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EVALUATION OF PRECISION APPROACH PATH INDICATOR (PAPI)

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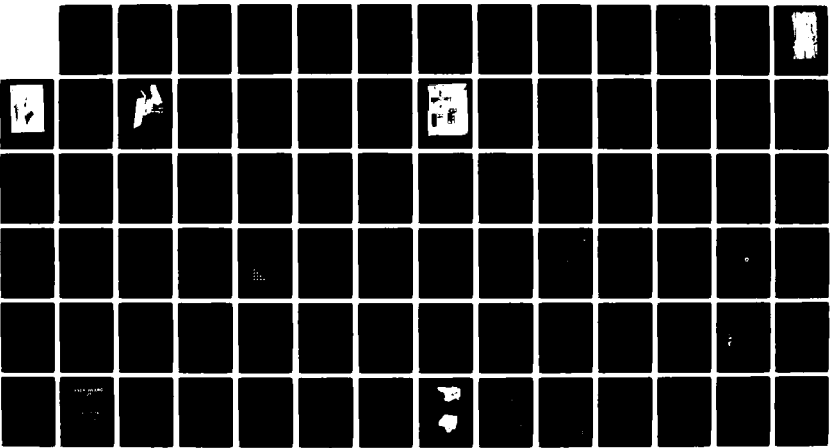
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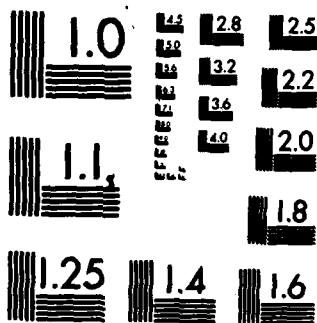
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# Evaluation of Precision Approach Path Indicator (PAPI)

AD A129007

Bret Castle

Prepared By  
FAA Technical Center  
Atlantic City Airport, N.J. 08405

April 1983  
Final Report

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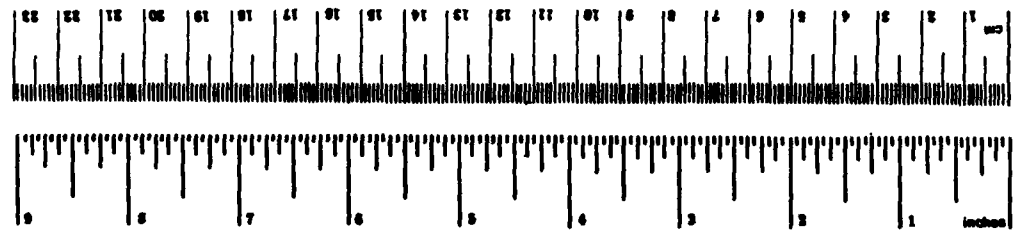
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16. Abstract <p>This report describes the evaluation of the Precision Approach Path Indicator (PAPI) to determine whether the PAPI provides sufficient advantages over the current standard red/white Visual Approach Slope Indicator (VASI) to warrant recommending it as the United States standard visual glidepath indicator. This process covered photometric testing, environmental testing, and flight evaluation. Various flight evaluations were accomplished at the FAA Technical Center (ACY), Newark Airport, New Jersey (EWR), Teterboro Airport, New Jersey (TEB), and at Bader Field in Atlantic City, New Jersey (AIY). The results indicate that PAPI was preferred over the standard red/white VASI system. In general, United States pilots find very little fault with the standard red/white VASI system, and the PAPI is preferred mainly because it gives more rate and position information and because of its quick transitions from one color to the other. It is a passive system (no moving parts to wear out), meeting all of the operational requirements of a glide slope system, and requires less equipment and real estate than the standard VASI.</p>					
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# METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures			Approximate Conversions from Metric Measures					
Symbol	When You Know	Multiply by	To Find	Symbol	When You Know	Multiply by	To Find	Symbol
<b>LENGTH</b>								
in	inches	2.5	centimeters	cm	centimeters	0.4	inches	in
ft	feet	30	centimeters	cm	centimeters	0.4	inches	in
yd	yards	0.9	meters	m	meters	3.3	feet	ft
mi	miles	1.6	kilometers	km	kilometers	0.6	yards	yd
<b>AREA</b>								
sq ft	square inches	6.5	square centimeters	cm <sup>2</sup>	square centimeters	0.16	square inches	sq in
sq ft	square feet	0.09	square meters	m <sup>2</sup>	square meters	1.2	square yards	sq yd
sq yd	square yards	0.8	square meters	m <sup>2</sup>	square meters	0.4	square miles	sq mi
sq mi	square miles	2.6	hectares	ha	hectares (10,000 m <sup>2</sup> )	2.5	acres	ac
<b>MASS (weight)</b>								
oz	ounces	28	grams	g	grams	0.035	ounces	oz
lb	pounds	0.45	kilograms	kg	kilograms	2.2	pounds	lb
short ton	short tons (2000 lb)	0.9	metric tons	t	metric tons	1.1	short tons	short tons
<b>VOLUME</b>								
cup	teaspoons	5	milliliters	ml	milliliters	0.035	fluid ounces	fl oz
fl oz	tablespoons	15	milliliters	ml	milliliters	2.1	gills	gi
pt	fluid ounces	30	milliliters	ml	milliliters	1.05	quarts	qt
qt	cup	0.25	liters	l	liters	0.26	gallons	gal
gal	pint	0.47	liters	l	liters	2.7	cubic feet	cu ft
cu ft	quart	0.95	liters	l	liters	2.8	cubic yards	cu yd
cu yd	gallon	2.7	cubic meters	m <sup>3</sup>	cubic meters	0.035		
cu yd	cubic feet	0.035	cubic meters	m <sup>3</sup>	cubic meters	0.76		
<b>TEMPERATURE (exact)</b>								
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



\* 1 in = 2.54 (exact). For other exact conversions and more detailed tables, see NBS Misc. Publ. 226, Units of Length and Measure, Price \$2.25, SD Catalog No. C13.10286.

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## EXECUTIVE SUMMARY

The work described in this report has been performed in response to the Office of Airport Programs request, number AAP-550-78-2 (dated May 22, 1978) "Evaluation of the Precision Approach Path Indicator (PAPI)." The purpose for testing PAPI was to determine whether it provides sufficient advantages over the standard red/white Visual Approach Slope Indicator (VASI) to warrant recommending it as the United States standard visual glidepath indicator.

The PAPI system was developed in the United Kingdom as an improvement to the VASI system adopted as a standard 20 years ago. The VASI system, although a good system, has certain shortcomings. Improvements claimed by proponents of the PAPI system are:

1. Better guidance below 200 feet.
2. Quick, sharp (red/white) transition from one color to the other.
3. Multiple path guidance (incremental information).
4. Single bar touch-down aiming point.

Testing of the PAPI systems was performed in two parts. Part one consisted of photometric, condensation, and transition zone shifting tests along with obstacle clearance tests, beam width tests, and tests to try to produce sharp color transition PAPI signals from modified VASI units. Part two consisted of flight evaluations of the PAPI systems at the Federal Aviation Administration (FAA) Technical Center, Atlantic City Airport, New Jersey, and other operational airports, namely, Newark International Airport, New Jersey (EWR); Teterboro Airport, New Jersey (TEB); and Bader Field, Atlantic City, New Jersey (AIY). These tests were configured so that the PAPI was used in conjunction with an Instrument Landing System (ILS) system where the PAPI was located (1) coincident with the ILS Glidepath Intercept (GPI) point, and (2) 300 feet beyond the ILS GPI with the PAPI configured especially to operate with wide-bodied aircraft. Flight tests were also accomplished on runways with no ILS and principally used by general aviation aircraft. In addition, flight testing of a two-box PAPI was performed, as were resolution tests on the PAPI system at the Technical Center.

The results of the testing determined that the PAPI units met or exceeded the existing requirements established for the standard red/white VASI system with regard to intensity distribution, beam width, stability of the projected signal and mechanical integrity of the units. It was found that during certain weather conditions, condensation could form on the PAPI lenses and produce transient false pink signals which must be eliminated by some means. A small amount of transition-zone shifting of the signal in the vertical plane was also found possible under certain changes in temperature and humidity. It was found that modification of the VASI box transition bar dimension alone was not a practical way to modify VASI boxes to produce PAPI signals but, by the proper use of lenses, the conversion of a VASI box to produce PAPI signals was possible. It was determined that an abbreviated two-box PAPI system fulfills all of the visual glide slope requirements for use on short runways where the five incremental paths provided by the four-box PAPI system are not needed. It was also determined that four-box PAPI system signals can be resolved and interpreted at a range of 4 nautical miles when the boxes are separated by at least 20 feet, and the signals can be resolved at a range of 2 nautical miles when the boxes are separated by a minimum of 10 feet.

The conclusions that were drawn from the testing were that the PAPI system does provide significantly improved visual approach slope guidance over that obtained from the standard red/white VASI system, and that the abbreviated two-box PAPI system can be used as an economical alternative to the four-box PAPI system at small airports. In addition, it was concluded that the separation of PAPI units in a four-box system need not be more than 20 feet, and for small airports, where typical approach distances are less than 2 nautical miles, the units need not be separated by more than 10 feet. Condensation on the exterior of the PAPI lenses must be prevented by either operational procedures or inclusion of heating devices in the fixture design. It was also concluded that it is unlikely that any single modification kit can be developed by the FAA to modify existing VASI units into PAPI units, due to the variations in construction dimensions of VASI units, the instability of VASI structural enclosures, and the expense of providing the necessary lenses.

## INTRODUCTION

### PURPOSE.

The work described in this report has been performed in response to the Office of Airports Programs request number AAP-550-78-2 (dated May 22, 1978) "Evaluation of the Precision Approach Path Indicator (PAPI)." It was completed under the Federal Aviation Administration (FAA) Technical Center Program Document number 08-493, Subprogram 081-502, Projects 510 "PAPI Evaluation" and 550 "Modification of VASI Fixtures to Produce PAPI Signals."

The purpose for testing the Precision Approach Path Indicator (PAPI) was to determine whether the PAPI provides sufficient advantages over the standard red/white Visual Approach Slope Indicator (VASI) to warrant recommending it as the United States standard visual glidepath indicator.

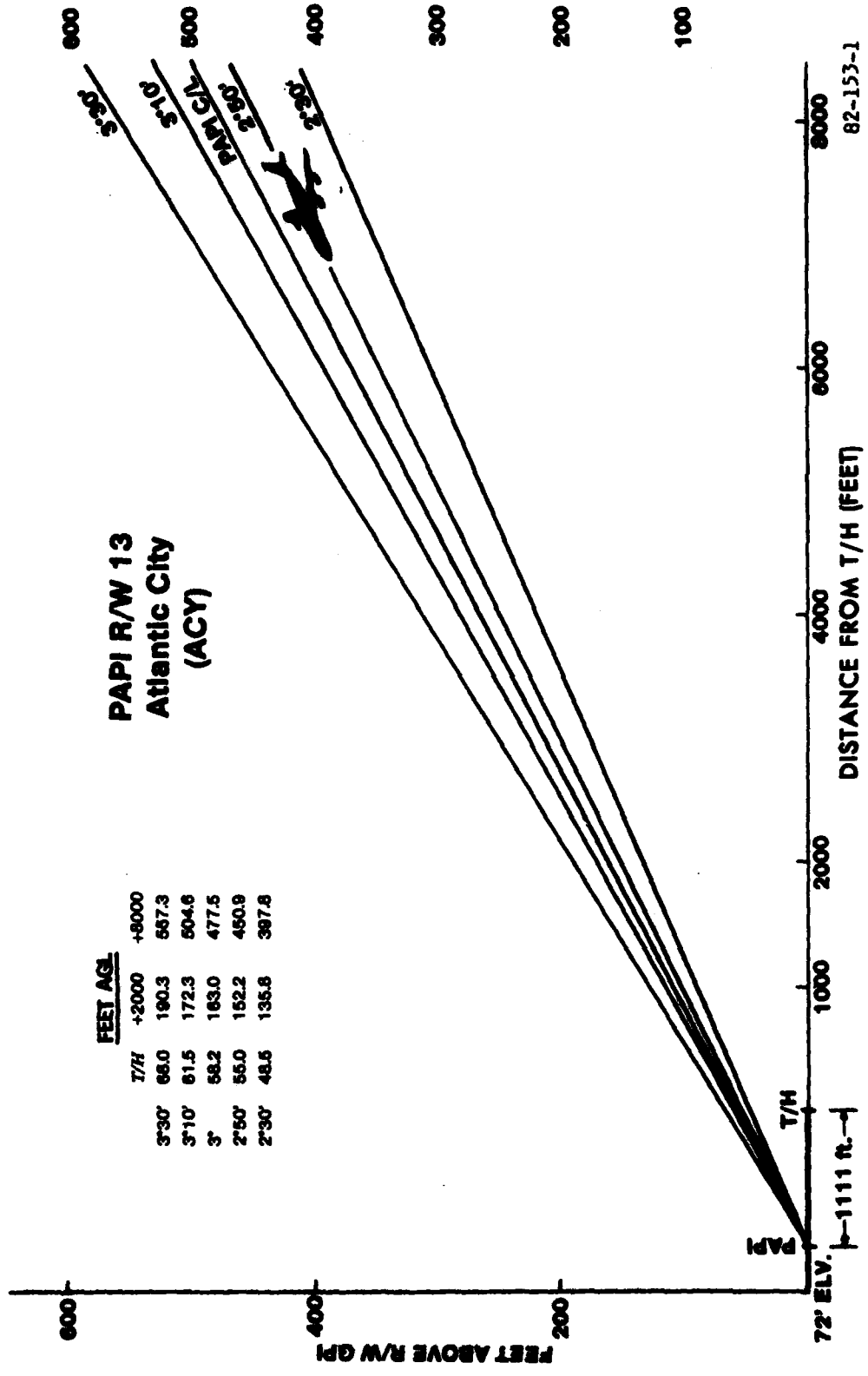
### BACKGROUND.

The PAPI system is the first red/white passive glide slope system that the Technical Center has been asked to evaluate in detail since the VASI was accepted as the United States standard. The PAPI system was developed in the United Kingdom as an improvement to the VASI system adopted as a standard 20 years ago by the International Civil Aviation Organization (ICAO). The VASI system, although a good system, has certain shortcomings. Improvements claimed by proponents of the PAPI system are:

1. Better guidance below 200 feet.
2. A quick, sharp red/white transition from one color to the other.
3. Multiple path guidance (incremental information).
4. A single bar touch-down aiming point.

The PAPI system consists of a bar of four light units (three lamps per unit) facing the approach end of the runway. Each unit is set at a slightly different angle (20 minutes apart) and emits a beam of high intensity light, the upper half showing white and the lower half showing red. Figure 1 depicts a side view of the signal sectors in the approach zone. As seen by the approaching pilot, it consists of a bar of four quick transition red/white light units whose on-glidepath signal (usually 3°) is two red and two white lights (figure 2). When the aircraft is slightly below glidepath (between 2° 50 minutes and 2° 30 minutes), the signal changes to three red and one white light. When the aircraft is further below glidepath (below 2° 30 minutes), a fly-up signal of four red lights is seen. Conversely, deviations above the glidepath will cause the red light units to turn successively white. In this configuration, the lights can be seen at about 5 miles from the threshold of the runway (in unlimited visibility) and the on-glidepath signal depth gradually reduces to approximately 6 feet at the threshold.

The physical configuration of the PAPI system (4 boxes) is shown in figure 3, each box being similar in appearance to the standard red/white VASI box. They require the same type and amount of power as required for a four-box VASI system and, therefore, there is no change in the power requirements if a PAPI system is to be substituted for a four-box VASI system. Most of the flight testing was accomplished on a model BLC MK 6 PAPI system (figure 4) manufactured by the Barrel Lighting Company, Limited of England. Some testing, however, was performed on early



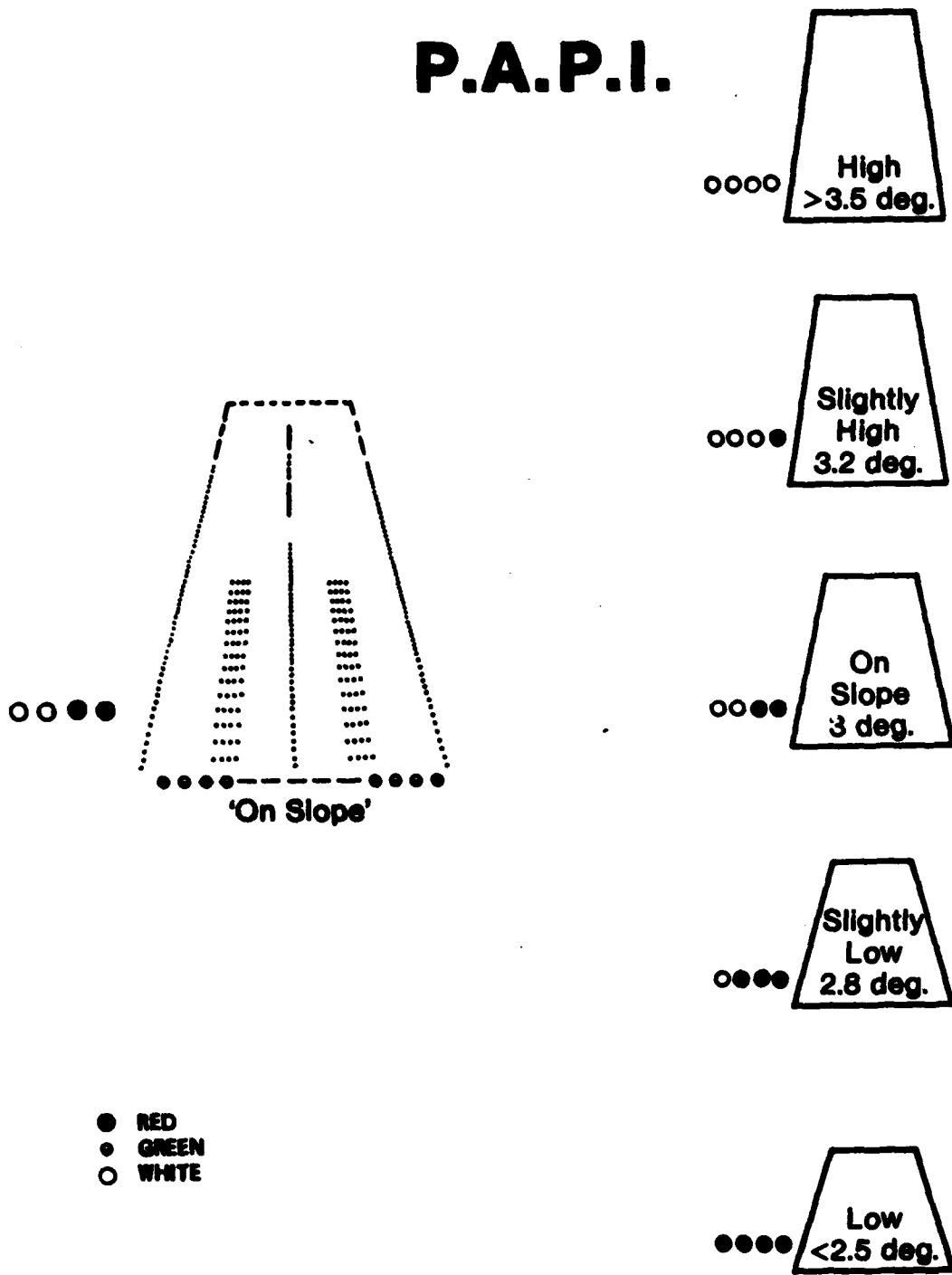
**PAPI R/W 13  
Atlantic City  
(ACY)**

FEET AGL	
T/H	+8000
3-30'	66.0
3-10'	61.5
3'	58.2
2-50'	56.0
2-30'	48.6
PAPI G/L	190.3
	172.3
	163.0
	152.2
	135.8
	604.6
	477.5
	450.8
	397.8

