach for landing with safety and yet maximizing utilization of the runway.

The threshold or displaced threshold markers, because of their reduced size and color configuration (green for threshold and red for runway end with a 3-inch white edge for greater conspicuity), are not as visible as the larger black/white edge markers and may not be seen until the approach is near the threshold (1/4 to 1/2 mile). However, their importance is greater near the threshold where they should be utilized in the final phase of the approach and flare, and they supplement the aiming point marker for delineating the area available for the final phase of the approach.

The black and white edge markers continue to be valuable as an aid in the flare, touchdown, and rollout phase for lateral guidance. In addition, a "go-around" marker of three yellow diamonds on a black background is provided on both sides of the 100 foot wide runway at a point approximately one-third the length of the runway. While this feature is optional and may be considered unnecessary by some pilots, it has been found to be a valuable guide for short runway operations. It provides a decision point for the pilot to determine if he can stop the aircraft, knowing that he has two-thirds of the runway left or if he should "go-around."

As an option, where taxiways are to be delineated, an exit identification marker (yellow arrow on black background) may be used on the edge of the runway to indicate an exit onto a taxiway area. Taxiway guidance can be accomplished with almost any type of a marker clored either blue or yellow. The use of blue plastic posts with bands of yellow retroreflective material or yellow plastic posts with bands of blue retroreflective material work satisfactorily.

NIGHTTIME SYSTEM.

Nighttime location of unpaved runways should be accomplished with an airport beacon. This may be a standard airport beacon of 250 watts, 500 watts, or 1,000 watts. However, instead of white/green for the standard lighted airport, the green filter is removed to provide a white/white signal which represents an unlighted or an unpaved, partially lighted, airport. The beacon is located at some convenient location on the airport, but should not be immediately adjacent to the runway.

After locating the airport with the beacon, the pilot should fly over the pyramid which is floodlighted to obtain the same information as in the daytime (see daytime system for explanation) for proper identification of the airport and runway selection for landing. This information should be reasonably visible from an altitude of 1,500 feet or lower.

Circling guidance is achieved by a combination of the pyramid/runway alignment markers and the green and red lights which outline the runway at the threshold and end of the runway, along with white aiming point lights. The red and green lights are about 30 watts each, in consideration of the filtering of the colored lenses to balance light intensity with the 15-watt clear lamps of the aiming point lights. Circling approaches at night should remain close in (approximately 1 mile or less) because the range of the low wattage lamps is limited. (Note: Range is adequate for low ambient lighted conditions; however, higher wattage lamps may be required under high ambient light conditions where many other lights are within the vicinity.)

Where high trees or other foliage restricts visibility, the pyramid and/or beacon may be required to provide assistance for the downwind portion of the approach. The two ends of the runway, as delineated by the runway threshold (6 green lights) and runway end (6 red lights) should provide circling guidance for the downwind and base leg portions of the approach as well as lateral guidance for the final approach phase.

After achieving lateral alignment with the runway utilizing the green/red threshold/runway end lights as well as the white aiming point lights (4 or 8, depending on the configuration), vertical approach guidance is achieved by use of the nighttime POMOLA or the Cumming Lane System, depending on which is installed. The nighttime POMOLA consists of placing three clear 15-watt incandescent bulbs on top of the single front panel and two 30- or 40-watt incandescent bulbs with a yellow or amber lens on top of each of the two rear panels. The system is then flown by aligning the three white front lights with the two sets of two yellow lights on the rear panels, as indicated, for the daytime system. It should be noted that the white lights on the front panel are in line with the white aiming point lights. When used with the nighttime POMOLA, the aiming point lights consist of four lights, two on each side of the runway. The Cumming Lane System, consists of eight aiming point lights (four on each side) aligned with one or two yellow lights on each side of the runway when on the correct glidepath angle. The white aiming point lights should be utilized as a fixation point at which the pilot wants the aircraft to land on the runway in a similar manner to the daytime aiming point marker.

