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EVALUATION OF WIND-DRIVEN RETROREFLECTIVE TAXIWAY EDGE
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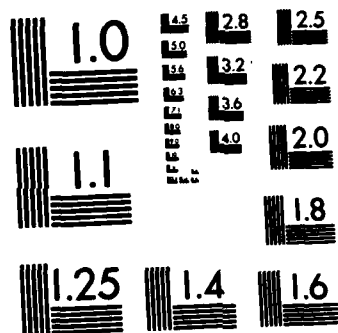
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Evaluation of Wind-Driven Retroreflective Taxiway Edge Markers

Guy S. Brown

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

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December 1982

Final Report

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16. Abstract An innovative taxiway edge retroreflective marker, designed to rotate when there is sufficient wind, was evaluated to determine whether the markers would provide adequate visual guidance at night while rotating and when stationary, and whether the innovative rotating feature adds to or detracts from the guidance value. The evaluation was not intended to determine whether the device will or will not meet Federal Aviation Administration (FAA) Specifications. The markers consist of a plastic can or cylinder, 6 1/4 inches by 8 inches tall, mounted on plastic Polyvinyl Chloride (PVC) pipe. Wind collector vanes on the cylinder are used to rotate the cylinder when winds are above approximately 8 knots. Light is reflected at night from retroreflective bands of yellow and blue material and from glass beads imbedded in the painted material. The retroreflective bands of material are staggered vertically producing motion or movement both when rotating horizontally and vertically. The test results concluded that the wind-driven edge markers adequately define the taxiway and provided adequate visual guidance for taxiing while the markers were stationary and when rotating during daylight hours and at night. There was not discernable advantage to the rotation feature. The rotation of the device did not significantly enhance guidance and some pilots felt it was distracting.					
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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

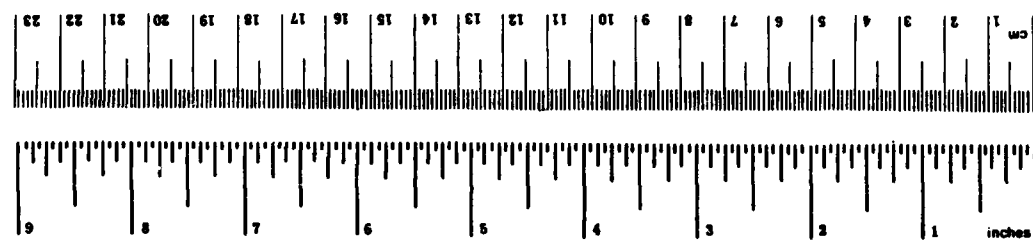
Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
AREA				
sq in	square inches	6.5	square centimeters	cm ²
sq ft	square feet	0.09	square meters	m ²
sq yd	square yards	0.8	square meters	m ²
sq mi	square miles	2.6	square kilometers	km ²
	acres	0.4	hectares	ha
MASS (weight)				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
VOLUME				
teaspoon	teaspoons	5	milliliters	ml
tablespoon	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.96	liters	l
gal	gallons	3.8	liters	l
cu ft	cubic feet	0.03	cubic meters	m ³
cu yd	cubic yards	0.76	cubic meters	m ³

TEMPERATURE (exact)

°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C
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Approximate Conversions from Metric Measures

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



* 1 m = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price \$2.25, SO Catalog No. C13.10-286.

PREFACE

The work described herein was accomplished in response to a request from ASO-610, Safety and Standards Branch, Airport Division, Southern Region, Federal Aviation Administration (FAA).

The work was conducted under Technical Center Program Document Number 08-493, subprogram 081-502, project 580. The Project Manager was Guy S. Brown and the Technical Program Manager was Thomas H. Paprocki, both of the Airport Technology Division of the FAA Technical Center.

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EXECUTIVE SUMMARY

The objective of this project was to evaluate an innovative taxiway edge retroreflective marker, designed to rotate when there is sufficient wind, to determine whether the markers would provide adequate visual guidance at night while rotating and when stationary, and whether the innovative rotating feature adds to or detracts from the guidance value. The markers consist of a plastic can or cylinder 6 1/4 inches by 8 inches tall mounted on plastic Polyvinyl Chloride (PVC) pipe. Wind collector vanes on the cylinder are used to rotate the cylinder when winds exceed approximately 8 knots.

The testing process involved the placement of 12 markers on a taxiway at the Technical Center's Airport, using standard locations and spacing, and an evaluation by subject pilots at night using three types of aircraft.

The test results conclude that the markers clearly define the taxiway and provide adequate visual guidance for taxiing while the markers were stationary and when rotating during daylight hours and at night. There was no discernable advantage to the rotation feature and some pilots felt the rotating feature was distracting.

Stationary retroreflective taxiway edge markers have been FAA approved and used successfully for a number of years; and from our evaluation there appears to be no compelling reason or advantage to utilize a rotating device.

INTRODUCTION

PURPOSE.

The purpose of this project was to evaluate an innovative type taxiway edge retroreflective marker designed to rotate when there is sufficient wind, and to determine,

1. whether the markers will provide adequate visual guidance at night when used as taxiway edge markers while rotating and when stationary, and
2. whether the innovative rotating feature adds to or detracts from the guidance value.

This evaluation was accomplished with the understanding that the Technical Center would not include testing to determine whether such devices will or will not meet FAA Specification L-853, Runway and Taxiway Retroreflective Markers. Such testing may be conducted at the manufacturer's plant or at an independent test laboratory acceptable to the FAA.

BACKGROUND.

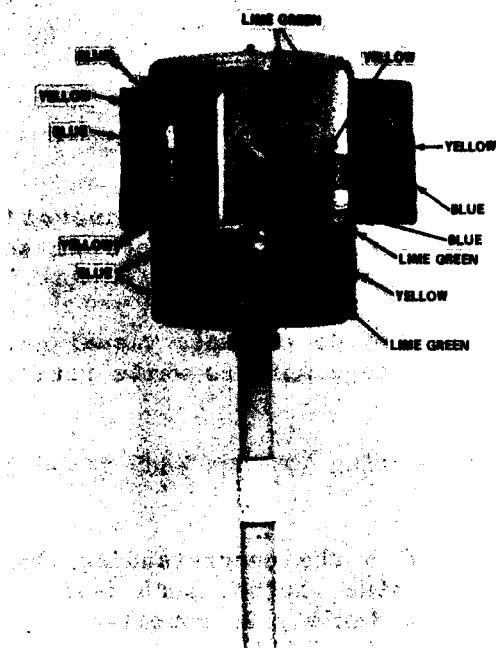
Retroreflective taxiway edge markers are approved by the FAA for use to supplement taxiway edge lights and for use at low activity airports in lieu of taxiway edge lights, reference Advisory Circular, AC-150/5340-24, "Runway and Taxiway Edge Lighting System." Those approved must meet FAA Specification L-853 "Runway and Taxiway Retroreflective Markers" as described in Advisory Circular AC-150/5345-39B. This specification includes requirements for retroreflective materials, environmental factors, and quality assurance provisions. The equipment qualifying under the specifications are listed in FAA Advisory Circular AC 150/5345-1, "Approved Airport Lighting Equipment."

The approved runway and taxiway retroreflective edge markers are of two general types, those that use retroreflective sheeting or tape and those of plastic molded material mounted on cylindrical or flat surfaces.

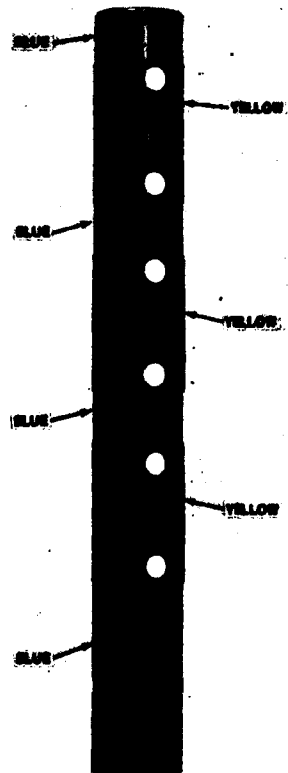
The wind-driven device evaluated was designed and fabricated by Mr. Richard E. Bibby, Supervisor, Airfield Maintenance, Tampa International Airport, Tampa, Florida. Mr. Bibby proposed an evaluation in discussions with and through a letter to the FAA Airport District Office, Atlanta, Georgia.

DESCRIPTION OF RETROREFLECTIVE EDGE MARKERS.

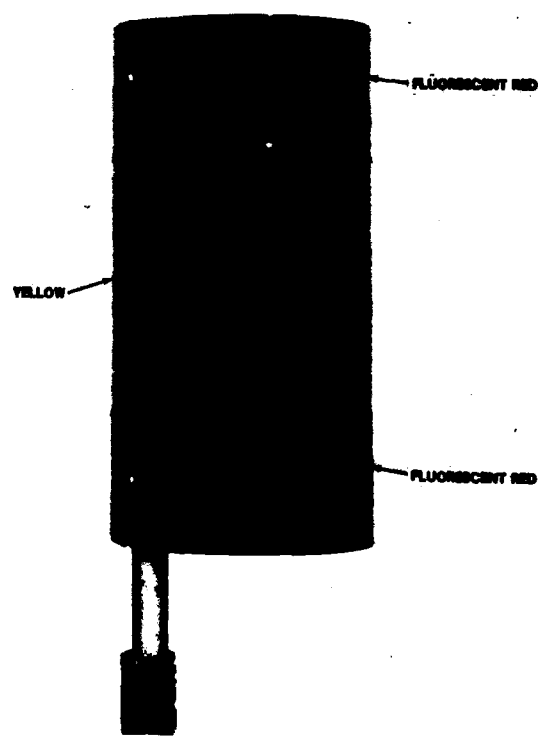
The markers (figure 1a) consist of a plastic can or cylinder 6 1/4 inches by 8 inches tall, mounted on 3/4-inch plastic Polyvinyl Chloride (PVC) pipe. The length of the pipe is dependent on the desired height above ground and the type of mounting, such as direct burial or surface mounting. As shown in figure 1a, five wind collector vanes, located on the side of the can or cylinder, are used to rotate the cylinder when winds are greater than approximately 8 knots. Light is reflected at night from the bands of yellow and blue retroreflective sheeting and also from glass beads imbedded in the lime green paint on the remainder of the surface. The retroreflective material is manufactured by Minnesota Mining and



a. Wind-Driven Taxiway Edge Marker



b. Unipar Taxiway Edge Marker



c. Valley Taxiway Edge Marker

FIGURE 1. RETROREFLECTIVE MARKERS

Manufacturing Company and the yellow is referred to as "Hi-Intensity" grade while the blue is referred to as "Engineering" grade. The positioning of the 1-inch bands of yellow and blue material on the wind vanes is not symmetric, that is, the bands are staggered vertically as shown in figure 1a. Consequently, when the device is rotating by wind the reflected light at night, produces motion or movement both vertically and horizontally. During daylight hours the different colors appear to have motion. The single 3/4-inch yellow band and the two 1/2 inch blue bands of retroreflective sheeting located on the lower part of the can does not, of course, produce motion effect.

In addition to the wind-driven edge marker, two other types of elevated edge markers were used for comparison in the evaluation as will be described under test procedures. Both were commercially available and listed in the Advisory Circular as approved equipment. The markers were cylindrical in shape and both used yellow retroreflective materials. One manufacturer, Unipar Inc., (figure 1b) uses a cylinder or tube, 2 1/2 inches in diameter and 30 inches high, made from flexible vinyl acetate, which is blue in color. Three retroreflective yellow bands, each 4 inches wide, and spaced 1 1/2 inches apart, are attached to the top part of the cylinder. The other marker, manufactured by Valley Illuminators (figure 1c), uses a thin-gauge aluminum cylinder, 6 1/2 inches in diameter and 12 inches high, with a 6-inch centerband of yellow retroreflective material. The top and bottom of the cylinder are painted fluorescent red, thus, producing fluorescent bands on the top and bottom, each 3 inches wide.

INSTALLATION.

The retroreflective markers were installed on a straight section of a taxiway and on the turn radius of a 90-degree intersecting taxiway (figure 2). The markers were spaced 200 feet apart on the straight section of the taxiway and 50 feet apart on the turn radius. This spacing is as specified for the installation of taxiway edge lights and retroreflective edge markers. The width of the taxiway was 75 feet and the markers were installed 5 feet from the edge of the pavement.

Of the 12 wind-driven markers on loan for the evaluation, eight were located on the straight section of the taxiway (four on each side). The remaining four were located on one turn radius at the intersection. These markers were illuminated by the aircraft lights when making a right turn from the straight section of the taxiway.

For a comparative evaluation with the two other types of markers, the wind-driven markers were removed from the south side of the straight section of the taxiway and replaced alternately with one of the other types. The temporary installation, using short sections of pipe mounted on small concrete pads, allowed quick changes between the different type markers. In order to stop the rotation of the wind-driven markers, simulating "no-wind" conditions, thin plastic rods about 1/8 inch in diameter and 30 inches long were inserted between wind collector vanes and extended to the ground.

DISCUSSION

EVALUATION AND TEST PROCEDURES.

Tests to evaluate the wind-driven retroreflective edge markers were conducted to independently evaluate the effectiveness of the wind-driven devices while rotating and stationary, and to compare wind-driven markers with the two previously noted types approved for use as taxiway edge markers.

Three types of aircraft were used for the evaluation; an Aero Commander-680 having two combination taxi-landing lights mounted in the nose section, a Convair-580 having a single taxi light mounted on the nose wheel strut and two wing-mounted landing lights, and a Piper Tomahawk Trainer with a nose-mounted light. At each test session, the aircraft was taxied onto the straight section of the taxiway, 1,350 feet from the first set of retroreflective markers located on each side of the 75-foot wide taxiway. Additional markers extended the test section another 600 feet. With the taxiway lights turned off, detection ranges were determined with the aircraft taxi light or with the combination taxi-landing lights as appropriate for the aircraft. The aircraft then continued on the taxi route with a right-hand turn at the intersection, as shown in figure 2. A minimum of two passes were made in each direction.

Ten pilots participated in the evaluation. Six were professional test pilots and four were experienced general aviation pilots, all familiar with the evaluation of visual aids. Three were subject pilots on more than one type aircraft resulting in a total of 20 responses to a questionnaire (appendix A). Prior to each session, the pilots were briefed on the purpose and route of taxi and were asked to taxi on or near the centerline.

After at least two passes, while observing the wind-driven devices, the pilots completed the questions pertaining to these markers. At this time, the wind-driven markers on the south side of the taxiway were removed and replaced by either the Unipar or Valley edge markers; these markers were alternated between test sessions. On completion of the comparison between the wind-driven markers on the north side and the other type on the south side of the taxiway, the appropriate question on the questionnaire was completed and the markers on the south side changed again for the final test runs.

The plan called for at least two passes to observe the devices while rotating and two passes while stationary. However, at all test sessions except two, there were insufficient wind to cause rotation. As is common in many geographical areas, the wind velocity diminishes at sunset resulting in no rotation of the units.

TEST RESULTS.

Analysis of the questionnaire responses (appendix A) indicates that, for visual flight rules (VFR) nighttime conditions, the subject pilots felt that the Tampa design wind-driven retroreflective edge markers defined the edges of the taxiway adequately. They provided sufficient visual guidance on the straight section and when taxiing on the right turn at the intersection while the markers were stationary (no rotation due to wind).

In rating the effectiveness or guidance value with no rotation, two pilots responded that they were "excellent," nine said "good," and four said "fair." When rotating slowly, one pilot rated the effectiveness as "excellent," five said "good," one said "fair," and one said "poor." When rotating fast, two pilots said they were "good," three said "fair," and one said "poor." Two pilots did not rate the markers for "rotating fast."

Problems were encountered in that during most test sessions pilots did not have the opportunity at night to observe the markers while rotating, except for an occasional very slow turn of one or two revolutions. The lack of sufficient wind to cause rotation of the devices after dark resulted in only 5 responses to the questions most pertinent to this evaluation; the effectiveness of the device while rotating slowly or fast and the effect of the motion or movement of the reflected light. The movement or motion, both vertically and horizontally, results from the non-symmetrical placement of the retroreflective material on the wind vanes of the markers as shown in figure 1. The rate of motion or flashing of the reflected light is variable and is dependent on windspeed and the resulting rate of rotation.

With higher rotation rates, however, there is little if any apparent motion. However, even with the few number of responses to questions concerning rotation, it is the opinion of the Technical Program Manager and the Project Manager that additional responses would not significantly change the distribution of results as presented.

In response to the question where the pilots were asked to consider the motion effect when there was sufficient wind to cause rotation, four pilots said the motion effect from rotation was "no help" and one said it was "distracting." The pilots comments offer some suggestions as to their responses. The comments were:

"The rotation effect did not appear to be helpful between 800 and 1,000 feet. Closer than 800 feet the rotation effect was more noticeable but not necessarily helpful. Closer approaches (distances) yielded a unique effect but not necessarily an advantage over stationary reflectors."

"Rotation of unit added no value to them as visual aids. They are a good reflector, though."

"There does not appear to be any advantage to the rotation. They are equally effective when not rotating. The difference in appearance with wind changes results in an inconsistent signal. This could be confusing if a pilot were not familiar with the device. All factors considered, the preference would be for stationary configurations."

"Rate of rotation varied between reflectors and small wind gusts. Would prefer brighter steady signal. Rotation is eye catching but is too variable with no uniform appearance."

"I did find the rotational movement to be distracting. The speed of rotation was different for individual fixtures, resulting in variations in appearance within the system (i.e., some fixtures exhibited vertical random motion; others were not rotating at all). The overall effect was that of a distinct lack of uniformity in system appearance, a factor that induced a feeling of lack of confidence in the guidance to

be derived. Acquisition range appeared to be the same regardless of fixture motion. This range seems adequate for providing guidance along the taxiway."

In comparing the effectiveness of the Tampa design wind-driven markers, located on the north side of the taxiway, with two approved types (Unipar and Valley), the pilots were unanimous in responding that both approved types were more effective than the Tampa design. Pilots comments were:

"Valley better than Unipar and both much more uniform in appearance. Random orientation of rotating reflectors, depending upon stopped position, detracts from impression created by system."

"Reflectors on south side of taxiway were superior."

"Both types of reflectors on south side seemed brighter and more uniform."

"Red top and bottom (as with Valley marker) would be helpful in snow."

"Unipar vs Tampa at a distance are same — up close Unipar is better."

"Unipar is more effective and Valley slightly more effective with this aircraft."

"Tampa may be better when it is in motion but the reliability of the motion (rotation) can't be counted on."

In comparing the different types of edge markers, it is noted that the total area of the bands of retroreflective material on the two approved types is greater and more symmetrically located than that on the wind-driven device. The yellow material is the same as that used on the Valley markers and should produce the same reflectivity for unit area. The blue material, however, on the wind-driven device, produces significantly less reflected light. Though laboratory tests were not conducted, it is doubtful, based on observations, that the glass beads imbedded in the painted surface together with the retroreflective material can equal the total reflectivity of the approved edge markers. This could, in part, explain why the two approved types were considered more effective.

Detection ranges, the distance at which the three types of taxiway edge markers could be seen, varied with the type aircraft and the aiming of the lights. The distances, ranging from just over 2,000 feet to about 1,000 feet, were all considered adequate to delineate the taxiway edges for operations in VFR nighttime conditions.

With the Aero Commander and Convair-580 aircraft, the two "approved" types of markers could be seen at distances just over 2,000 feet while the Tampa design could be seen dimly at about 2,000 feet and appeared fairly bright at about 1,600 feet. With the Tomahawk aircraft, they were first seen at about 1,000 feet and did not appear very bright at closer ranges, due to the aiming of the aircraft light.

The nose mounted combination taxi-landing light, while aimed appropriately when in the landing attitude, is aimed appreciably downward with the aircraft in a nose-down attitude when taxiing. Even though the wind-driven markers did not appear overly bright they were reported as adequate to delineate the edges of the 75-foot wide taxiway.

With respect to daytime use of the wind driven taxiway edge markers, it was decided that an informal assessment could be made since, over a period of almost 5 months, at least 15 pilots had many opportunities to observe them in varying wind and weather conditions. Discussion and comments from these pilots, which included project test pilots, are summarized as follows:

Attention getting when rotating and adequately define taxiway edges, however, not really necessary since the edges of the pavement are well defined by the grass; they would help define the edge of the taxiway in snow in daytime and increasing the amount of blue material would make them more conspicuous, when turning they attract attention because they are novel — different — but not really a necessary feature; not too discernable at distance, yellow color blends with concrete and brown grass and shows up better when grass is green; motion from turning is distracting. Based on the overall comments and discussions, the wind-driven markers were judged to adequately define taxiway edges while stationary or when rotating with wind in daytime conditions. Most pilots felt the rotation was not necessary and some thought it was distracting.

Further test of the wind-driven markers were not conducted to address environmental, maintenance and durability considerations nor to determine effectiveness in rain conditions at night. The test results indicated that the rotating feature does not appear to offer any real advantage or significant improvement over stationary markers. Such tests are normally conducted by the manufacturer or an independent testing laboratory, in accordance with FAA requirements when the manufacturer desires FAA approval of the equipment.

In general, the lightweight plastic markers held up well during a period of approximately 6 months while subjected to winds of up to 52 knots. While located on the taxiway during this period, they were also subjected to adverse effects from operation of numerous large multi-engine aircraft to include Boeing 747's and Air Force C-141's. Small cracks and paint chipping appeared on several of the wind vanes, probably a result of flexing of the vanes.

CONCLUSIONS

The wind-driven design retroreflective edge markers adequately define the taxiway and provide adequate visual guidance for taxiing while the markers were stationary and when rotating.

When considering the responses and comments concerning rotation of the devices when used as taxiway edge markers, the rotating feature does not appear to offer any real advantage or significant improvement in performance over that produced when the device is stationary and may in fact be a distracting feature.

While the rotation and effects from rotation are innovative, producing a unique effect that is "eye-catching," the wind and the rate of rotation is not consistent and dependable. This appears to be a disadvantage, at least in the opinion of some pilots, due to the visual variations between different markers and the lack of uniformity in overall system appearance.

The FAA's Advisory Circulars concerning taxiway edge markers prescribes the performance specifications including the size, color, and so forth. Such specifications inherently provide a degree of standardization for taxiway edge markers and other visual aids. The United States as well as other countries, working through ICAO, have been striving for standardization for many years in order that pilots may expect basically the same visual aids and guidance at all airports. Stationary retroreflective taxiway edge markers have been used successfully, with a reasonable degree of standardization, for a number of years and there appears to be no compelling reason or advantage to add a rotating device which is subject to variable wind conditions.

APPENDIX A
SUMMARY OF PILOT RESPONSES

Appendix A

Summary of Pilot Responses

EVALUATION OF TAXIWAY EDGE RETROREFLECTIVE MARKERS

081-502-580

Pilot Questionnaire

Name _____ Type A/C _____ Date _____

Location
Taxi Light/s Nose _____ Weather VFR _____ Wind _____

Evaluation of "Tampa Design" Edge Markers

1. Did the retroreflective edge marker define the edges of the taxiway sufficiently well to provide adequate visual guidance when:

a. Taxiing on the straight section of T/W Bravo between T/W's Kilo and Juliett?

Yes 20 No 0 Please comment:

b. Taxiing on the right turn from T/W Bravo to Juliett?

Yes 19 No 1 Please comment:

2. Since the retroreflective taxiway markers are designed to rotate when there is sufficient wind, how would you rate the effectiveness or guidance value when:

a. Rotating fast	Exc. <u>0</u>	Good <u>2</u>	Fair <u>3</u>	Poor <u>1</u>
b. Rotating slowly	Exc. <u>1</u>	Good <u>5</u>	Fair <u>1</u>	Poor <u>1</u>
c. No rotation	Exc. <u>2</u>	Good <u>9</u>	Fair <u>4</u>	Poor <u>0</u>

3. The standard taxiway and runway visual aids are steady burning lights and/or stationary retroreflective devices whereas the taxiway markers being evaluated produce an effect of motion from the reflected light when they are rotating at night. When there is sufficient wind to cause rotation, would you consider the motion effect to be:

a. Night	Very helpful <u>0</u>	helpful <u>0</u>	no help <u>6</u>	distracting <u>2</u>
b. Day not formally evaluated -see text	Very helpful _____	helpful _____	no help _____	distracting _____

Please comment:

Comparison of Different Type Edge Markers

4. In comparing the effectiveness of different type reflectors located on each side of the taxiway, which side would you consider more effective:

a. (Unipar) South side? <u>11</u> (Tampa)	North side? <u>0</u>	No difference <u>0</u>
b. (Valley) South side? <u>11</u> (Tampa)	North side? <u>0</u>	No difference <u>0</u>

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

END