FIGURE 1. PAPI APPROACH PATH (SIDE VIEW)

82-153-1

# P.A.P.I.



82-153-2

FIGURE 2. APPROACH PATH ILLUSTRATION

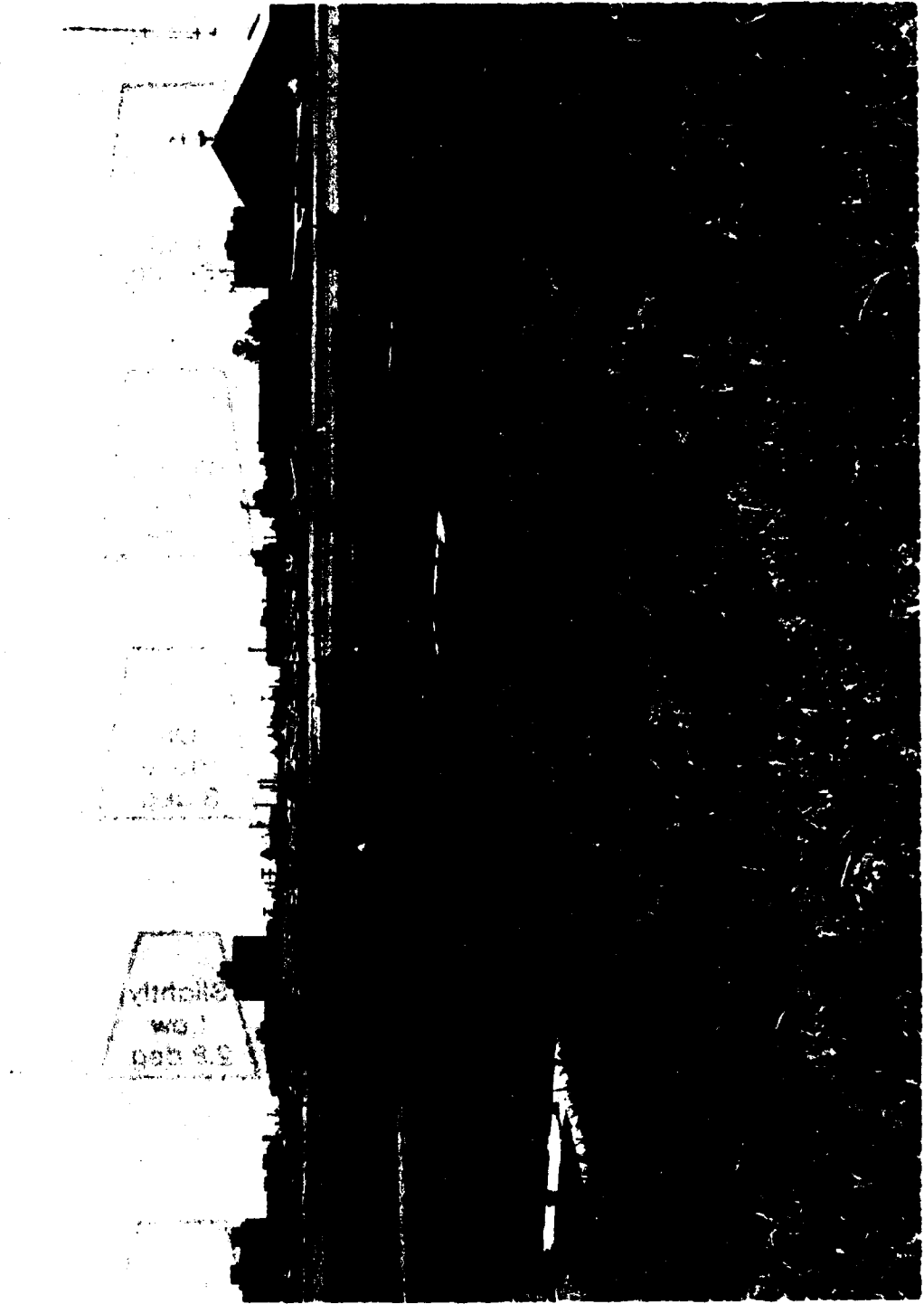


FIGURE 3. BARREL PAPI SYSTEM AT BADER FIELD



FIGURE 4. BARREL BLC MK 6 PAPI UNIT

versions of PAPI units built by ADB of Belgium and by Crouse-Hinds, Syracuse, New York (figure 5).

#### METHOD OF APPROACH

Testing of the PAPI systems was performed in two parts. Part one consisted of photometric, signal configuration, and environmental testing covering the following:

1. Photometric tests.
2. Condensation tests.
3. Transition zone shifting tests.
4. Obstacle clearance tests.
5. Beam width tests.
6. Modification of VASI units to produce PAPI signals (sharp color transition).

Part two consisted of flight evaluation of PAPI systems at the FAA Technical Center, Atlantic City Airport, New Jersey and at other operational airports as follows:

1. Flight testing with the PAPI located coincident with the ILS Glidepath Intercept (GPI) point at the Technical Center (ACY).
2. Flight testing with the PAPI located 300 feet beyond the ILS GPI at Newark International Airport, New Jersey (EWR).
3. Flight testing at Teterboro Airport, New Jersey (TEB) (no ILS).
4. Flight testing at Bader Field, New Jersey (AIY) (no ILS).
5. Flight testing of a Two-Box PAPI at ACY.
6. PAPI signal resolution testing at ACY.

#### PHOTOMETRIC AND ENVIRONMENTAL TESTING (PART I)

##### PHOTOMETRIC TESTS.

Photometric measurements were made on the Barrel Lighting Co. PAPI fixture. The lamps are standard 30 volt, 200 watt, 200PAR locomotive lamps. Horizontal and vertical intensity distribution measurements were obtained for the units. Figure 6 shows the vertical beam distribution of both the red and the white signals of one PAPI unit when measured from minus 10 degrees to a plus 10-degree elevation. It also displays the quick transition (approximately 3 minutes of arc) from one color to the other. Figures 7 and 8 show the horizontal intensity distribution of the white and red signals, respectively, taken at peak beam intensity. The peak intensity of the white signal, occurring at 1.5° elevation, was 112,000 candelas and the peak intensity of the red signal, occurring at 0° elevation, was 22,000 candelas. Transmittance tests were made on the red filters of the Barrel unit, and



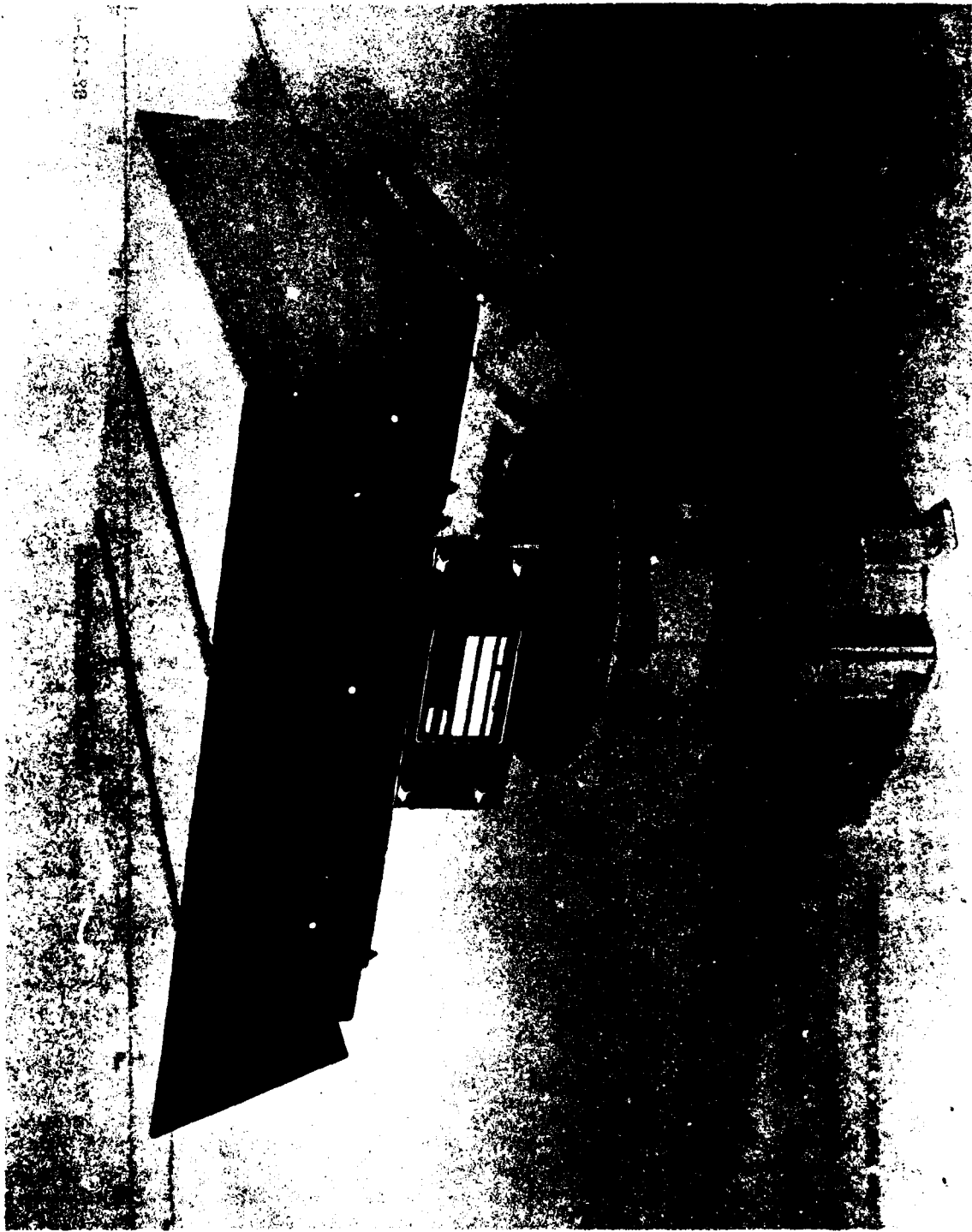
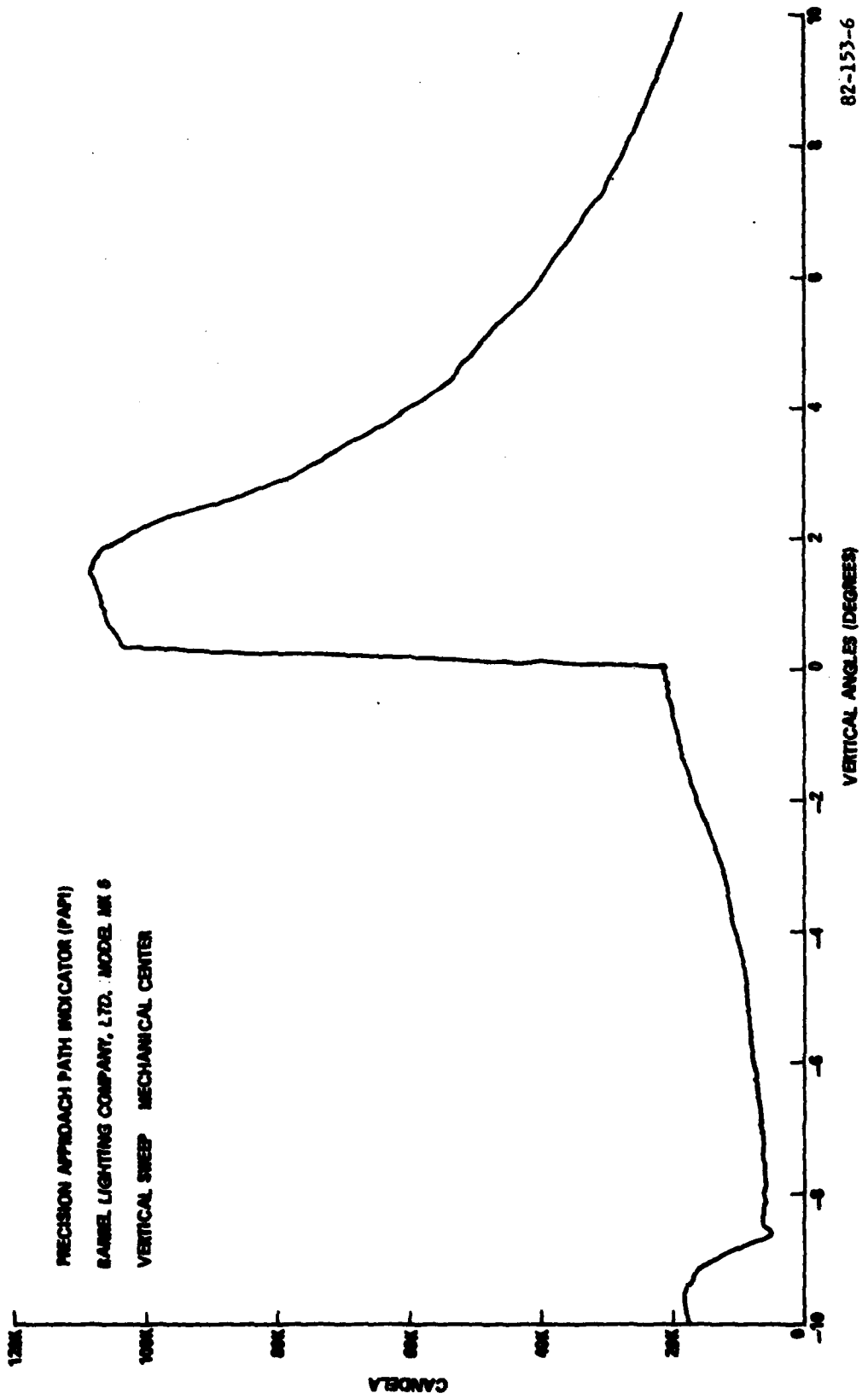
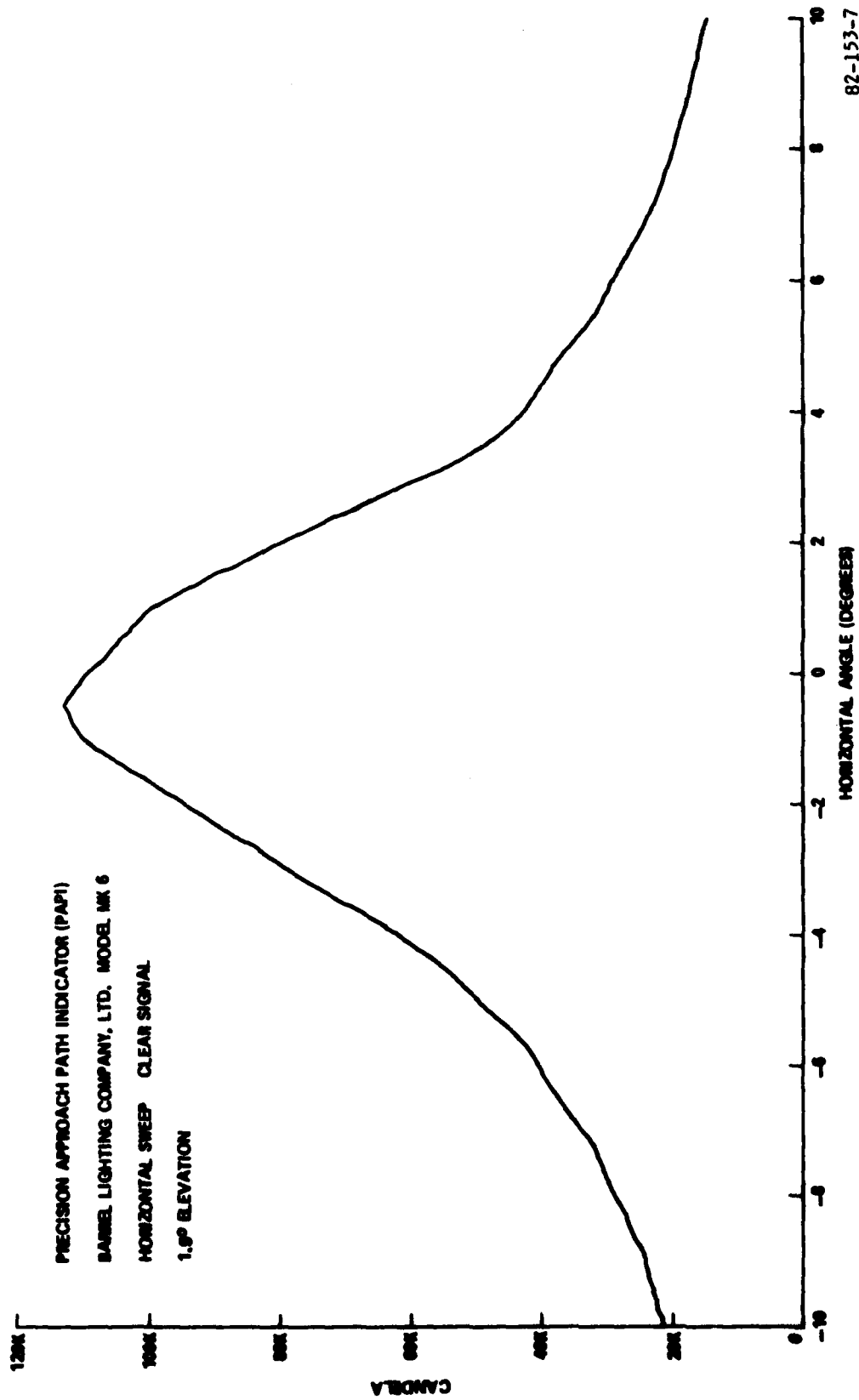


FIGURE 5. CROUSE-HINDS PAPI UNIT



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FIGURE 6. VERTICAL INTENSITY DISTRIBUTION CURVE



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FIGURE 7. CLEAR SIGNAL INTENSITY DISTRIBUTION CURVE

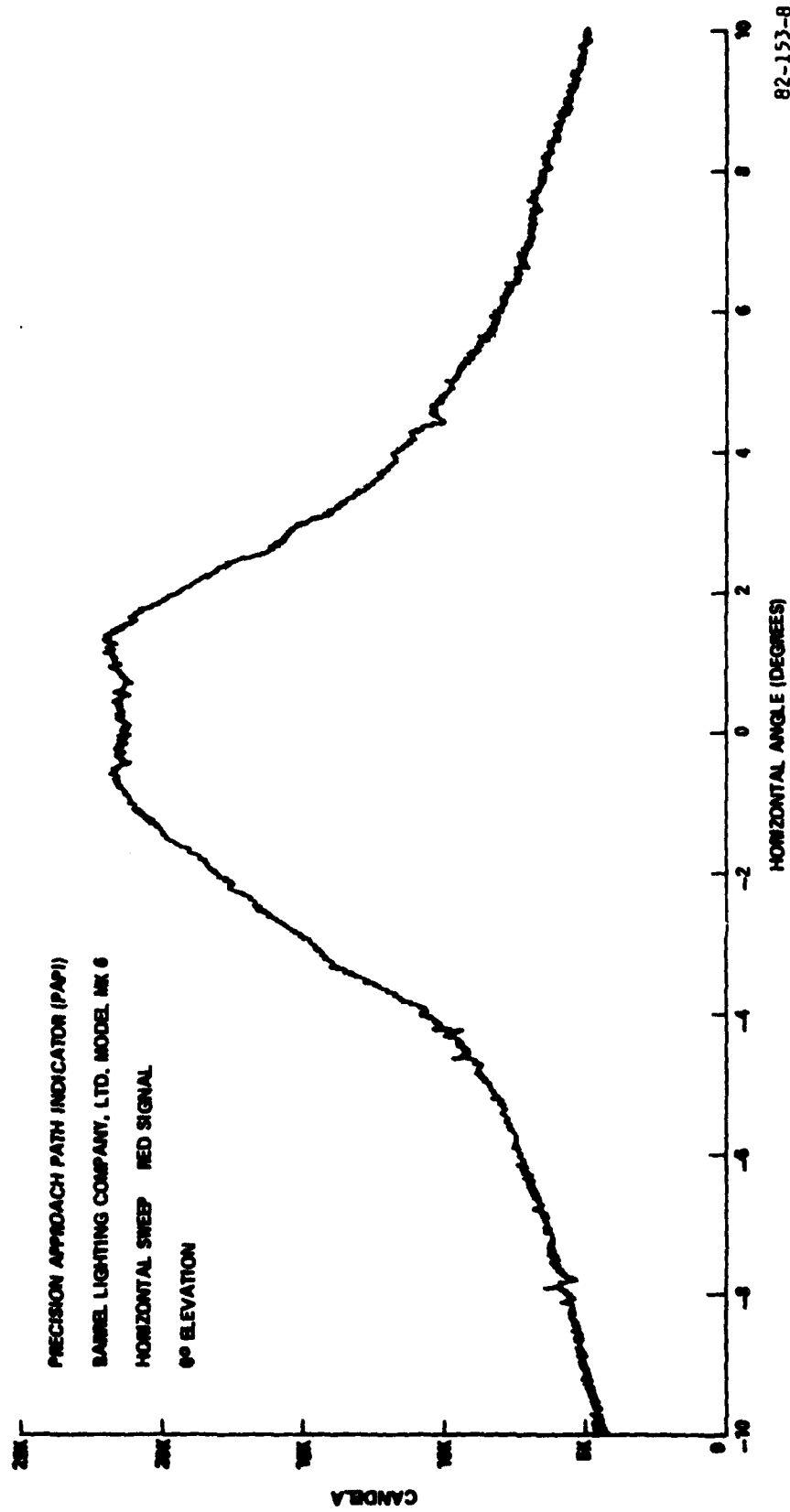


FIGURE 8. RED SIGNAL INTENSITY DISTRIBUTION CURVE

this was found to be 21 1/4 percent in the cold condition which meets acceptable standards.

#### CONDENSATION TESTS.

Because the PAPI systems use lenses to improve the signals, and since these lenses are usually exposed to the weather, particular attention was paid to the possibility of condensation forming to obscure the correct signal. The weather conditions were monitored carefully for high humidity periods that would create this problem and field observations made accordingly. During the early work on PAPI systems, it was determined that the Belgian ADB PAPI units tended to form condensation upon the exposed frontal surfaces of the lenses during high humidity conditions while the system was deenergized. Upon energization, diffusion and mixing of the projected colors created a broad "pink" signal which could not be easily interpreted. Correct color signals were restored within 15 minutes after turning the PAPI unit on as the heat from the lamps dissipated the accumulated moisture.

In order to test this atmospheric moisture condition on the PAPI units, man-made fog or condensation was created by soaking the units in a temperature chamber at low temperatures (30° F) and then immediately subjecting them to normal room temperatures that were at least 30° F higher and more humid. This created condensation on the units, similar to that observed when a bathroom mirror fogs up after a shower. The following four condensation tests were performed to determine the operational conditions under which condensation, with resultant signal deterioration, would or would not occur.

For the initial test, both the British Barrel Lighting Company Limited MK 6 and the Belgian ADB units were installed in the walk-in temperature/humidity chamber (figure 9) in such a manner that their signals could be seen through the glass viewing port. After the units were cold soaked at 30° F for 2 hours with the lamps deenergized, the chamber door was opened and warm humid air was allowed to enter the chamber. The exterior lens surfaces of both PAPI units were almost immediately covered with condensation, resulting in a uniform distortion of the projected signal that was perceived as a pink overall signal. The units were energized at 6.6 amperes intensity at this time. The ADB unit displayed a deeper pink hue since its red filters are normally a deeper red hue than those of the Barrel unit. The interiors of the boxes were then checked and virtually no internal condensation was found. Within 1/2 hour, the lenses of both units were clear of any condensation and normal signal presentations were evident.

The second test was conducted in the same manner, except that the heaters in the Barrel unit were energized during the cold soak preparation. No heaters were provided with the ADB unit. After soaking the units at 30° F for 2 hours with the lamps off, the chamber door was again opened to the warm air (72° F) and 61 percent relative humidity. Condensation again immediately formed on the glass front of both units and the same signal anomalies were observed for a period of approximately 1/2 hour. The Barrel unit heater did not appear to have any significant remedial effect under these extreme temperature differential conditions.

For the third test, the units were again soaked for 2 hours at 30° F, with the heaters energized in the Barrel unit and, this time, with the lamps of both units operating on step 5 (6.6 amperes) intensity during the cold soak preparation. After the door of the chamber was opened to the warm (74° F) temperature (61 percent relative humidity), it was observed that no condensation formed on the frontal lens surfaces of either unit.



FIGURE 9. ENVIRONMENTAL TESTING OF PAPI UNITS

For the fourth test, the above conditions were repeated with the only change being that the intensity of the lamps was set at step 3 (4.1 amperes). After opening the door to the room atmosphere, temperature 71° F and relative humidity of 56 percent, small amounts of condensation formed on the center lens of the Barrel unit and on the ADB plexiglas shield. Condensation cleared within 10 minutes and normal signal presentations were restored.

From the above tests, it can be seen that, even under these extreme conditions, leaving the units energized for 30 minutes before use will serve to dissipate any formation of condensation due to temperature and humidity changes.

During the period of October through December 1981, freezing and near freezing weather, with attendant fog and high humidity conditions, occurred at the Technical Center. Observations as to the effects of such naturally occurring conditions upon signal projections from field installed PAPI systems were made and recorded on both the Barrel and Crouse-Hinds manufactured lighting fixtures. The PAPI units were numbered consecutively so that number 1 was the inboard unit and number 4 was the outboard unit.

Typically, the official weather report at 0800 hours was overcast, temperature 35°, dew point 35°, light drizzle and fog. Both Barrel and Crouse-Hinds units, installed to serve runway 4, were monitored with units 1 and 2 continuously operating and units 3 and 4 deenergized. Correct colors and signals were observed on units 1 and 2. Units 3 and 4 had droplets of water on the inside of the lenses and about 1/2 inch of snow on the lower portion of the outside of the lenses. Number 3 was then energized to step 5 (6.6 amperes) and it was observed that the projected signal color was a pinkish white through all vertical angles. This pink signal, as viewed by a pilot, could have been interpreted to be white, giving a false 'fly down' signal. A dangerous condition. Step 5 intensity operation for approximately 4 minutes with the Crouse-Hinds units and approximately 10 minutes with the Barrel units (no heaters) dissipated the condensation from the lenses and restored the proper signal presentation. Number 4 units were then energized to step 5 intensity and the same results were noted.

During many non-operational periods, ice was found on the sides of the PAPI units with no ice formed on the lenses, or functional portion of PAPI. The design of the units, with the lenses recessed under an overhang, served to keep the lenses clear.

This freezing condensation problem is recognized by the manufacturers and the Barrel units have heaters installed close to the lenses in an attempt to prevent this condition. The Crouse-Hinds units are extremely compact and the heat from the lamps develops quickly to eliminate this condition within a few minutes after energization. Because this problem can be expected to occur with any PAPI unit, specifications should be written to include means for preventing such an occurrence.

#### TRANSITION ZONE SHIFTING TESTS.

In order to check for possible transition zone shifting in the vertical plane, due to changes in temperature and/or humidity, tests under varying environmental conditions were performed.

One of each of the Barrel and the ADB PAPI units were placed in the temperature/humidity chamber (figure 9) in such a manner that their light signals were projected through the viewing port with the red/white transition zone clearly

displayed 24 feet from the units. Lines were marked on a wall at the precise location of the transition zone for each unit. Both units, with lamps deenergized, were then heat soaked for 24 hours at 131° F and 95 percent humidity. After the soaking, the units were energized and the position of the transition zone noted. The ADB unit transition zone had not shifted at all, although the zone was slightly less well defined. The Barrel unit transition zone had shifted upward 3/16 of an inch with the zone just as distinct as before the soaking. The lamps were left ON for 1/2 hour and then turned OFF for 1/2 hour. They were then turned back ON and it was found that the transition zones had not shifted. The units were then deenergized and left OFF for 24 hours at a normal room temperature and humidity. After this 24-hour period, the light transition zones were again checked and it was found that the Barrel unit transition zone had returned to its original position. The ADB unit transition zone displayed no evident shifting during the entire test procedure.

From the above test, it can be seen that the Barrel system, under high temperature and humidity conditions, may exhibit a transition zone shift of approximately 2 1/4 minutes of arc upward. This is equivalent to 7.81 inches upward at a distance of 1000 feet from the unit, or 6.51 feet upward at a range of 2 miles. This transition zone shifting, even with such extreme temperature and humidity changes, is not of sufficient magnitude to be considered an operational problem.

#### OBSTACLE CLEARANCE TESTS.

The transition angles of each Barrel PAPI unit were flight checked to insure that the red/white color transition path projected was exactly the aiming angle set into the unit using the aiming clinometer provided with the system. Each PAPI box was energized individually and its transition angle flown as closely as possible with a Convair 580 aircraft (N-49) (figure 1). A portable theodolite was set up at the PAPI boxes and the average approach angle flown by the pilot was noted. The theodolite was set 19 feet in front of the PAPI boxes in order to have the eye piece in the actual line-of-sight between the aircraft and the PAPI units. As the pilot was continually trying to fly the thin transition line in the sky, the result was a continual cycling above and below that line. An observer aboard the aircraft was in constant communications with the portable theodolite operator on the ground reporting whether above, on, or below the transition line (red or white signal). This allowed the operator to get a fix on the transition angle created by the PAPI signal. Three approaches were made to each unit. At the same time, the photo-theodolite system tracked the aircraft and recorded the flight path flown. These results are shown in table 1.

TABLE 1. MEASURED FLIGHT TRANSITION ANGLES PRODUCED BY PAPI UNITS

<u>PAPI Box Number</u>	<u>PAPI Box Aiming Angle Deg - Min</u>		<u>Average Angle With Portable Theodolite Deg - Min</u>		<u>Average Angle With Photo Theodolite Deg - Min</u>
1	3	30	3	37	(no recording obtained)
2	3	10	3	11	3 05
3	2	40	2	46	2 37
4	2	20	2	28	2 22



As shown above, the differences in the recorded angles and the clinometer set aiming angles was never more than 8 minutes of arc.

As a part of the Obstacle Clearance Tests, a High Ranger Lifting Device (maximum height - 75 feet) was used to measure the exact height of the transition signals over the threshold. The PAPI units were located 1,411 feet down runway 13 and to the side. At ACY, the threshold is 3 feet above the elevation where the PAPI units were located. Table 2 shows the results.

TABLE 2. MEASURED TRANSITION ANGLES PRODUCED OVER THRESHOLD

<u>PAPI Box Number</u>	<u>PAPI Box Aiming Angle Deg - Min</u>		<u>Theoretical Transition Height Above Threshold (Feet)</u>	<u>Measured Transition Height Above Threshold (Feet)</u>
1	3	30	83.3	(no measurement)
2	3	10	75.06	73.5
3	2	40	62.72	60.5
4	2	20	54.5	54.5

The measured heights agree within acceptable tolerances with the theoretical values computed for the threshold crossing heights. It is noted that measurements of transition points to better than one foot are very difficult.

BEAM WIDTH TESTS.

On two occasions, the beam width of the Barrel PAPI system was measured by use of a Bell 206 helicopter (N-10) and a portable theodolite. The portable theodolite was placed on the ground adjacent to the PAPI units and communications maintained between the theodolite unit operator and the helicopter observer. Four flights across the PAPI path, perpendicular to the runway centerline, were made at night at a range of 4 nautical miles from the PAPI units. Widths recorded were 33°, 34°, 35°, and 35° (average beam width at night of 34 1/4°). Four passes were made during the daytime at a range of 3 miles from the PAPI units. The average of these runs was 28°. This exceeds the minimum beam width specified (20°) for the standard red/white VASI during daytime or nighttime.

MODIFICATION OF VASI UNITS TO PRODUCE PAPI SIGNALS.

Both VASI and PAPI lighting fixtures are similar in that they generate a solid red signal below the fixture aiming line and a solid white signal above the line. They differ, however, in that the PAPI fixture utilizes an additional lens arrangement to minimize the vertical height of the transition (pink) zone to less than three minutes of arc. VASI fixtures typically display a wider transition zone of approximately fifteen to twenty minutes of arc, and have been determined to be unsuitable for use in the PAPI configuration.

Efforts undertaken in the past at the FAA Technical Center, in an attempt to reduce the VASI transition zone height by varying the vertical width of the transition bar were successful to a limited extent. Increasing the vertical width of the bar from 1/2 inch to 1 inch reduced the transition zone to approximately 8 minutes of arc,

with an attendant but yet acceptable reduction of signal intensity within the transition zone. Attempts under this project effort to further increase the width of the transition bar beyond 1 inch, however, resulted in much greater transition zone signal attenuation, to the extent that a resultant weak signal was perceived, from a distance, to be no signal at all. Substitution of unfluted clear and red filters, to narrow the emitted beam spread and increase signal intensity, did not provide sufficient enhancement of the weak transition zone display to render it useable, and narrowed the system horizontal coverage to the point of being insufficient for operational use. These results demonstrated that the VASI fixtures cannot, through modification of the transition bar width alone, be rendered suitable for use in the PAPI configuration.

Considerable work was then performed in an attempt to modify standard red/white VASI boxes with installed lenses to produce the quick transition of signals. Two manufacturer's types of VASI units, General Electric and Sylvania, were available for experimentation, and the first modification attempts were performed on the General Electric VASI boxes.

Three types of projection lenses were considered for use. They were:

- Type I: Glass plano-convex spherical lenses
- Type II: Plastic flat circular-zoned lenses
- Type III: Glass or plastic cylindrical lenses

Among the three types of lenses, type III lenses were considered because they would have been compatible with the spread lenses usually found in existing VASI boxes and would have given the same width to height ratio with the required intensity pattern. However, costs of such lenses (approximately \$500 each) was considered not cost beneficial for a VASI to PAPI modification and therefore were eliminated from further consideration.

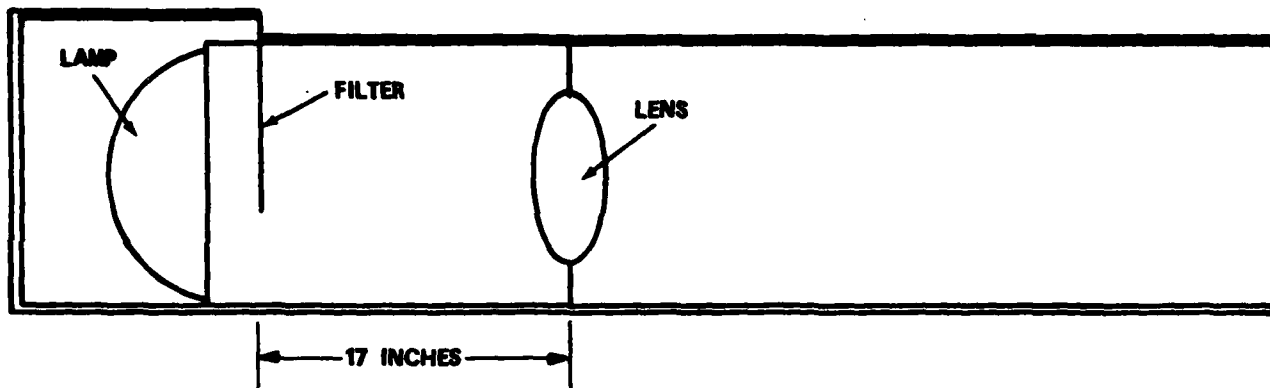
Several diameters and focal lengths of both types I and II lenses were used. Each has its own advantages and disadvantages which can be ascertained by a study of each manufacturer's lenses. The type I 6-inch diameter lens was chosen as the best compromise between cost and weight versus maximum utilization of the light coming from the 8-inch diameter lamps and filters used in VASI boxes.

Twelve type I lenses, with nominal 6-inch diameter and 17-inch focal lengths, were mounted securely in split-ring holders with hose clamps around the rings to assure stability when mounted in the VASI boxes.

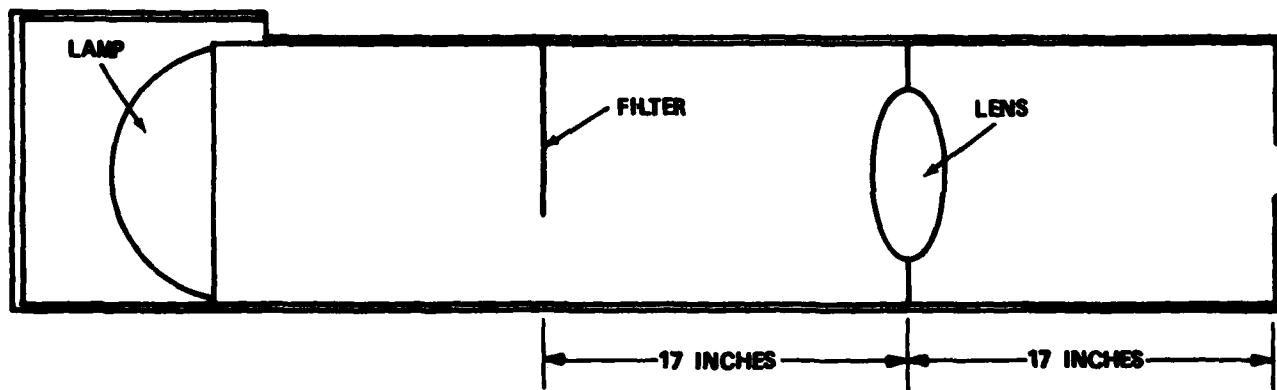
Two types of modifications were then devised, each suited to a unique lens mounting position (figure 10). Sylvania VASI boxes were used in these experiments, with each modification designated as either the "open slot" model or the "narrow slot" model.

The "open slot" model mounting arrangement of the optical components included unfluted red filters in their normal mounting positions, with the 6-inch lenses mounted at the focal length, 17 inches forward of the red filters. The normal 2-inch slotted front face of the VASI box was completely removed, leaving the front of the box open.

The "narrow slot" model design required that the 6-inch lenses be moved forward so that the focal length plane was coincident with the normal 2-inch slot on the front of the box to insure maximum signal emission through the 2-inch slot. The lens,



OPEN SLOT MODEL



NARROW SLOT MODEL

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FIGURE 10. VASI/PAPI MODIFICATIONS

therefore, was located 17 inches in back of the 2-inch slot with the red filter 17 inches to the rear of the lens, as shown in figure 10.

Prototypes of the above two models were then installed on runway 13 at the Technical Center, side by side, and flight checked for proper signals. Pilot opinion indicated that both modified units displayed a signal closely approximating that of commercially available PAPI systems, and it was decided to fabricate a full four-box PAPI system from the design that was easiest to make and least costly. The "open slot" model was chosen as the most practical design.

Four Sylvania boxes were modified with the addition of 17-inch focal length, 6-inch diameter, fire-polished glass lenses (type I) in each box located at the focal length distance from the flat glass red filters. The red filters were left in their original positions. The front face material at the slot end of the boxes was removed allowing the signal to be properly beamed through the open end of the VASI box. The added lenses were mounted in a metal frame which blocked any stray light and added considerable strength to the VASI boxes.

The modified units were mounted in a PAPI configuration on the left side of runway 13, with the Crouse-Hinds PAPI units mounted on the right side for comparison. No standard means of setting the angles of the VASI/PAPI boxes was provided for in these experiments and the aiming angles of the units were set by use of a portable theodolite. It should be noted that this modification kit was installed in Sylvania VASI units, and that VASI units of different manufacture would probably require unique modification techniques.

Subsequent flight testing verified that the modified units functioned as well as the Crouse-Hinds PAPI units by providing the typical PAPI quick transition characteristics. Mathematical calculations indicated that the horizontal beam width of the modified VASI units would be, in theory, only slightly narrower than that of a standard PAPI system; flight tests confirmed this calculation.

## FLIGHT TESTING (PART II)

### FLIGHT TESTING AT THE TECHNICAL CENTER.

An informal interim report entitled "Evaluation of PAPI by the U.S.A." sent to Airports Standards (AAS-200) on 7-1-80 (appendix A), describes in detail the PAPI system flight testing conducted at the Technical Center before 7-1-80.

To summarize this report, the PAPI system was installed on the right hand side of runway 13, adjacent to the Glidepath Intercept (GPI) point, 1,111 feet down from the runway threshold, and 108 tracked approaches were made by FAA test pilots while using the PAPI system. The usable height, accuracy, compatibility with the ILS, pilot acceptance and other related issues are discussed in appendix A. The conclusions of 12 test pilots flying an Aero-Commander, a Gulfstream G-159, a Convair 580 and a Convair 880 were that 58 percent preferred PAPI, 42 percent thought PAPI and VASI were about the same and none preferred VASI over PAPI. Tracking of the aircraft was accomplished by a phototheodolite system.

During the flight testing at the Technical Center, pilots were instructed to disregard ILS glide slope indications and to derive vertical approach slope guidance from the PAPI visual presentation only. In fact, during October 1980, 32 special flights were made with the ILS system in the aircraft turned off during the approach phase of flight. No significant differences were noted in the results of this portion of the flight testing as compared to tests where the ILS avionics was operated.

#### FLIGHT TESTING AT NEWARK INTERNATIONAL AIRPORT, NJ (EWR).

An interim report, DOT/FAA/RD-81/95, dated December 1981 (appendix B) details the evaluation of PAPI when located to take into account the large eye to ILS antenna separation associated with wide-bodied aircraft. Four months of inservice testing was accomplished at Newark (EWR) (runway 4R) where pilots of wide-bodied aircraft compared the PAPI to the standard red/white VASI system.

Special attention was given to the use of a PAPI system with large aircraft with an operating ILS system (figure 11). The on-course PAPI signal (two red and two white) was compatible with the ILS glide slope indications for all aircraft (large and small) from as far out as the lights could be seen (about 5 miles) to a point approximately 1300 feet from the threshold. At this point, pilots of wide bodied aircraft, following the ILS, saw three white and one red light due to the large eye-to-antenna separation. Pilots of small aircraft saw three red and one white at this point, due to small eye-to-antenna separation. All aircraft therefore could use the PAPI without special interpretation to a point 1300 feet from the threshold, still on the ILS glide slope, with an "on-course" indication. This is diagrammed in figure 11. The United States presently does not recommend that a visual glide slope be used in conjunction with an ILS system (Handbook 6850.2). Under these conditions at EWR, 61 percent of the pilots flying wide-bodied aircraft (with large eye-to-antenna separation, and landing with an ILS system) preferred PAPI over the VASI system. An additional 28 percent of the pilots felt that the PAPI and VASI systems were equally effective. The rest of the pilots (11 percent) preferred the VASI system.

#### FLIGHT TESTING AT TETERBORO AIRPORT, NJ (TEB).

In order to obtain opinions from the General Aviation segment of the aviation community, a 3-month inservice test of PAPI was conducted at Teterboro Airport. A data report was issued in February 1982 detailing the test results at Teterboro Airport and is included as appendix C to this report.

Although a great deal of interest in the PAPI was evidenced, only 17 completed questionnaires (out of approximately 300 distributed) were returned for analysis. Because of this, additional inservice testing, to obtain General Aviation user input, was later conducted at another airport (see Flight Testing at Bader Airport, Atlantic City, New Jersey, in this report). In order to maintain conformity the same questionnaire format was used for all flight testing of the PAPI system.

At least 75 percent of the pilots that completed questionnaires were corporate or business pilots, and responses covered both daytime and nighttime approaches.

The results, summarized, indicated that 88 percent of the pilots felt the PAPI system to be superior to the VASI in overall effectiveness. The remaining 12 percent of the pilots felt that the PAPI was at least equal to the VASI in overall effectiveness, and superior in some respects.

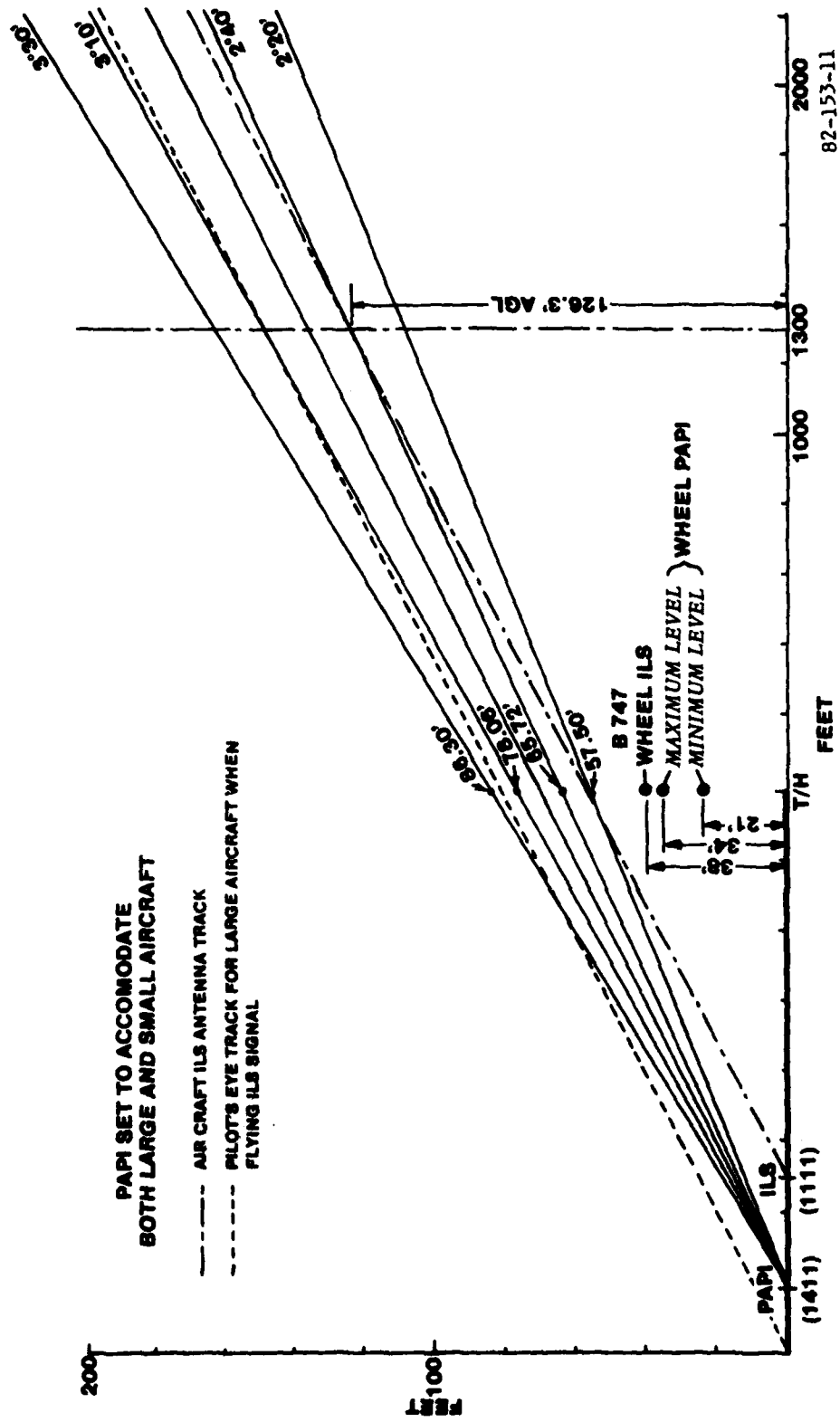


FIGURE 11. TYPICAL PAPI APPROACH PATH WITH ILS

## FLIGHT TESTING AT BADER FIELD, ATLANTIC CITY, NJ (AIY).

In order to expand the input from General Aviation pilots, 3 months of inservice flight testing was performed at Bader Field (AIY). The PAPI system was installed 375 feet from the threshold; on the left hand side of runway 11. The Barrel Lighting Co. Ltd. PAPI units used at AIY were the same as those used in the previous flight testing at other airports. The inboard unit was located 50 feet from the edge of the runway with a lateral separation of 33 feet between adjacent units (figure 3). The Questionnaires (same ones used at EWR, TEB, and AIY), and Approach Path Illustrations (figure 2) were furnished by the Atlantic City Airport Administrator.

During the testing period, construction work on the airport required that, at times, the 2950-foot runway be shortened to 2350 feet. The PAPI system was not in operation whenever the runway threshold was so displaced. As requested by many of the local pilots, and concurred with by Eastern Region personnel, the PAPI on-course signal was set at 4 degrees, due to the existence of a relatively short runway, predominantly small aircraft landing at steep angles, and obstacles in the approach zone. The unit aiming angles were separated by 20 minutes of arc starting at 4° 30 minutes for the high angle. Thus, the low transitions were set at 4° 10 minutes, 3° 50 minutes, and 3° 30 minutes.

Forty-six questionnaires were returned by pilots who had flown the PAPI system. As had been done at EWR and TEB, the PAPI was compared with the standard red/white VASI system. Pilots from many diversified backgrounds flew the system involving 20 different aircraft types, most of which were not regularly based at Bader Field. The largest aircraft was the de Havilland DHC-7 (DASH-7) along with many small Piper and Cessna aircraft. Seventeen questionnaires were received from the de Havilland DHC-6 (OTTER) pilots who regularly fly into and out of Bader on scheduled commuter flights. All of the landings were made during VFR weather. Eighty percent of the landings were made during the daylight hours from 0700 to 1930. Twenty percent landed at night between the hours from 2000 to 2400. Table 3 shows the questionnaire results of the comparison of the PAPI system with the standard red/ white VASI system at AIY.

TABLE 3. A PERCENTAGE COMPARISON OF PAPI WITH VASI AT AIY

<u>Rating Factors</u>	<u>Response (Percentage)</u>		
	<u>Better</u>	<u>Same</u>	<u>Worse</u>
Rate Information	70	28	2
Ease of Maintaining Approach Angle	58	38	4
Correcting Vertical Excursions	67	26	7
Usefulness of Touchdown Aiming Point	39	57	4
Initial Contact Range	71	27	2
Overall Value Compared with VASI	70	26	4

As shown above, 70 percent of the pilot responses indicated that, overall, PAPI was preferred to the VASI system, 26 percent thought they were about the same, and 4 percent thought the VASI system was better than PAPI. All of the rating factors indicated that PAPI was preferred for that particular rating factor except for the "Usefulness of the Touchdown Aiming Point" which indicated that more pilots thought that the usefulness of the aiming point was about the same for both the PAPI and VASI systems.

The numerical values of responses are included on the Summary Questionnaire (figure 12).

**BADER FIELD AIRPORT**

**ATLANTIC CITY, NEW JERSEY**

**PAPI TESTING AT BADER**

An operational evaluation of the Precision Approach Path Indicator (PAPI) is being conducted at Bader Field in cooperation with the FAA Technical Center. PAPI is a possible replacement for the standard red/white VASI (Visual Approach Slope Indicator) and is installed on the left hand side of runway 11 at Bader, 375 feet down the runway from the threshold. The attached pictorial diagram has been prepared for your assistance in evaluating the system. After you have flown the system, please fill out the questionnaire below and return it to the operations desk. Your views are considered vital to the tests. Thank you.

- - GLIDE SLOPE NOW AT 4 DEGREES - -

Date 6-18-82 9-18-82 Time \_\_\_\_\_ Aircraft Type VARIOUS  
VFR \_\_\_\_\_ IFR \_\_\_\_\_ Rain (yes or no) \_\_\_\_\_

In comparison with VASIS, please assess PAPI on the following points:

1. Rate Information
2. Ease of Maintaining Approach Angle
3. Correcting Vertical Excursions
4. Usefulness on Touchdown Aiming Point
5. Initial Contact Range
6. Overall value compared with VASIS

Better	Same	Worse
32	13	1
26	17	2
31	12	3
18	26	2
31	12	1
32	12	2

Additional Comments:

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FIGURE 12. BADER FIELD PAPI QUESTIONNAIRE (Sheet 1 of 2)



Listed below are the written comments that were provided on the Questionnaire.

1. Excellent glide slope information - Easy to transition degree of glide slope.
2. At this airport it should be closer to the end of the runway. I think lights change too fast for non-professional pilots. Would chase lights for proper indication rather than paying attention to runway environment for landing.
3. It provides better vertical resolution. I like it!
4. This is first time use and without any prior knowledge of system I had a little confusion on initial contact and was high all the way down.
5. First time I've used it - might get better with familiarity.
6. Seems much brighter and appears to give more information quicker.
7. Approach seems to be set too high. Frequently the system is inoperative or off.
8. Glide slope was better at 3 degrees.
9. Four degrees for Bader is too high.
10. Great - please leave on runway 11 and install one on runway 29.
11. The on-glidepath indication seems to be a little low for the obstacles at Bader. The 3.2 degree path seems to be better. For an Otter anyway.
12. Glide slope angle too steep.
13. Runway 29 should have PAPI, not runway 11. Both would be nice.
14. Touchdown aiming point a waste for DHC-6; needed runway;
15. Gives much more (better) rate and intercept data than VASI.
16. Like the way system changes, instant change - no pink in the middle.
17. PAPI lights can be seen easier at wider angles from runway centerline. There are more increments in the glidepath which helps accuracy. These increments are also easier to identify.

FIGURE 12. BADER FIELD PAPI QUESTIONNAIRE (Sheet 2 of 2)

#### FLIGHT TESTING OF A TWO-BOX PAPI AT THE TECHNICAL CENTER (ACY).

A discussion concerning the testing of a two-box PAPI system is given in a data report entitled "Flight Test Results of a Two-Box PAPI Tested at the FAA Technical Center" dated November 1981; reference Appendix D. The purpose of these tests was to determine whether a two-box PAPI system could be used where the five incremental paths provided by the full four-box PAPI system may not be necessary. Such usage would be at smaller airports where smaller general aviation aircraft constitute the greater proportion of traffic.

In summary, a Crouse-Hinds PAPI system was set up in a two-box configuration on runway 4 at the Technical Center and forty-five approaches were made while using the system by Technical Center test pilots. Flights were tracked with the EAIR Radar Tracking System. The EAIR Radar Tracking system is located in an area such that it is impossible to track flights below 50 feet during the approach to runway 4. Therefore, portions of the radar track below 50 feet were disregarded.

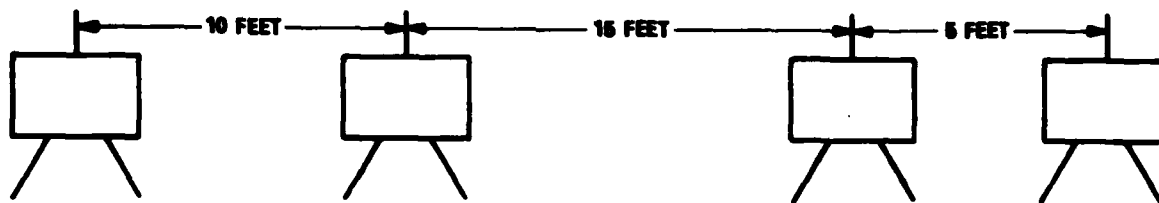
Generally, the test pilots that flew the system were quite enthusiastic about the two-box PAPI for general aviation use and thought that it served the purpose adequately without the need for the five paths that are provided with the four-box system. Most of the responses to the questionnaire were favorable with regard to the two-box PAPI except for the question comparing the two-box PAPI with the two-box VASI wherein the pilots thought they were about equal. Some pilots remarked that, aside from the range of the two-box PAPI system, all of the glide path information that was necessary for all airports is provided by the two-box PAPI system.

Subsequently, the two-box system was temporarily put in service on runway 31 and pilots from the Air National Guard, flying F-106 fighter/interceptor aircraft, were asked to provide comments. These pilots completed eleven questionnaires and expressed the added opinions that, for them, the approach path should be at 2.5°, and that the present red/white VASI system, with its shades of colors, was useful for their purposes. They generally felt that the PAPI system gave the minimum guidance required but not much more. At least half of the military pilots indicated that the two-box VASI system should be continued in service.

It should be noted that the optimum glidepath of approach angle for high performance fighter aircraft, such as the F-106 mentioned above, is well below the three degree angle normally used by commercial and general aviation aircraft. Several of the Air National Guard pilots participating in the two-box PAPI evaluation commented that they felt "uncomfortable" with the higher approach path angle used for the evaluation, and would have preferred a system adjusted for a 2- or 2 1/2 degree approach path.

#### PAPI SIGNAL RESOLUTION TESTING AT THE TECHNICAL CENTER.

Additional flight testing was conducted to determine whether PAPI signals could be readily seen and resolved with individual PAPI units installed closer together than specified by the British (minimum spacing of 33 feet). Four Barrel PAPI units were installed at the Technical Center in the configuration shown below.



The spacing of the experimental arrangement was so constituted that individual pairs of units could be energized, in turn, to provide lateral spacings of 5, 10, 15, 20, 25, and 30 feet as desired. Approaches were flown, from extreme range, with an Aero Commander 680 aircraft, a Bell 206L helicopter, and a Sikorski S-76 helicopter to determine the maximum distances (range) at which signals from two PAPI light units could be resolved and identified as two distinct light sources. Known landmarks on the ground and distance measurement equipment (DME) in the aircraft were used to observe and record maximum resolution ranges for pairs of PAPI units with lateral spacings as indicated above. A conservative approach was taken in this test and resolution ranges were not established until the lights were judged to be sufficiently distinct so as to insure that an unfamiliar pilot could clearly determine that individual lights from the PAPI system could be seen separately. The flight tests were conducted in VFR weather conditions, in daylight and at night, with at least 4 1/2 nautical miles of visibility.

**NIGHTTIME TEST RESULTS.** (Figure 13). Power supply current, at night, was set at 3.8 amperes, midway between the current values for intensity steps 2 and 3 on the standard five-step regulator. It had been determined, during the previous night flight testing of the PAPI system, that this intensity was preferred by the majority of pilots who flew the PAPI at the Technical Center. In each test session, it was determined that the pilots, at night, were able to resolve individual PAPI red and white light signals with spacing as close as 20 feet at ranges of 4 nautical miles. FAA Advisory Circular AC 150/5340-25, "Visual Approach Slope Indicator (VASI) Systems," specifies 4 nautical miles as the minimum useable range for a standard four-box VASI. Lateral spacing of less than 20 feet resulted in determined resolution ranges of less than the required 4 nautical miles and were judged to be inadequate.

**DAYTIME TEST RESULTS.** (Figure 14). Power supply current, during daytime, was set at 6.6 amperes which is the current value for intensity step 5 on the standard five-step regulator. Pilots were barely able to resolve the PAPI red light signal at 4-nautical mile range with the greatest lateral spacing of 30 feet. In fact, resolution ranges for the red signals were relatively constant at slightly greater than 3 nautical miles, regardless of lateral spacings less than 30 feet. This should not be construed to mean that a full four-box PAPI system could not be used at a 4-nautical mile range, in daylight, since a pilot familiar with the system could easily determine his long range relationship to glide path by counting the discernible white lights of the system.

The average resolution range of the PAPI white lights, during daytime, exceeded 4 nautical miles even when the lateral spacing of PAPI units was as close as 10 feet.

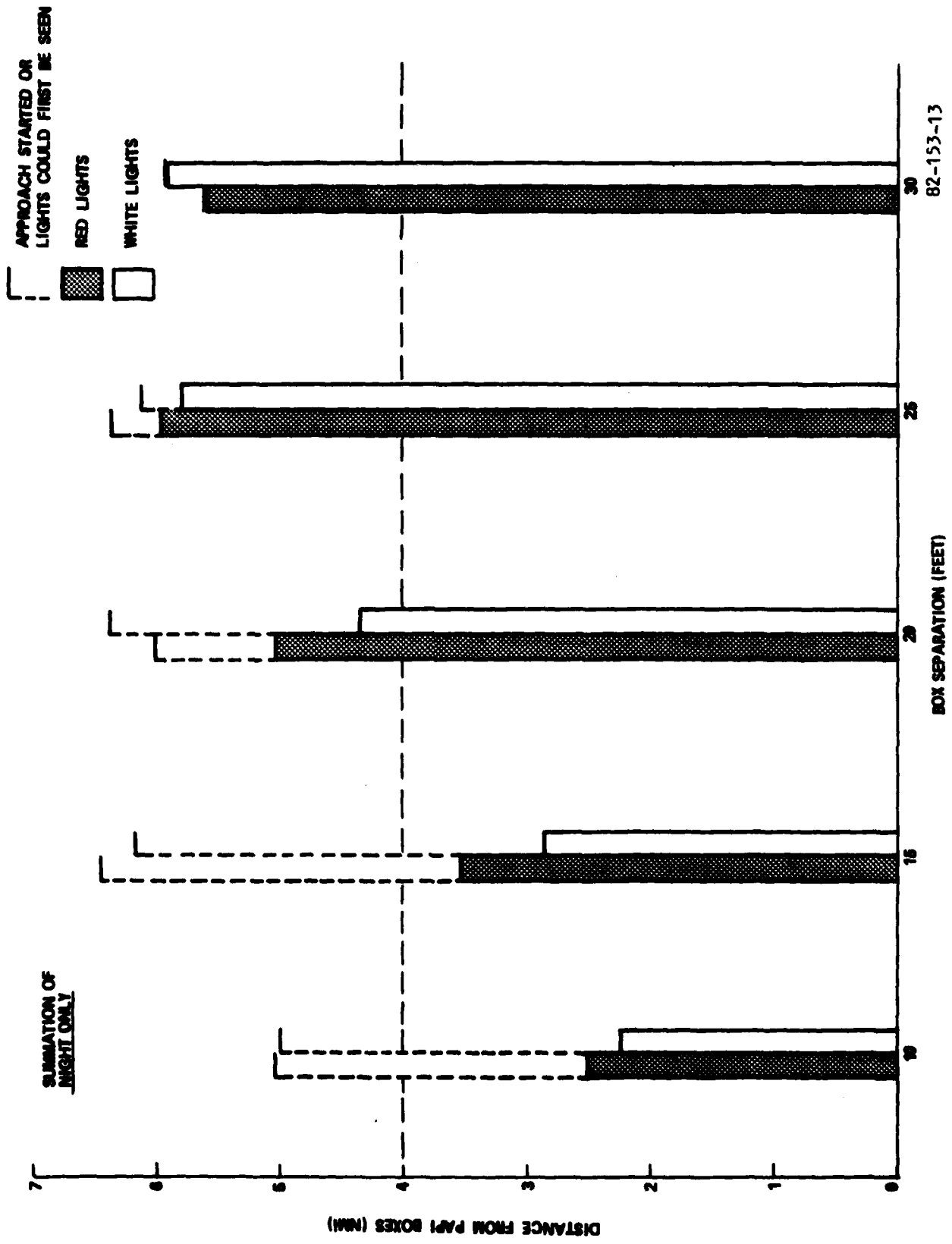
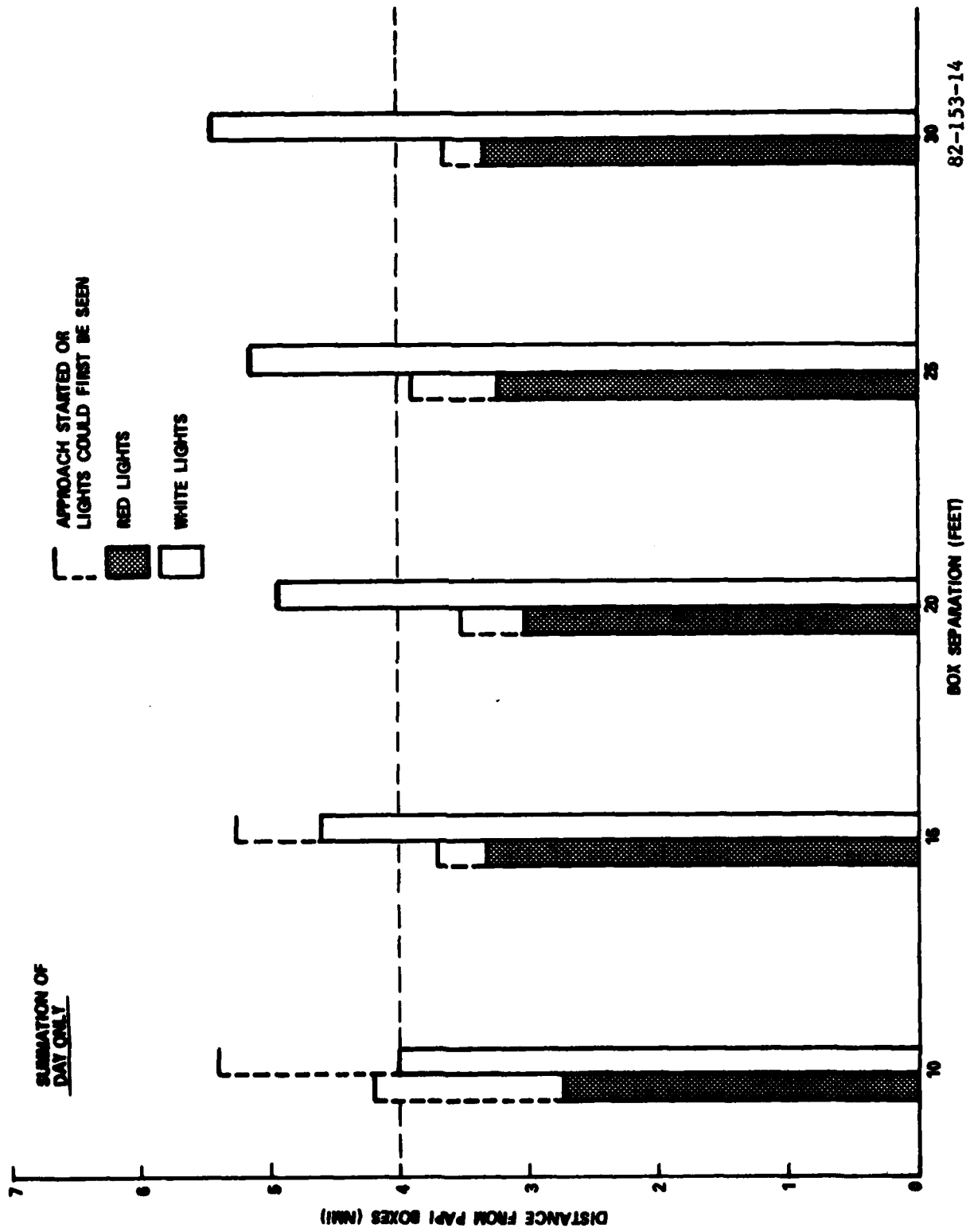


FIGURE 13. GRAPH OF NIGHTTIME RESOLUTION TESTS

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82-153-14

FIGURE 14. GRAPH OF DAYTIME RESOLUTION TESTS

It follows from the above determinations, with regard to both night and day conditions, that lateral spacing of PAPI units installed at smaller General Aviation airports could be reduced to as little as 10 feet and still provide adequate guidance within ranges of 2 to 3 miles from the runway threshold.

Spacing of at least 20 feet between PAPI units should be maintained for systems installed at larger airports where a minimum visual approach guidance range of 4 nautical miles is required.

#### SUMMARY OF RESULTS

Extensive testing was performed on the PAPI glide slope system at the Technical Center and at a number of operational airports, both large and small. During the testing the following results were observed:

1. Photometric and environmental testing determined that the PAPI units met or exceeded the existing requirements established for the standard red/white VASI system with regard to intensity distribution, beam width, stability of the projected signal and mechanical integrity of units. No major maintenance problems were encountered during the 3 years of testing.

2. It was found that during certain critical weather conditions, condensation forming on the PAPI lenses could produce transient false pink signals. Methods found that would eliminate this problem are:

- a. Energize system continuously.
- b. Energize system at least 30 minutes before flight operation.
- c. Install heaters in close proximity to the lenses.

3. Vertical shifting of the transition zone signal due to changes in temperature and humidity was observed. However, the magnitude of these signal changes was slight and should not create operational problems.

4. It was found that Sylvania and General Electric VASI boxes can be modified to project the sharp transition PAPI signal through retrofitting of projector lenses in the units. Modification of the VASI box transition bar dimension alone does not provide the required sharp transition signal.

5. It was determined that an abbreviated two-box PAPI system fulfills all of the requirements for use on short runways where the five incremental paths provided by the four-box PAPI system are not needed.

6. It was determined that four-box PAPI system signals can be resolved and interpreted at a range of 4 nautical miles when the boxes are separated by at least 20 feet or more. At a range of 2 nautical miles the signals can be resolved when the boxes are separated by at least 10 feet.

7. A summary of questionnaire results from testing of the 4-box PAPI system at Newark, Teterboro, and Atlantic City Airports is shown below.

Compared to a VASI system, the items below are:	<u>RESPONSE (PERCENTAGE)</u>		
	<u>BETTER</u>	<u>SAME</u>	<u>WORSE</u>
1. Rate Information	63	32	5
2. Ease of Maintaining Approach Angle	72	20	8
3. Correcting Vertical Excursions	61	31	8
4. Usefulness of Touchdown Aiming Point	41	53	6
5. Initial Contact Range	62	31	8
6. Overall Value Compared with VASIS	63	32	5

### CONCLUSIONS

It can be concluded from the testing that:

1. The PAPI system provides significantly improved visual approach slope guidance over that obtained from the standard red/white VASI system.
2. The abbreviated two-box PAPI system can be used as an economical alternative to the four-box PAPI system at small airports.
3. The separation of PAPI units in a four-box system need not be more than 20 feet; and for small airports, where typical approach distances are less than 2 nautical miles, the units need not be separated by more than 10 feet.
4. Condensation on the exterior of the PAPI lenses must be prevented by either operational procedures or inclusion of heating devices in the fixture design.
5. It seems unlikely that any single modification kit can be developed by the Federal Aviation Administration (FAA) to modify existing VASI units into PAPI units, due to the variations in construction dimensions of VASI units, the instability of VASI structural enclosures, and the expense of providing the necessary lenses.

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3. Gates, R. F., Paprocki, T. H., VASIS Signal Transition Zone and Color Modifications, Report Number FAA-ARD-72-91, DOT/FAA, NAFEC, September 1972.
4. Advisory Circular Number 150/5340-25, Visual Approach Slope Indicator (VASI) Systems, DOT/FAA dated September 24, 1976.
5. Advisory Circular Number 150/5345-28C, Specification For L-851 Visual Approach Slope Indicator and Accessories, DOT/FAA dated March 23, 1977.
6. Handbook 6850.2, Visual Guidance Lighting Systems, DOT/FAA Change 7, dated March 18, 1974.



APPENDIX A  
"EVALUATION OF PAPI BY THE U.S.A"  
(July 1, 1980)

## EVALUATION OF PAPI BY THE U.S.A.

Evaluation of the Precision Approach Path Indicator (PAPI) System in the United States is being conducted by the Federal Aviation Administration at the FAA Technical Center, Atlantic City, New Jersey. The evaluation effort includes experimental tests at the Technical Center (Phase I) and, possibly, "In-Service" testing at some Air Carrier Airport within the continental United States.

Flight testing of the standard United Kingdom proposed PAPI configuration has been completed using Aero-Commander, Gulfstream G-159, Convair 580 and Convair 880 type aircraft. FAA Test Pilots accomplished a total of 108 approaches to the PAPI installed as a single bar right-side only system at a point adjacent to the main instrument runway touchdown point and at a distance of 1111 feet (339 meters) from the runway threshold. The inboard lighting fixture was situated 50 feet (15 meters) outboard of the right edge of the 300 foot (91 meter) wide runway, with the remaining three lighting fixtures located on 33 foot (10 meter) centers outboard of the innermost fixture. Lighting fixtures used were the BLC Mk 6 P.A.P.I. units as manufactured by Barrel Lighting Company Limited, of England. Standard FAA specification constant current regulators provided 6.6 Ampere (Intensity step 5) circuit current for daylight operation of the PAPI and 4.1 Ampere (Intensity step 3) circuit current for night operations. The PAPI fixtures are adjusted to provide an "on-course" signal (RED/RED/WHITE/WHITE) at  $3.0^{\circ}$ , with a standard 20 minute difference between fixture aiming angles.

Fixture spacing and location was kept constant during all test flights. Previously accomplished testing, using Belgian made two-lamp PAPI fixtures, had established the 33 foot (10 meter) spacing between fixtures as optimum for visual separation of the individual fixture light sources. Additional tests, using a 300 foot (91 meter) system displacement further down from runway threshold and widening of the angle between center fixtures to 30 minutes, will be conducted in time to have results available for the next ICAO Visual Aids Panel meeting. This modification has been suggested by the United Kingdom representative as appropriate for better suiting the system to wide-bodied jet use.

#### Usable Height

Pilot responses to the post-flight questionnaire indicated that they were able to obtain useful guidance from the PAPI system to the point at which the aircraft passed over the runway threshold, or to a height of approximately 54 feet (16 meters).

#### Accuracy of PAPI System

The accuracy of the PAPI System was determined by 72 Photo-theodolite tracked approaches. Data was computer reduced and analyzed to give a composite plot of raw data and a statistical plot. The statistical analysis was made of the segments of the approaches when the pilots were flying "on-course." At each 200 foot segment of range, the mean,  $\pm 1\sigma$  (standard deviation) and  $\pm 3\sigma$  values were calculated for all approaches and plotted. A linear regression line was drawn through each set of points. Lines representing the  $\pm 1\sigma$  deviation indicate that 68.26 percent of all aircraft flying the PAPI would remain within this

corridor. The  $\pm 3\sigma$  lines indicate the corridor in which 99.74 percent, or all aircraft, can be expected to remain.

The statistical values for the PAPI were:

$$\begin{aligned} 3\sigma &= 3.39^\circ = 3^\circ 23' \\ 1\sigma &= 3.14^\circ = 3^\circ 08' \\ \text{mean} &= 3.01^\circ = 3^\circ 0' \\ -1\sigma &= 2.89^\circ = 2^\circ 53' \\ -3\sigma &= 2.64^\circ = 2^\circ 38' \end{aligned}$$

The composite and statistical plots are included.

#### Use of Conventional VASI's Fixtures in the PAPI Configuration

Tests previously conducted at the FAA Technical Center using standard United States VASI lighting fixtures in the PAPI configuration revealed that system performance is seriously degraded by the wide "Pink" transition zone displayed by the standard VASI fixtures. It appears essential that fixtures having a transition zone vertical width of not more than 3 minutes of arc be used in the PAPI system.

Attempts by the FAA to modify standard VASI fixtures to obtain the necessary narrow transition zone have, thus far, been unsuccessful. Further efforts are presently being undertaken, using additional lenses within the unit, and it is hoped that more information about this modification effort will be available for presentation at the next ICAO Visual Aids Panel Meeting.

#### Winter Operations

No experience with Winter operation of PAPI Lens Type equipment has been obtained during FAA testing of the system. It is hoped that such testing can be accomplished during the "In-Service" phase of the evaluation effort.

Previous testing at the FAA Technical Center, using Belgian made PAPI units, revealed a tendency for moisture to condense upon the exposed frontal surfaces of the lenses during periods of rain or high humidity while the system was deenergized. Upon energization of the system, the water droplets caused diffusion of the projected light signals, with the result that a pure "pink" signal was perceived for a short period of time subsequent to startup. The heat generated within the lenses was sufficient to restore proper signal appearance after approximately 15 minutes of on-time. This projection of an improper signal, although of only short duration, must be considered as a problem area for the PAPI.

#### Single Side Acceptability

The United States has, for a number of years, specified a "single-side only" 4 unit VASI system as the National Standard. Arguments based on the benefit of roll guidance that may be provided by a double-sided VASI system have not been substantiated by user pilot opinion in the United States, since numerous other visual cues available to the pilot appear sufficient for providing such information. It seems reasonable that the single-sided PAPI system would provide adequate visual approach path guidance without the additional cost and siting difficulties attendant to installation of the double-sided system.

#### Compatibility with Instrument Landing System (ILS)

While the two-bar PAPI system will provide compatibility with the ILS for both conventional and wide-bodied aircraft, the

multiplicity of signals attendant to use of such a system appears to introduce a distinct potential for pilot confusion. For this reason the two-bar system has not been tested by the FAA, and it is hoped that further evaluation of configuration modifications, as proposed by the United Kingdom, will result in a solution to this problem without the necessity of providing more than one PAPI bar. We hope that further information concerning this aspect of the PAPI testing will be available in time for presentation at the next ICAO Visual Aids Panel meeting.

#### PILOT ACCEPTANCE AND PREFERENCE

The following results are based on over 100 approaches conducted by 12 Test Pilots at the Federal Aviation Technical Center, Atlantic City, New Jersey. The overall acceptance of the PAPI system was favorable. Pilots were able to obtain continual guidance throughout the approach and were able to acquire the PAPI at a range of 6.5 nmi (10.5 km.) daytime and 10+ nmi (16 km.) nighttime. Course dimensions were sufficient to permit comfortable conformance to the desired flight path. With minimum pilot briefing, there was no difficulty interpreting the PAPI signals. When pilots were asked to rate PAPI in comparison to VASI, 58 percent favored PAPI, 42 percent said they were about the same, and no one favored the VASI. Of the 42 percent who thought PAPI and VASI were about the same, many gave favorable comments.

Typical Pilot comments were: (1) "Easy to fly;" (2) "However, this system does seem to give a more precise path;" (3) "I'm impressed and like it very much;" (4) "Very easy to fly;" (5) "Both excellent." A summary of the questionnaire is included.

## Precision Approach Path Indicator

### PAPI

#### Pilot Briefing

The PAPI System was developed by the British and is currently under consideration by ICAO for adoption as an International Standard. The tests now being conducted will provide data for support of the United States representative's position at the next ICAO meeting.

The PAPI System consists of a bar of four sharp transition red/white light units. The units are spaced laterally, on the right side of runway 13, 1000 feet from the threshold adjacent to the ILS glideslope intercept point. The angular settings of the light units are graded at 20 minutes of arc between adjacent units. The glideslope (3°) is midway between the angular settings of the center pair of light units. Therefore, the on-course signal is two red and two white lights in the bar. When aircraft deviate below the desired glideslope, the remaining white light units turn successively red. And conversely, deviations above the desired glideslope cause the red light units to turn successively white. See figure for further information.



HIGH 3° 30'



SLIGHTLY HIGH 3° 10'



ON-COURSE 3°



SLIGHT LOW 2° 50'



LOW 2° 30'

Once you have accomplished a sufficient number of approaches to this system, please fill out the postflight questionnaire provided.

DAY FLIGHT SUMMARY SHEET

POSTFLIGHT QUESTIONNAIRE

PRECISION APPROACH PATH INDICATOR (PAPI)

PILOT'S NAME \_\_\_\_\_ DATE: (DAY) X  
(NIGHT) \_\_\_\_\_

WEATHER \_\_\_\_\_ AIRCRAFT \_\_\_\_\_

1. At what ranges (DME) were you able to acquire and derive useful guidance from the PAPI?

Daytime 6 1/2 NM. NIGHTTIME \_\_\_\_\_ NM.

2. Were you able to obtain continual guidance from the PAPI throughout the approach?

Yes 12 No 0 Not Always 0

Comments:

3. Were the course dimensions (vertical height of "On-Course," "Fly-Down" and "Fly-Up" signals) sufficient to permit comfortable conformance to the desired flight path throughout the approach?

Yes 12 No 0 Not Always 0

Comments:

4. Did you feel that the system allowed you to pick your own desired approach path (slightly high, slightly low, etc.) and follow it precisely?

Yes 12 No 0 Not Always 0

Comments:



2

SUMMARY (CON'T)

5. Was there a point during the final portion of the approach at which the usefulness of the PAPI became marginal?

Yes 7 No 5 Minimum Range 100 ft.

Comments: over threshold

6. If you have had previous experience with the Three-Bar Standard "Red/White" VASI System, how do you rate this PAPI System in comparison?

Better than 3-Bar 7 Not as Good as 3-Bar 0

Both about the Same 5

Comments:

7. With the minimum pilot briefing provided, did you experience any difficulty in first interpreting the PAPI signals?

No Problem 11 Slight Confusions 1 Trouble 0

Comments:

8. Is the PAPI System signal sufficiently distinctive that it cannot be readily confused with other lights on the airport and in the near vicinity?

Yes 8 No 2 2- no answers

Comments:

9. Have you any other remarks or comments concerning this system, or would you like to bring up any considerations that may not have been covered in this questionnaire?

Thank you.

NIGHT FLIGHT SUMMARY SHEET

POSTFLIGHT QUESTIONNAIRE

PRECISION APPROACH PATH INDICATOR (PAPI)

PILOT'S NAME \_\_\_\_\_ DATE: (DAY) \_\_\_\_\_  
(NIGHT) X

WEATHER \_\_\_\_\_ AIRCRAFT \_\_\_\_\_

1. At what ranges (DME) were you able to acquire and derive useful guidance from the PAPI?

Daytime \_\_\_\_\_ NM. NIGHTTIME 11 + NM.

2. Were you able to obtain continual guidance from the PAPI throughout the approach?

Yes 12 No 0 Not Always 0

Comments:

3. Were the course dimensions (vertical height of "On-Course," "Fly-Down" and "Fly-Up" signals) sufficient to permit comfortable conformance to the desired flight path throughout the approach?

Yes 12 No 0 Not Always 0

Comments:

4. Did you feel that the system allowed you to pick your own desired approach path (slightly high, slightly low, etc.) and follow it precisely?

Yes 12 No 0 Not Always 0

Comments:

NIGHT SUMMARY (CON'T)

2

5. Was there a point during the final portion of the approach at which the usefulness of the PAPI became marginal?

Yes 3 No 9 Minimum Range \_\_\_\_\_

Comments:

6. If you have had previous experience with the Three-Bar Standard "Red/White" VASI System, how do you rate this PAPI System in comparison?

Better than 3-Bar 7 Not as Good as 3-Bar 0

Both about the Same 5

Comments:

7. With the minimum pilot briefing provided, did you experience any difficulty in first interpreting the PAPI signals?

No Problem 12 Slight Confusions 0 Trouble 0

Comments:

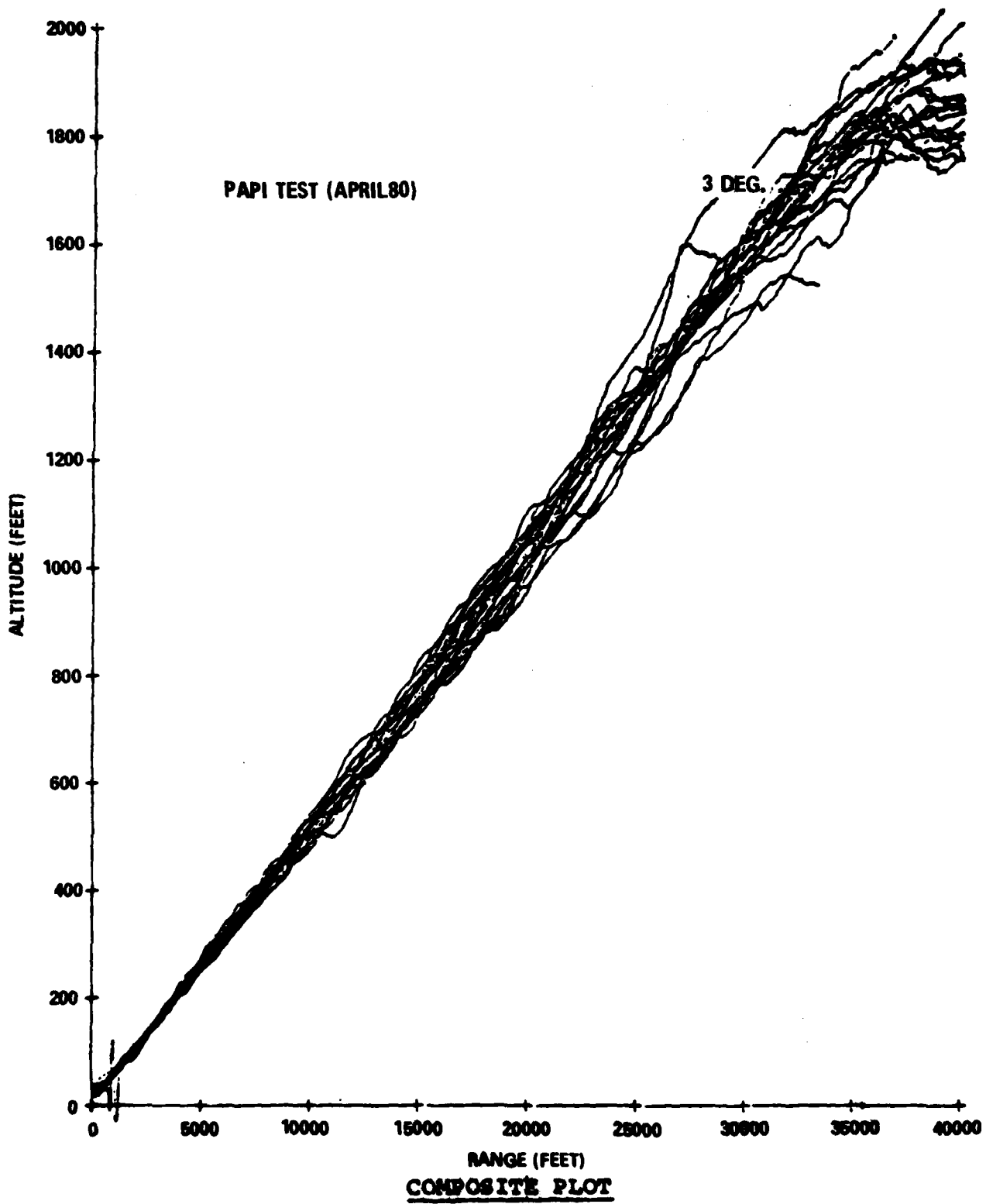
8. Is the PAPI System signal sufficiently distinctive that it cannot be readily confused with other lights on the airport and in the near vicinity?

Yes 11 No 1

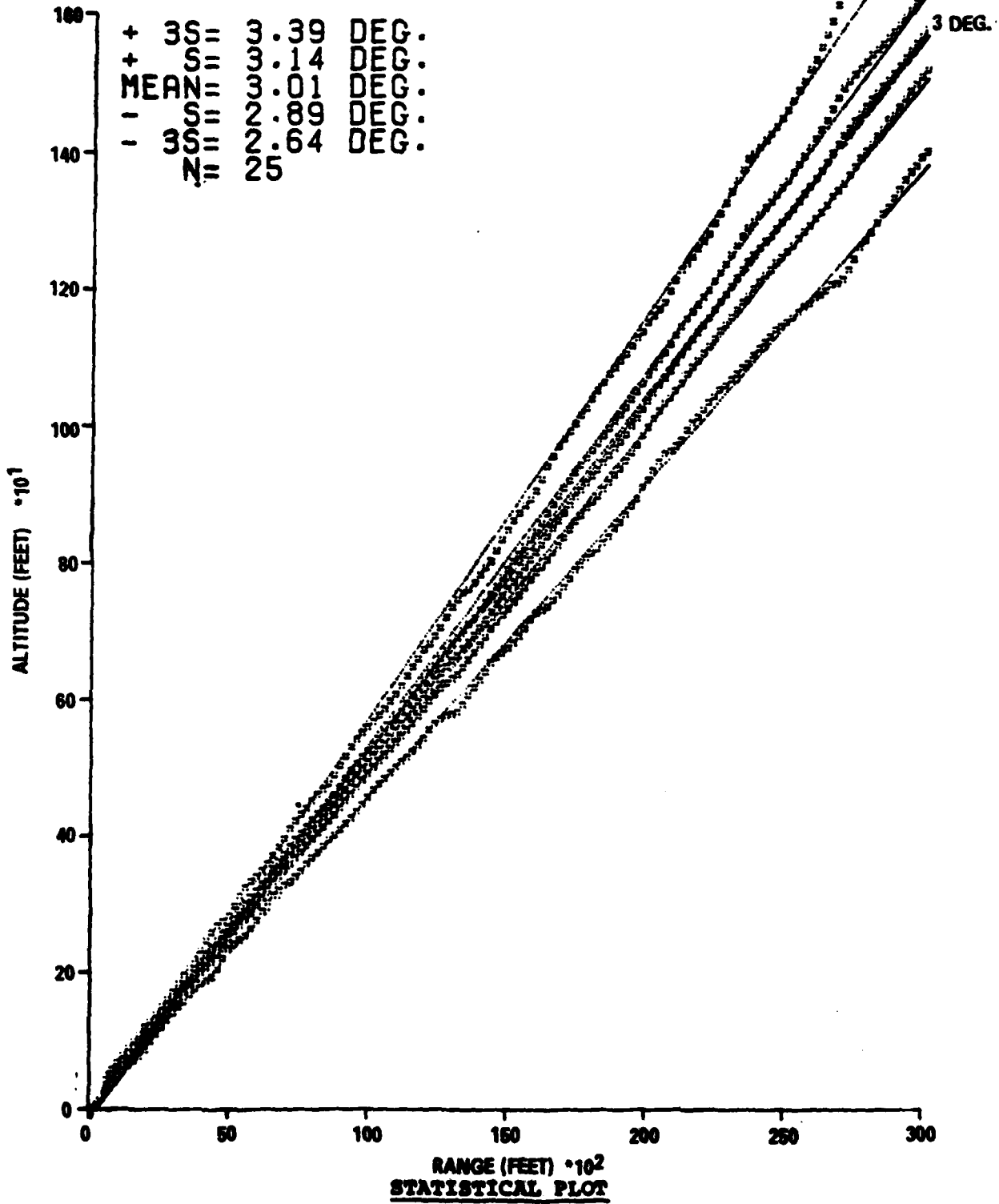
Comments:

9. Have you any other remarks or comments concerning this system, or would you like to bring up any considerations that may not have been covered in this questionnaire?

Thank you.



PAPI TEST (APRIL 80)



APPENDIX B

"IN-SERVICE TESTING OF PAPI AT NEWARK AIRPORT (EWR)"

(December 1, 1980)

**Report No. DOT/FAA/RD-81/95  
DOT/FAA/CT-81/79**

**IN-SERVICE TESTING OF THE  
PRECISION APPROACH PATH INDICATOR (PAPI)  
AT NEWARK INTERNATIONAL AIRPORT, NEW JERSEY**

**Bret B. Castle**

**FEDERAL AVIATION ADMINISTRATION TECHNICAL CENTER  
Atlantic City Airport, New Jersey 08406**



**INTERIM REPORT**

**DECEMBER 1981**

Document is available to the U.S. public through  
the National Technical Information Service,  
Springfield, Virginia 22161.

Prepared for  
**U. S. DEPARTMENT OF TRANSPORTATION  
FEDERAL AVIATION ADMINISTRATION  
Systems Research & Development Service  
Washington, D. C. 20590**

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14. Sponsoring Agency Code		15. Supplementary Notes "NAFEC" referenced in this report is now known as the FAA Technical Center.			
16. Abstract <p>This report covers that portion of the Precision Approach Path Indicator (PAPI) tests involving 4 months of in-service testing at Newark International Airport, New Jersey. Basically, the PAPI was compared against the standard red/white Visual Approach Slope Indicator (VASI) system at a large airport and on a runway with an Instrument Landing System (ILS).</p> <p>The PAPI system was installed in a manner to take care of aircraft of all sizes; that is, different wheel-to-eye distances. The information was obtained from pilots of large commercial aircraft. Questionnaires from general aviation aircraft pilots were not used for this particular report.</p> <p>Results showed that under these conditions about 60 percent of the pilots (a total of 117 questionnaires) preferred the PAPI over the VASI system.</p>					
17. Key Words PAPI Visual Aids VASI ILS Wheel-to-Eye Distance In-Service Testing			18. Distribution Statement Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161		
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## INTRODUCTION

### PURPOSE.

The Precision Approach Path Indicator (PAPI) system is a visual glidepath indicator similar to the standard Visual Approach Slope Indicator (VASI) system. Previous testing of PAPI at the Technical Center has shown that the differences in PAPI over the standard VASI may be advantageous to the pilots who use the PAPI system. The purpose of this Interim Report is to document the in-service testing of the system at Newark International Airport (EWR).

## DISCUSSION

### GENERAL.

Four months (December 8, 1980 to April 8, 1981) of in-service testing was accomplished at EWR on runway 4R. Questionnaires (appendix) were provided to the pilots by the Air Line Pilots Association and collected by it and the Air Transport Association. The results are shown in this report.

In order to allow for the large difference in wheel-to-eye height between some small aircraft and some large aircraft, the scheme used at EWR was to move the PAPI units down the runway 300 feet beyond the Instrument Landing System (ILS) glide slope intercept point (a total of 1350 feet down from the displaced threshold at EWR), and open up the on-course signal to 30 minutes of a degree instead of the regular 20-minute segment. This allows the wheels of the small aircraft to cross the threshold at 62 feet and the wheels of the largest aircraft (B-747) to cross the threshold at 21 feet when following the bottom of the visual on-course signal.

Newark International Airport was selected to obtain data from large commercial aircraft and no general aviation testing was performed. Testing at a general aviation airport utilizing small aircraft and general aviation pilots is scheduled for a later date.

### EQUIPMENT.

The PAPI equipment used during the EWR tests was the standard four-box model Mk 6 PAPI system manufactured by the Barrel Lighting Company Limited, of Stansted, England. It was installed on the right-hand side of runway 4R with the intensity controlled by a photo cell (bright during the daylight hours and dim during the hours of darkness). The system was left in the ON condition except when requested to be turned off by pilots and during low visibility conditions.

## RESULTS

### TEST.

During the 4 months of flight testing, a total of 117 questionnaires were returned. Basically, they compared the PAPI system to the standard red/white VASI system generally used throughout the United States. Table 1 shows the mix of aircraft used to obtain information for the tests.

Questionnaires were received from pilots of seven different aircraft types, all of which are considered transport aircraft, giving a good sampling of today's commercial aircraft. No questionnaires were received from general aviation pilots.

More than 90 percent of the flights were made with the visibility greater than 3 miles, the ceiling higher than 2000 feet, and with no precipitation. A few flights reported rain, snow, fog, cloudiness, and smog. Some 63 percent of the approaches were made during the

hours of 1600 to 2400, 34 percent during the hours of 0800 to 1600, and 3 percent during the hours of 0000 to 0800.

Table 2 shows the results of the comparison of the PAPI system with the standard red/white VASI system, in percentage form.

TABLE 1. PERCENTAGE OF TYPES OF AIRCRAFT

<u>Aircraft Type</u>	<u>% of Total</u>
B-727	42
DC-10	22
B-737	13
DC-8	9
B-747	8
L-1011	5
B-707	1

TABLE 2. A PERCENTAGE COMPARISON OF PAPI WITH VASI

	<u>BETTER</u>	<u>SAME</u>	<u>WORSE</u>
Rate Information	57	37	6
Ease of Maintaining Approach Angle	50	43	7
Correcting Vertical Excursions	57	33	10
Usefulness of Touchdown Aiming Point	40	53	7
Coincidence with ILS	40	57	3
Initial Contact Range	60	29	11
Overall Value Compared with VASI's	61	28	11

SUMMARY.

Analysis of these data show that the United States pilots were not quite as enthusiastic about PAPI as testing results have shown in England, Canada, or France. PAPI, however, was rated better than VASI in all rating factors at Newark except in the "Usefulness of Touchdown Aiming Point" and the "Coincidence with ILS." In these two cases, most pilots thought that both PAPI and VASI rated about the same.

No overall test ratings by the pilots indicated that the VASI was better than

PAPI. In the "Overall Value Compared with VASI's," 61 percent favored PAPI, 27 percent thought they were about the same and 11 percent thought the VASI was better than the PAPI. This clearly indicates that, overall, the pilots who evaluated the PAPI at Newark considered the PAPI to be an improvement over the VASI. It must be remembered that these in-service tests include only information derived from commercial pilots of large aircraft and do not include the general aviation segment of the flying public. Further testing of this type is presently in process.

APPENDIX

QUESTIONNAIRE AND SAMPLE COMMENTS

Figure A-1 is a summation of the results of the questionnaires received from the 117 pilots who flew the system at Newark. It also contains samples of the majority of comments received from the pilots.

(After completion of the approach,  
please check the appropriate boxes)

**EWR TEST RESULTS**

Date: 12-8-80 to 4-8-81	Time: 0000-0800-34 0800-1600-34 1600-2400-63	Aircraft Type:
-------------------------------	--	----------------

RVR or Visibility on Approach	1200 to 1800	1800 to 2400	2400 to 4000	1-3 miles	> 3 miles X
----------------------------------	--------------------	--------------------	--------------------	-----------	-------------

Lowest Clouds	100 to 200 ft.	200 to 300 ft.	300 to 500 ft.	500 to 2000 ft.	> 2000 ft. X
------------------	----------------------	----------------------	----------------------	-----------------------	--------------

Precipitation/Visibility Restriction

Type:

None:

X

Comparison with VASIS. Please assess FAPI on the following points:

(NUMBER OF PILOT RESPONSES)

	Better	Same	Worse
1. Rate Information	64	42	7
2. Ease of Maintaining Approach Angle	56	48	8
3. Correcting Vertical Excursions	64	38	11
4. Usefulness on Touchdown Aiming Point	44	59	8
5. Coincidence with ILS	42	61	3
6. Initial Contact Range	67	33	12
7. Overall value compared with VASIS	70	31	13

FIGURE A-1. QUESTIONNAIRE WITH NEWARK TEST RESULTS (Sheet 1 of 2)

SAMPLE COMMENTS TAKEN FROM THE QUESTIONNAIRES

1. By far the vast majority of comments (at least 20) concerned the control of the brilliance of the lights. Most indicated that the white lights were too bright compared to the red lights; or the red ones were not bright enough compared to the white. Some thought both colors (red and white) were overpowering and should be dimmed.
2. At least eight comments stated that overall, the Precision Approach Path Indicator (PAPI) system is better than the Visual Approach Slope Indicator (VASI) system. Samples - "PAPI gives more precise information," and "An excellent system."
3. At least six comments concerned the rapid change in colors. Most thought this was beneficial but two preferred the subtle pink transitional area of the VASI.

QUOTED COMMENTS

1. "Since interpretation is not based on pink/red shading, the positive change of one light from white to red shows very positive trend allowing faster recognition and thus correction. I purposely went to 3 red/1 white, then 3 white/1 red, then to 2 red/2 white. I feel the system is a vast improvement from VASI."
2. "The visibility, intensity of PAPI is much greater than VASI. I particularly like knowing its location, touchdown aiming point, extremely useful. PAPI is a highly acceptable, flyable, visual landing aid. However, I would rather have a VASI on all non-ILS runways than PAPI on the runways that now have a VASI."
3. "One light low and high corresponded to exactly one dot low and high on ILS glide slope."
4. "Appears to be more definitive in close; i.e., inside the outer marker. Cannot be seen as far out as VASI."
5. "Biggest factors were ease of acquisition even at 10 nmi and rapid transition from red to white and back. I like it much better than conventional VASI."
6. "Easier to determine small excursions early in approach."
7. "Information is not as obvious as VASI."
8. "Requires horizontal plane scanning which is not normal during approach."

FIGURE A-1. QUESTIONNAIRE WITH NEWARK TEST RESULTS (Sheet 2 of 2)



APPENDIX C

"PAPI FLIGHT TEST RESULTS AT TETERBORO AIRPORT (TEB)"

(February 1982)

DATA REPORT

PRECISION APPROACH PATH INDICATOR (PAPI)  
FLIGHT TEST RESULTS AT TETERBORO, N.J. (TEB) AIRPORT

FEBRUARY 1982

DEPARTMENT OF TRANSPORTATION  
Federal Aviation Administration  
FAA Technical Center  
Airport Technology Division  
Atlantic City Airport, NJ 08405

PRECISION APPROACH PATH INDICATOR (PAPI)  
FLIGHT TEST RESULTS AT TETERBORO, N.J. (TEB) AIRPORT

PURPOSE.

As a part of the overall evaluation of the Precision Approach Path Indicator (PAPI) system, 3 months of inservice testing was accomplished at Teterboro during October, November, and December of 1981. This was done specifically to obtain the assessment of general aviation pilots concerning the PAPI system.

DISCUSSION.

Previous evaluation of the PAPI system has been performed at the Federal Aviation Administration (FAA) Technical Center and at Newark International Airport where an evaluation by user pilots was obtained. At Newark, the PAPI system was installed to allow for different eye-to-wheel distances of all aircraft including large wide-bodied aircraft such as the B-747. It was installed on an Instrument Landing System (ILS) runway (runway 4R) where it could be checked against the ILS system. As it turned out, no questionnaires were obtained (at Newark) from general aviation pilots, and it was decided to make a concerted effort to get the reaction of general aviation pilots by moving the PAPI system to TEB where almost all of the air traffic is either business or private aircraft. The "FAA Air Traffic Activity" report for 1979 documents the fact that TEB has more general aviation traffic than any airport in the local States of New Jersey, Pennsylvania, Delaware, and Maryland; and runway 19 is one of the busiest on that airport. It was therefore decided to install the PAPI system on the non-ILS runway 19 at TEB.

TEST PROCEDURES.

The same Barrel Lighting Co. Ltd. units used at Newark were installed at TEB on runway 19 in place of the standard red/white Visual Approach Slope Indicator (VASI) system at that location.

The PAPI system was located on the left-hand side of the runway, 813 feet down from the threshold in the same configuration as used at Newark. The inboard unit was located 50 feet from the edge of the runway, and each of the other three were located 33 feet outward from the previous unit as shown in figure 1. Eastern Region personnel helped install the system on cement pads at the proper locations. The angles of the units were set so that each path was 20 minutes of an arc deep starting at a high angle of 3°30'. The three transitions to the next lower paths were set at 3°10', 2°50', and 2°30' on the low side. This provided the on-course signal (two red and two white) at 3 degrees; with the above-course (three white and one red) signal at 3 1/3 degrees, and the fly-down (four white) signal at any approach angle above 3 1/2 degrees. Conversely, the below-course (three red and one white) signal was at 2 2/3 degrees and the fly-up (four red) signal was any approach angle below 2 1/2 degrees.

The Aircraft Owners and Pilots Association (AOPA) furnished the questionnaires for the pilots along with a letter of explanation (see figures 2 and 3). They also collected the questionnaires as they were received. TEB has six Fixed Base Operators (FBO's) on the airport, and a display (see figure 4) concerning PAPI was set up at each FBO for distribution of the questionnaires. AOPA also distributed questionnaires to their local members via the U.S. mail.

#### TEST RESULTS.

Three months of inservice testing was accomplished between September 21 and December 21, 1981. Over 300 questionnaires were distributed and picked up at TEB, which gave us an indication that a lot of interest was being shown in the PAPI. However, we received a total of only 17 questionnaires from pilots who flew the PAPI at TEB. The reasons for this must include the fact that the prevailing winds at that time of the year turned out to be in the wrong direction for use of runway 19. Normally, runway 19 is used about 30 percent of the time; however, the record shows that during October, runway 19 was used 17 percent of the time; during November it was used 8 percent of the time; and during December it was used 8 percent of the time. Other reasons could include a lack of pilot interest, and the fact that the PATCO Controllers strike was on and the Controllers were extremely busy and could not spend time telling pilots about PAPI.

A summary of the data results is included as appendix A to this report. No conclusions are included in this data report, and further testing is planned for more general aviation pilot comments.

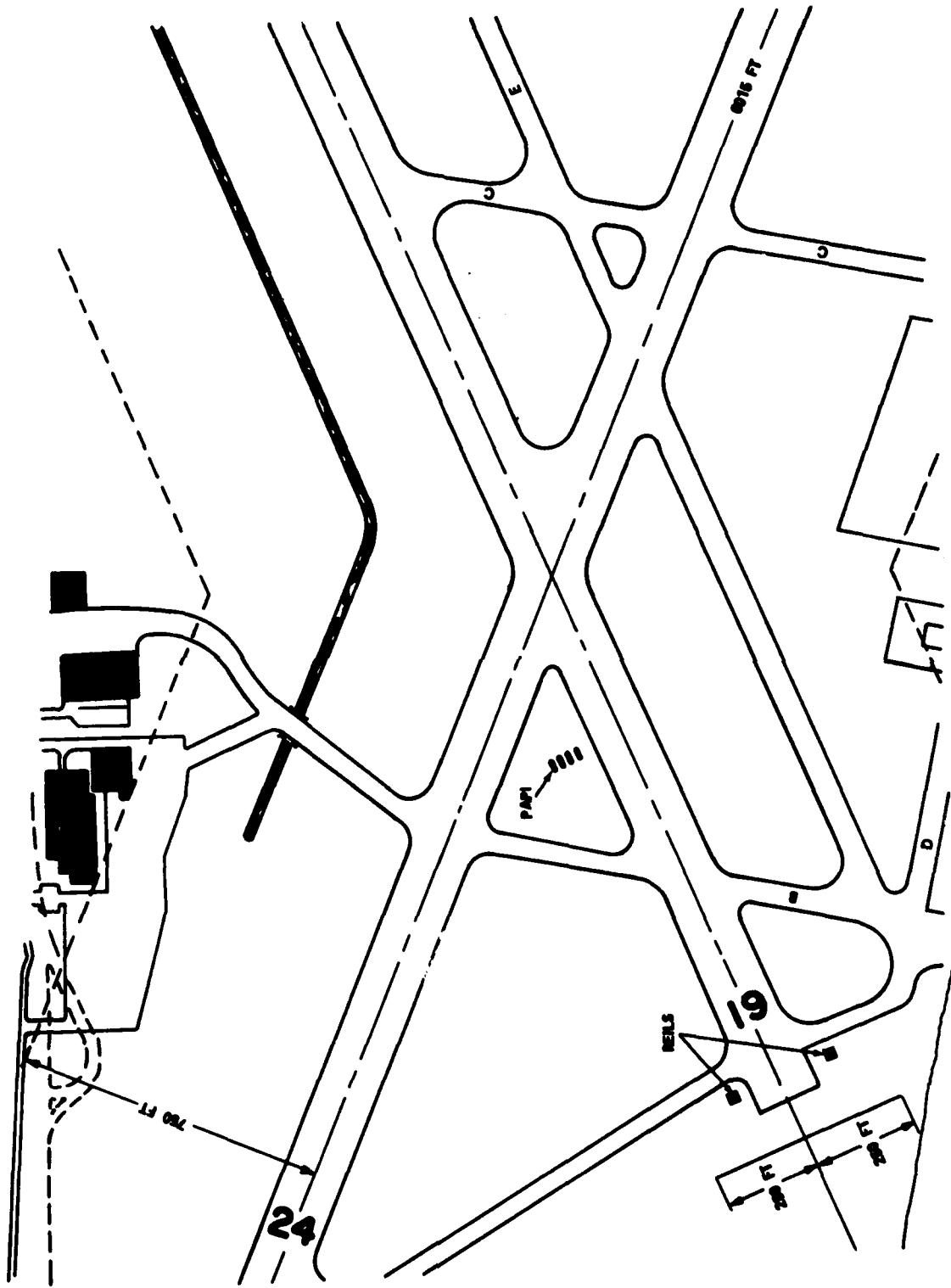
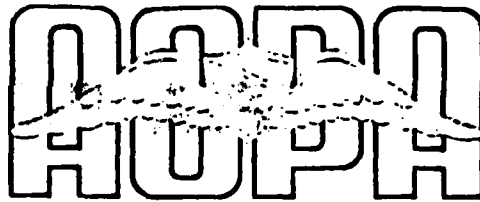


FIGURE C-1. PAPI LAYOUT AT TETERBORO



AIRCRAFT  
OWNERS  
AND  
PILOTS  
ASSOCIATION

PILOTS

PAPI (Precision Approach Path Indicator) was developed and introduced by the United Kingdom and is under consideration as an International Standard. An operational evaluation of this system is being conducted at Teterboro Airport on Runway 19 by the FAA. Aircraft Owners and Pilots Association is very interested in obtaining pilot evaluation input on the flyability and acceptability of the PAPI system.

The attached questionnaire and brief description was prepared in assisting your evaluation of this system. Your reply and return of the questionnaire will be extremely helpful. Please return this questionnaire to the collection box in the FBO or send to:

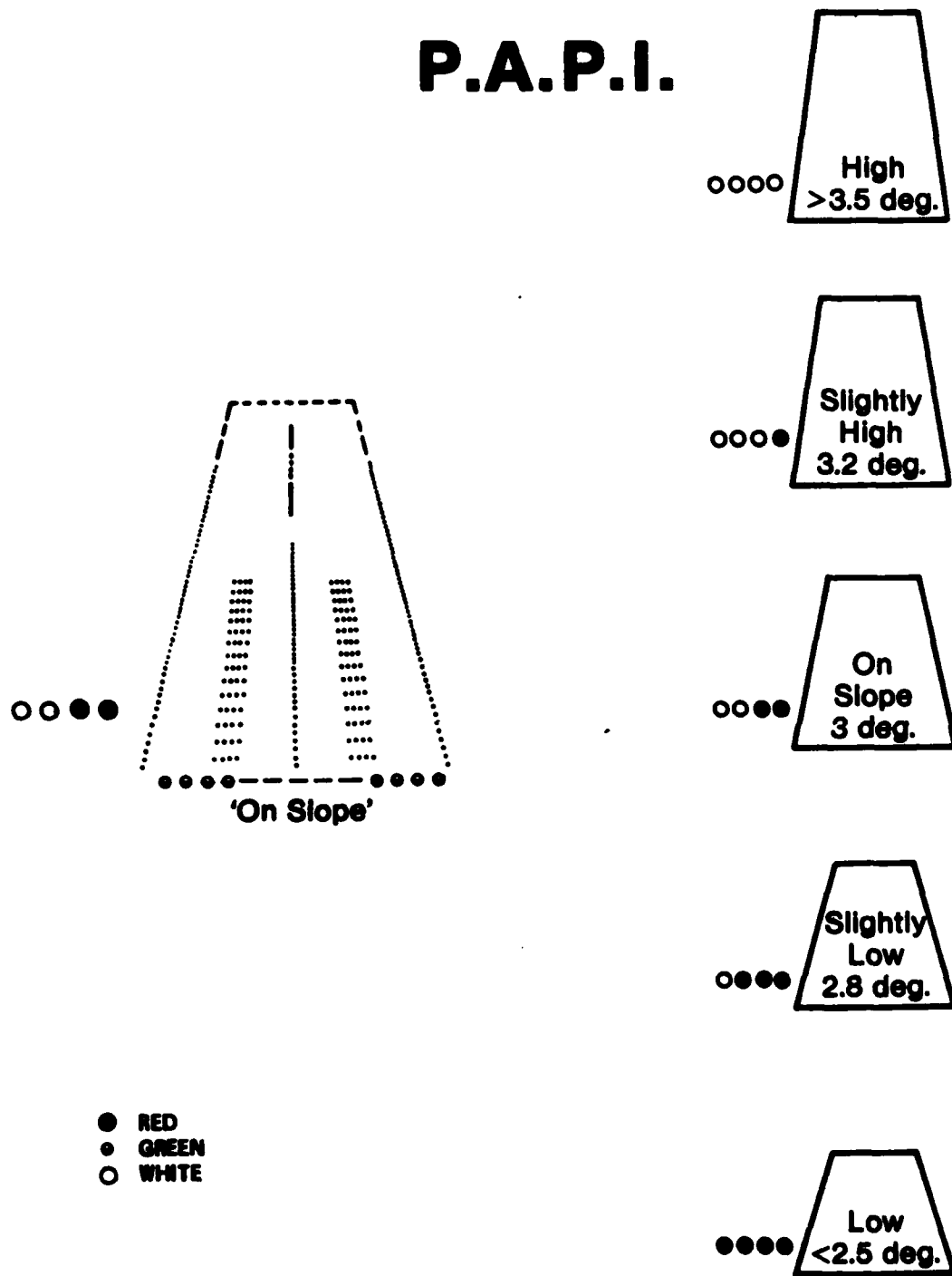
AOPA  
Airspace Technology Department, #650W  
P. O. Box 5800  
Washington, DC 20014

Thank you for your help.

Remember: Two red and two white means on glide slope -  
increased white means above glide slope,  
increased red means below glide slope.

FIGURE C-2. LETTER OF EXPLANATION

# P.A.P.I.



82-153-2

FIGURE C-3. DESCRIPTIVE DIAGRAM

**EVER HEARD  
OF**

**PAPI?**

**TRY IT ON**

**RUNWAY 19 at TEB**

**And Answer  
Our Questionnaire**

FIGURE C-4. PAPI DISPLAY



# APPENDIX A

(After completion of the approach, please check the appropriate boxes)

## SUMMARY

Date: <b>9-21-81</b> To <b>12-31-81</b>	Time: <b>VARIOUS</b>	Aircraft Type: <b>PRIVATE &amp; BUSINESS</b>
---	----------------------	---

RVR or Visibility on Approach	1200 to 1800	1900 to 2400	2400 to 4000 <b>2</b>	1-3 miles <b>2</b>	> 3 miles <b>13</b>
-------------------------------	--------------	--------------	-----------------------	--------------------	---------------------

Lowest Clouds	100 to 200 ft.	200 to 300 ft.	300 to 500 ft.	500 to 2000 ft. <b>5</b>	> 2000 ft. <b>12</b>
---------------	----------------	----------------	----------------	--------------------------	----------------------

Precipitation/Visibility Restriction	Type: <b>HAZE</b> <b>LT. RAIN</b> <b>5</b>	None: <b>12</b>
--------------------------------------	---	-----------------

Comparison with VASIS. Please assess PAPI on the following points:

	Better	Same	Worse
1. Rate Information	<b>15</b>	<b>2</b>	<b>0</b>
2. Ease of Maintaining Approach Angle	<b>9</b>	<b>8</b>	<b>0</b>
3. Correcting Vertical Excursions	<b>12</b>	<b>5</b>	<b>0</b>
4. Usefulness on Touchdown Aiming Point	<b>9</b>	<b>8</b>	<b>0</b>
5. Coincidence with ILS	<del> </del>		
6. Initial Contact Range	<b>9</b>	<b>8</b>	<b>0</b>
7. Overall value compared with VASIS	<b>15</b>	<b>2</b>	<b>0</b>

Additional Comments:

APPENDIX D

"FLIGHT TEST RESULTS OF A TWO-BOX PAPI (ACY)"

(November 1981)

DATA REPORT  
FLIGHT TEST RESULTS OF A TWO-BOX PAPI  
TESTED AT THE FAA TECHNICAL CENTER

NOVEMBER 1981

DEPARTMENT OF TRANSPORTATION  
Federal Aviation Administration  
FAA Technical Center  
Airport Technology Division  
Atlantic City, NJ 08201

## FLIGHT TEST RESULTS OF A TWO-BOX PAPI TESTED AT THE TECHNICAL CENTER

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### PURPOSE

The purpose of this phase of the overall PAPI testing program was to compile some pilot reactions to the possible use of a two-box PAPI system where the five incremental paths provided by the full blown PAPI system may not be necessary. This data report provides those results.

### DISCUSSION

During the process of testing the PAPI system for use in the United States as an alternate to the standard red/white VASI system, it came to our attention that a two-box PAPI would give an on-course signal, an above-course signal and a below-course signal quite similar to the standard VASI equipment. It was thought that although it would not cover as many vertical angles nor be visible for as many miles out as the regular PAPI, it could very well be used for general aviation airports on relatively short runways at a reduced cost of the system. Testing of such a system seemed to be in order.

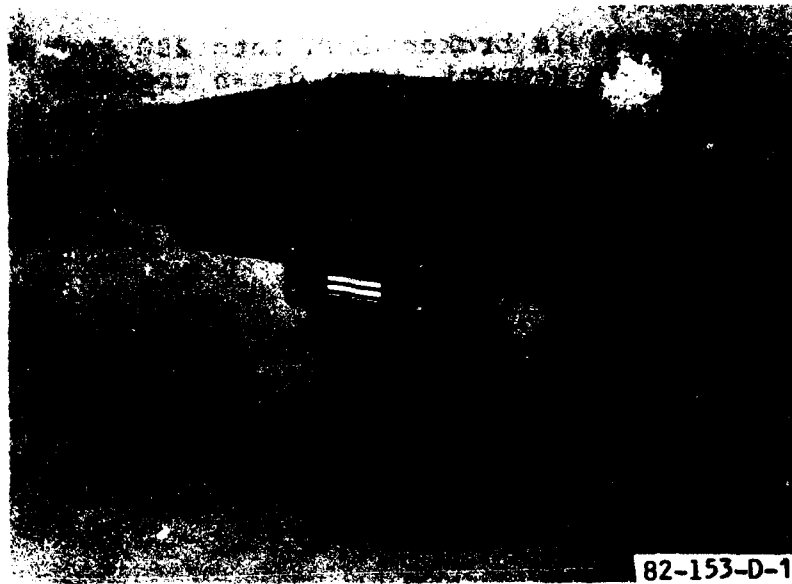
### TEST PROCEDURES

A PAPI system was furnished by the Crouse-Hinds Company (figures 1 and 2) for testing and was set up in a two-box configuration on the Technical Center runway 4; 1000 feet down the runway on the right-hand side. It was set up so that the 3° glideslope was midway between the angular settings of the pair of light units. The on-course signal then, was one red and one white light, the above course (greater than 3°15') was two white lights and the below course (less than 2°45') was two red lights. A questionnaire was prepared and the system was flown by our test pilots and tracked by the EAIR Radar system here at the Technical Center. Each test pilot flew about three runs during the day and again during the nighttime. The aircraft, for the most part, was a two engine Aero-Commander belonging to the Technical Center. Forty-five runs were made during August to the two-box system and twelve different pilots completed questionnaires on the system and provided us with comments.

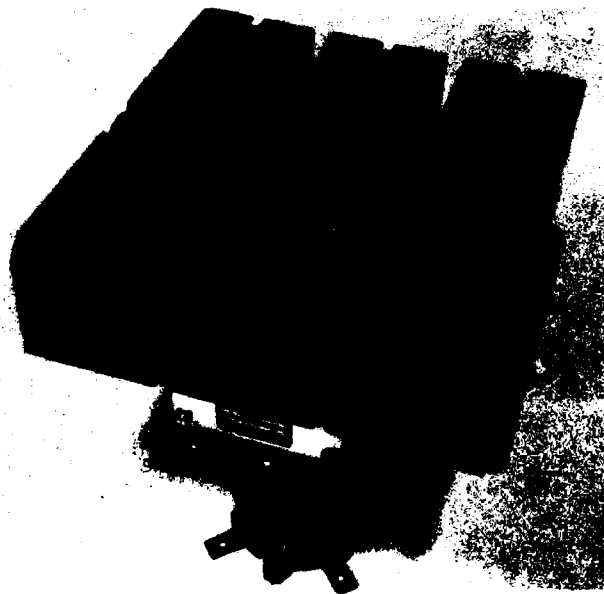
### TEST RESULTS

Attached as Appendix I is a compilation and summary of the data results of the questionnaires obtained from the test pilots during these tests. Also included are composite graphs, separated into daytime runs (figure 3) and nighttime runs (figure 4), showing the accuracy of the system as obtained by Radar tracking and reduced by our computer system. A statistical plot in figure 5

provides a graph that is broken down into 200 foot segments of range. Each range segment, when drawn together, provides a linear regression line. Lines representing the  $\pm 3 \sigma$  deviation indicate that 99.74 percent of all aircraft flying the PAPI would remain within this corridor. The data obtained is offered without comment for this data report. Further testing of this type is planned and will be included in the final report of PAPI.



**FIGURE D-1. CROUSE-HINDS PAPI UNIT**



**FIGURE D-2. CROUSE-HINDS PAPI UNIT SHOWING INTERNAL PARTS**

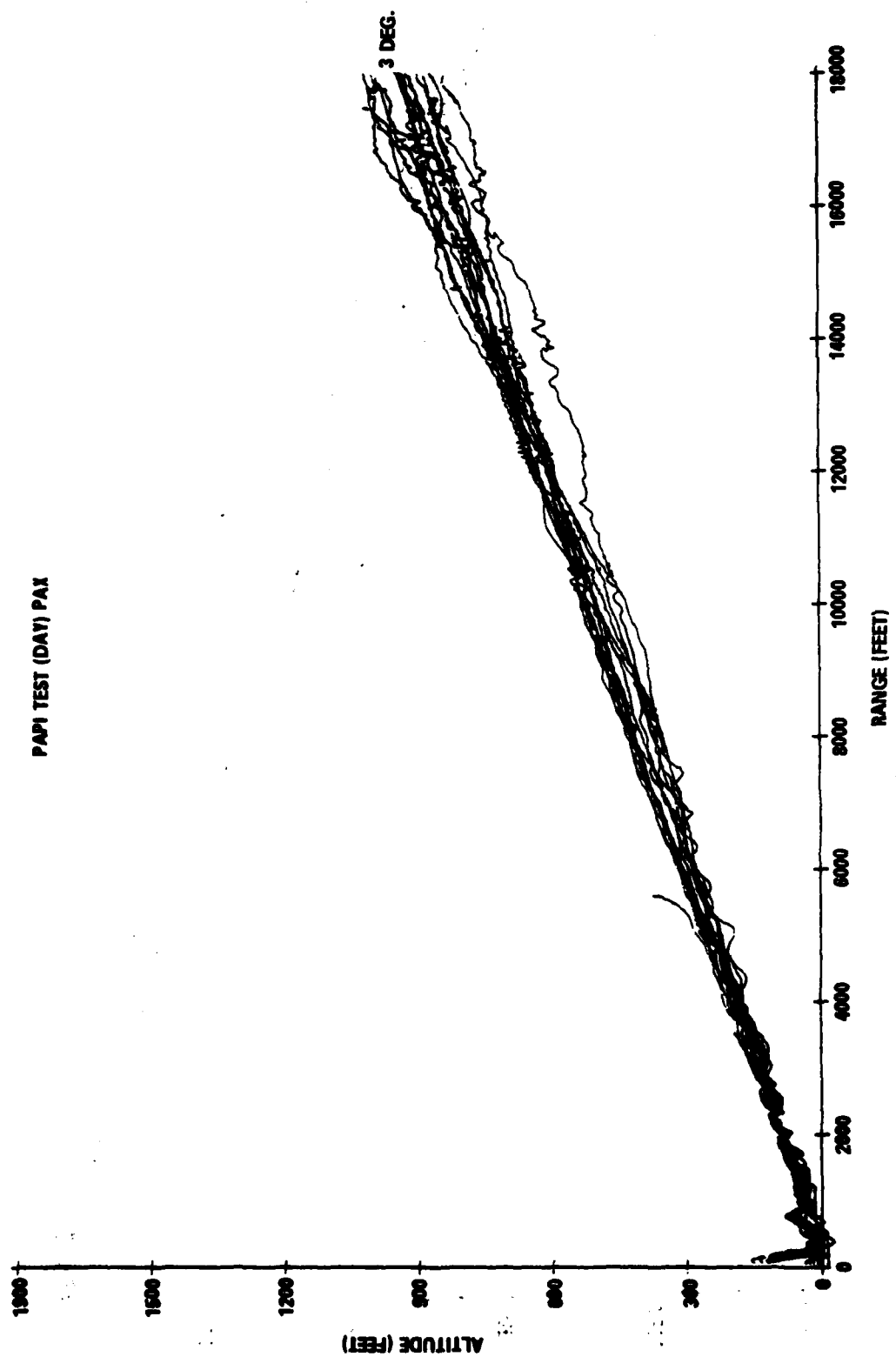


FIGURE D-3. PAPI TWO-BOX DAY TESTS

PAPI TEST (NIGHT) PAX

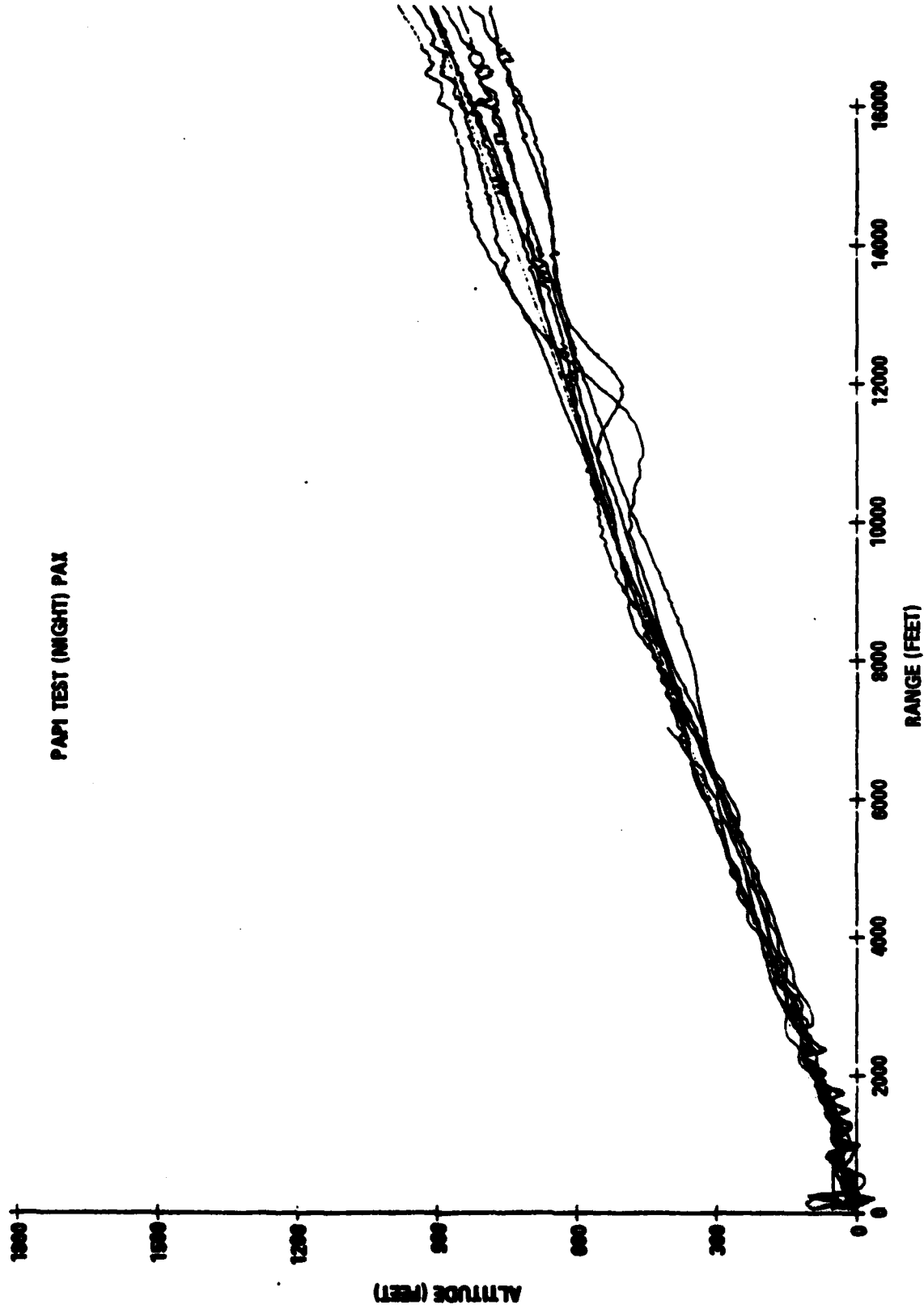


FIGURE D-4. PAPI TWO-BOX NIGHT TESTS



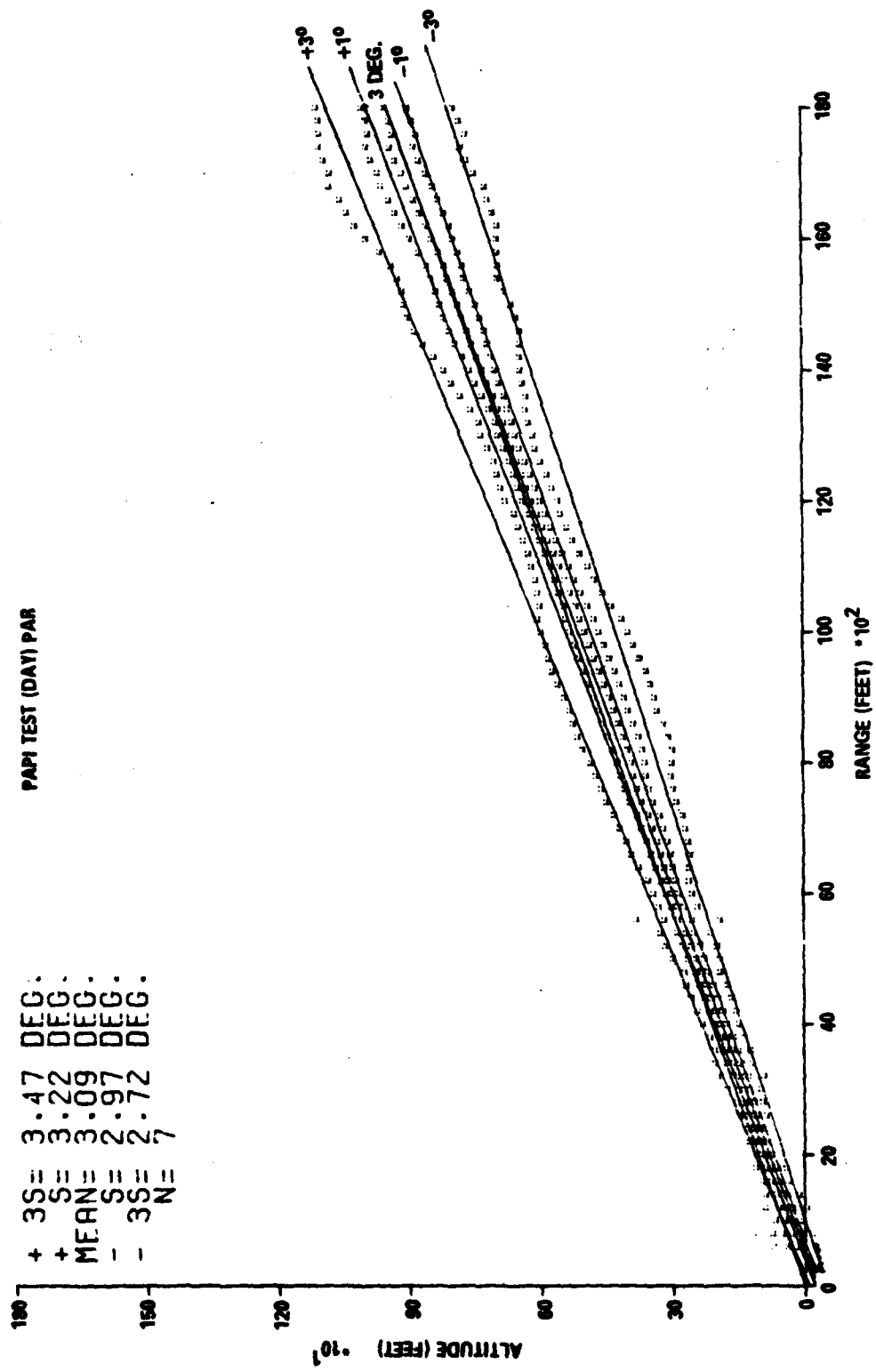


FIGURE D-5. PAPI STATISTICAL DAY PLOT

# SUMMARY

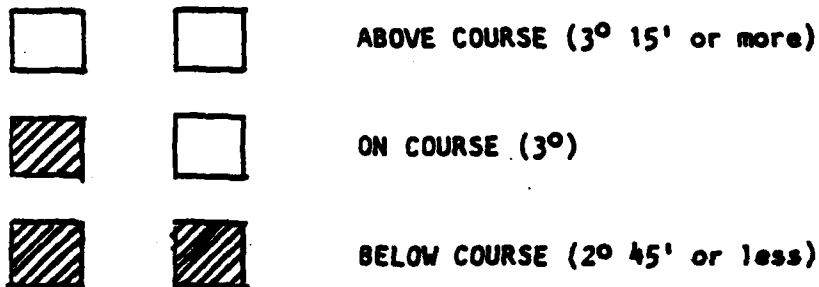
APPENDIX I

## PRECISION APPROACH PATH INDICATOR

"Two Box" PAPI

### Pilot Briefing

The tests now being conducted will provide data to determine whether a "Two Box" PAPI system can be successfully used on small airports with runways of 5,000 feet or less. The intended purpose of the "Two Box" PAPI is for use where it may not be necessary to have the five incremental paths provided by the full blown PAPI system. The arrangement of the units is similar to the full blown PAPI system except that only two boxes are used. The  $3^{\circ}$  glide-slope is midway between the angular setting of the pair of light units. The on-course signal is one red and one white light, the above course (greater than  $3^{\circ} 15'$ ) is two white lights, and the below course (less than  $2^{\circ} 45'$ ) is two red lights. These are depicted in the diagram below.



For this test, the units are located 1,000 feet down runway 4 on the right-hand side. Once you have accomplished a sufficient number of approaches to this system, please fill out the postflight questionnaire provided.

POSTFLIGHT QUESTIONNAIRE

PRECISION APPROACH PATH INDICATOR (PAPI)

"TWO BOX" PAPI

PILOT'S NAME \_\_\_\_\_ DATE: (DAY) AUG. 1981  
(Optional)\* \_\_\_\_\_ (NIGHT) \_\_\_\_\_

WEATHER \_\_\_\_\_ AIRCRAFT \_\_\_\_\_

1. At what ranges (DME) were you able to acquire and derive useful guidance from the "TWO BOX" PAPI?

Daytime 4.4 AV. NM. NIGHTTIME 7.7 AV. NM.

2. Were you able to obtain continual guidance from the "TWO BOX" PAPI throughout the approach?

Yes 23 No 0 Not Always 0

Comments:

3. Were the course dimensions (vertical height of "On-Course," "Fly-Down" and "Fly-Up" signals) sufficient to permit comfortable conformance to the desired flight path throughout the approach?

Yes 22 No 0 Not Always 1

Comments:

4. Do you feel that the "TWO BOX" PAPI gives at least the minimum necessary signal for successful 3<sup>o</sup> glide path approaches?

Yes 23 No 0 Not Always 0

Comments:

\* Names will not be used when results and comments are compiled.

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5. Was there a point during the final portion of the approach at which the usefulness of the "TWO BOX" PAPI became marginal?

Yes 8 No 15 Minimum Range \_\_\_\_\_

Comments:

6. If you have had previous experience with the Standard "TWO BOX" "Red/White" VASI System, how do you rate this PAPI System in comparison?

Better than 10 NOT AS Good as 2

Both about the Same 9

Comments:

7. With the minimum pilot briefing provided, did you experience any difficulty in first interpreting the "TWO BOX" PAPI signals?

No Problem 22 Slight Confusion 1 Trouble 0

Comments:

8. Is the system signal sufficiently distinctive that it cannot be readily confused with other lights on the airport and in the near vicinity?

Yes 18 No 5

Comments:

9. Have you any other remarks or comments concerning this system, or would you like to bring up any considerations that may not have been covered in this questionnaire?

TOTAL OF ELEVEN COMMENTS.

ELEVEN FAVORABLE COMMENTS.

EIGHT SAID "VERY GOOD SYSTEM".

Thank you.

TWO SAID "IT COULD BE USED FOR BOTH LARGE AND SMALL AIRPORTS."

ONE SAID "1000' down the runway seems to be a little far for "small" airplane operations".

**LME**

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