Retroreflectors (these are differentiated from reflectors in that they reflect light back to the source of that light) are placed on all the daytime markers. Therefore, the edge markers will suddenly blossom as if edge lights were turned on. The location and distance from the runway at which this happens depends upon several variables, such as the distance from the light source and the angle the light makes with the approach path. The closer the landing light is to the pilot's eyes, the earlier the retroreflectors are seen and the more intense they will be (i.e., lights on the aircraft nose are better than on the wing). The retroreflectors can be seen as far out as 1 1/2 miles under good conditions; however, they are generally useful from about 1/2 to 3/4 miles out.

If a crosswind approach is necessary, it is recommended that the wing low and/or cross control technique be utilized in lieu of the crabbing method to keep the longitudinal axis of the aircraft, and hence the landing lights, in line with the runway. With a properly adjusted landing light, the retroreflectors will provide adequate intensity for proper guidance during the latter part of the final approach, flare, touchdown, and rollout. The go-around marker is also appropriately outlined by retroreflective material such that the three yellow diamonds can

readily be distinguished for go-around guidance, as discussed for the daytime systems.

If exit identification is provided, the yellow arrow will be of retroreflective material so that it can be seen during night operations. Likewise, the taxiway guidance, if provided, will incorporate either blue or yellow retroreflective material which, will provide ample taxiway guidance.

During takeoff operations, the retroreflectors on the edge markers will provide adequate guidance for the takeoff roll and lift-off.

APPENDIX B

STATISTICAL SUMMARY OF QUESTIONNAIRE RESPONSES

QUESTIONNAIRE

DAYTIME OPERATIONS — MARKING AND LIGHTING OF UNPAVED RUNWAYS

	Total Responses	
	Yes	No
1. Does the pyramid with runway alignment markers help you locate the airport in VFR conditions?	114 (92%)	10 (62%)
2. Does the airport identifier (TP) and airport altitude painted on the pyramid (airport locator) provide any useful information to you?	116 (95%)	7 (6%)
3. Do you find the combination of pyramid with windsock on top, runway alignment markers, and runway direction numbers to provide adequate information for selection of proper runway for landing and circling guidance?	115 (93%)	9 (7%)
4. Do the runway edge markers provide adequate lateral guidance on final approach?	119 (97%)	4 (3%)
5. Does the POMOLA provide adequate vertical glidepath guidance and obstruction clearance on final approach?	110 (93%)	8 (7%)
6. Do the aiming point markers and threshold or displaced threshold markers provide proper indication for touchdown guidance?	117 (97%)	4 (3%)
7. Do you consider the aiming point markers useful?	107 (91%)	11 (9%)
8. Do the "go-around" markers perform a useful function?	96 (85%)	17 (15%)

REMARKS: (additional comments)

SUGGESTIONS FOR IMPROVEMENT:

QUESTIONNAIRE

NIGHTTIME OPERATIONS — MARKING AND LIGHTING OF UNPAVED RUNWAYS

	Total Responses	
	Yes	No
1. Is the beacon, in combination with lighted pyramid with runway alignment markers, adequate for locating the airport at night?	27 (100%)	0
2. Is nighttime lighting adequate to identify airport and obtain wind information (from windsock on top of pyramid) and runway landing direction?	22 (85%)	4 (15%)
3. Do the runway end lights provide adequate circling guidance and lateral alignment on final approach?	21 (78%)	6 (22%)
4. Does the nighttime POMOLA provide adequate vertical glidepath guidance and obstruction clearance on final approach?	23 (92%)	2 (8%)
5. Do the retroreflective runway edge markers provide sufficient delineation of the runway during the latter portion of the final approach, flare, landing, and taxiing?	25 (93%)	2 (7%)
6. Do the white aiming point lights and threshold or displaced threshold lights provide proper indication for touchdown guidance?	22 (85%)	4 (15%)
7. Do the yellow "go-around" retroreflective markers perform a useful function?	19 (76%)	6 (24%)

REMARKS: (additonal comments)

SUGGESTIONS FOR IMPROVEMENT: