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16. Abstract <p>The objectives of this report were to investigate 1) the potential benefits of using flexible posts for post delineators and 2) the possibility of not requiring post delineators on sections of interstate-type highways where recessed markers are installed.</p> <p>It is recommended that post delineators should only be used when the design curvature is 1.5 degrees or more, and the spacing should be based on the formula given in Table III - 1. of the MUTCD. Data obtained concerning the performance of flexible posts do not support widespread use at this time. A testing program should be developed to obtain an approved list of flexible posts and, after an evaluation period, expanded use of flexible posts might be recommended. Steel posts used as delineator posts should be lightweight (1.1 pounds per foot).</p>					
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Research Report  
UKTRP-86-10

USE OF POST DELINEATORS ON INTERSTATES

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## INTRODUCTION

Kentucky has always used steel posts for the installation of post delineators and has placed the post delineators on both the mainline and ramps on interstates and parkways. The current standard practice is a 400-foot spacing on the mainline and a 100-foot spacing on ramps.

Although flexible posts have been used for many years across the nation, there has been very limited use of them in Kentucky. There is a need to determine whether flexible posts could provide an effective and cost-efficient alternative to steel posts.

A recent revision to the Manual on Uniform Traffic Control Devices (MUTCD) allows for the substitution of raised pavement markers for post delineators on tangent sections of freeways. Since recessed markers are currently being installed on interstates in Kentucky, the possibility of not using post delineators on those sections should be considered.

The objectives of this report were to investigate 1) the potential benefits of using flexible posts for post delineators and 2) the possibility of not requiring post delineators on sections of interstate-type highways where recessed markers are installed.

## REVIEW OF LITERATURE

A bibliography, consisting of a few references that deal with the subject of this report, is given in the Appendix. Studies that have dealt with an evaluation of post delineators have involved two-lane highways rather than freeways and typically are only concerned with curves. In general, there have been mixed results concerning the effectiveness of post delineators. Many agencies feel that the post delineator, used as a supplement to standard pavement markings, produces an effective delineation system, especially during wet weather and snow conditions.

A comparison of costs of flexible and steel posts reveals that flexible posts are about twice as expensive as steel posts. However, in high-hit areas the flexible posts may be cost-effective if they can survive two or more hits. Literature did not provide any recommendation concerning the types of flexible posts which are best.

## SURVEY OF STATES

To determine the policy of other states in the same general region of the country regarding their use of post delineators, a telephone survey was conducted. A total of 18 states were contacted. These states consisted of the seven states that border Kentucky and, generally, other states in the southeastern region of the nation.

The first question asked concerned the use of post delineators on the mainline interstate. Comments to that question are presented in Table 1. All states used post delineators on interchange ramps. Nine states used post delineators routinely on the mainline interstate. The other nine states

either 1) do not use post delineators on the mainline, 2) are in the process of discontinuing use on the mainline, or 3) use post delineators on a portion of the mainline. In general, states still using post delineators on the mainline were northern states such as Illinois, Indiana, and Ohio. States not using post delineators were southern states such as Florida, Georgia, and Louisiana. The general comment of the states where post delineators are still used on the mainline is that they are needed because snow obscures pavement markings in the winter. Generally, states not using post delineators referred to the lack of snow and presence of raised pavement markers as justification for not using them. These states were not completely free of snow, and raised pavement markers were not used in all states.

Two states (Alabama and Texas) used post delineators only on mainline curves. Alabama used post delineators on the mainline having a 30-minute or greater curve and Texas used them on a one-degree or greater curve. Texas also used post delineators in the northern part of the state where it snows and raised pavement markers are not used.

The use of flexible posts was then investigated. Comments to this question are presented in Table 2. All states surveyed had used flexible posts to some degree. Usage varied from very limited use of a few hundred to total use of flexible posts in Ohio. Most states limited use of flexible posts to high-hit areas. An exception is Ohio where flexible posts are used routinely on the mainline interstate as well as on ramps. In Kansas, the policy is to use flexible posts in urban areas on ramps and the mainline and steel posts in rural areas on ramps and the mainline. While some states indicated a desire for expanded use of flexible posts in the future, most noted their use would be limited to high-hit areas.

The types of flexible posts used was investigated and the comments are summarized in Table 3. The flexible post used most often was the Carsonite (either the Roadmarker or Curv-Flex). There was no general agreement concerning the best post to use. For example, some states only used the Carsonite Curv-Flex while others rejected use of that post. The other posts that were used more often included the Safe Hit by Unistrut Corporation and the Carson post. Other posts also were mentioned.

Comments concerning the cost comparison of flexible and steel posts are presented in Table 4. It was the general opinion that flexible posts cost considerably more than steel posts, with opinions varying between a very similar cost to flexible posts costing three times that of steel posts. Considering all comments, an estimate would be that the cost of flexible posts would be about twice that of steel posts.

Comments concerning problems associated with flexible posts are summarized in Table 5. Several problems were noted but the most common were 1) the problem of driving flexible posts in rocky soil, 2) the problem of keeping the posts straight, and 3) the damage from mowers and snowplows.

#### MUTCD REVISION

Section 3D-4 of the MUTCD deals with delineator application. The Federal Register of January 10, 1984, contained the following proposed change to this

section of the MUTCD:

"The Texas State Department of Highways and Public Transportation requested that the MUTCD be changed to delete the requirement for delineators on tangent sections of freeways. The State feels that continuous delineators are not needed for motorist guidance where edge markings are used.

Research has shown that raised pavement markers serve well as both near and far delineation. Raised pavement markers present a more accurate perspective of the driving surface and they have a more significant effect on mean lateral placement than post mounted delineators. Drivers need some form of roadway delineation under all weather conditions, but with a minimum of redundancy.

In light of the experience of several States and the research findings, the FHWA is proposing to amend Section 3D-4 to allow the use of raised pavement markers as a substitute for delineators on tangents.

This proposed change would not impose any additional costs, but provide highway agencies with greater flexibility in the use of freeway delineation."

Almost two years later, the Federal Register of December 12, 1985, summarized the action taken by FHWA on the proposed change. The amendment to Section 3D-4 was approved and allows, under certain conditions, raised pavement markers to be substituted for delineators on tangent sections of freeways. Specifically, the change resulted in adding the following to the last paragraph of Section 3D-4:

"Roadside delineators shall be optional on tangent sections of expressway and freeway roadways when all of the following three (3) conditions are met:

1. Raised Pavement Markers are used continuously on lane lines throughout all curves and on all tangents to supplement pavement markings.
2. Where whole routes or substantial portions of routes have large sections of tangent alignment. Where, if roadside delineators were not required on tangents, only short sections of curved alignment would need delineators.
3. Roadside delineators are used to lead into all curves as shown in Table III-1."

There were 21 commenters to the proposed change, of which 15 were in favor, two were opposed, one was neutral, and three requested deferral. After review and evaluation, the three requesting deferral expressed support for the change.

Comments from 18 of the commenters are presented in Table 6. Those that disagreed felt that post delineators served a useful purpose in winter

conditions in snowbelt states. Among the suggestions of those in agreement with the proposed change were that 1) snowbelt areas should still be required to erect post delineators, 2) snowplowable markers should be referred to in addition to raised pavement markers, and 3) curves having given radii should be treated as tangents.

#### CONDITION OF POST DELINEATORS

A problem with post delineators is the maintenance associated with keeping the post delineator in good condition. To estimate the extent of the required maintenance, a section of roadway was located where the post delineators had not been checked for several months. The survey section was the Mountain Parkway in Clark County. The survey length was 11 miles in each direction. A summary of the results is presented in Table 7.

The condition of each post delineator was classified according to whether the delineator was present and whether the post was straight. The number missing was determined by assuming that, at a spacing of 400 feet, there should be 13 post delineators per mile. Of the 286 post delineators that should have been in place over the survey section, 10 percent was missing while 198 post delineators or 69 percent were observed to be in good condition. Of the 286 post delineators, 33 or 12 percent did not have a delineator and 36 or 13 percent of the posts were leaning substantially.

#### ACCIDENT ANALYSIS

While there was not a substantial amount of accident data available to estimate the effect of removing post delineators from an interstate, a limited analysis was performed using a small section of Interstate 71 (I 71). Upon completion of a project on I 71 on June 30, 1983, post delineators were removed and not replaced between Milepoints 56.6 and 65.9 (a 9.3-mile section). Recessed markers were placed in April 1985 so, for a 21-month period, neither post delineators or recessed markers were present. Accidents during that period were compared to a similar 21-month period before the construction project to determine if any differences could be detected. As a control section, accidents on a 9.3-mile section adjacent to this section were summarized. Post delineators were present during both periods on this section.

The accident summary is shown in Table 8. Post delineators should not have an effect on daytime accidents, so the relevant numbers are the nighttime and wet-nighttime accidents. The number of wet-nighttime accidents was very low in each instance. The number of nighttime accidents was almost identical during each time period. This analysis does not appear to indicate a negative impact on either nighttime or wet-nighttime accidents as a result of removing the post delineators. The contrasting change in total accidents over these adjacent short sections of interstate can not be explained, so percentages of accidents during the nighttime and wet-nighttime were not calculated. The numbers of accidents on these sections that occurred on a curve and on a curve during nighttime conditions are also listed in Table 8. For both sections, the number of accidents on curves increased slightly in the second time period. The numbers are so small that there is no basis to conclude that lack

of post delineators had any effect on accidents. A much larger sample of data would be required before conclusive results could be documented.

The revision in the MUTCD allows post delineators to be optional on tangent sections of expressways and freeways where raised pavement markers have been installed. In the case of interstate highways in Kentucky, recessed markers are planned for all sections and contracts have been awarded for approximately 482 miles of the total interstate mileage of almost 750 miles. To obtain some information on the effects that recessed markers are having on nighttime and wet-nighttime accidents, a two-year before and one-year after comparison of accidents was summarized for 122 miles of interstate highways where recessed markers were installed in 1984 (Table 9). Post delineators were present during both the before and after periods. There was a large unexplained increase in total accidents in the year after compared to the two years before, so the percentages of nighttime and wet-nighttime accidents were compared. Considering both years before, the percentage of nighttime accidents decreased from 38 percent before to 32 percent after and the percentage of wet-nighttime accidents decreased from 5.4 before to 4.1 percent after. While more data and more detailed analysis are needed before conclusive results may be reached, the available data indicate that recessed markers are an effective nighttime and wet-nighttime delineation device.

#### VISUAL OBSERVATIONS

To determine the effects removing post delineators would have on nighttime delineation, nighttime observations were made on a section of I 71 that had both post delineators and recessed markers and another section that had recessed markers only. A desire was to observe the delineation on curves having varying degrees of curvature. To accomplish this, the highway plans were reviewed and curves having varying degrees of curvature were selected. Over the survey section, the maximum curvature noted, except for one four-degree curve, was three degrees.

The curves were first viewed during the day to obtain a better perspective of how a curve having a given degree would appear. Figures 1 through 4 are daytime photographs of curves having one-, two-, three-, and four-degrees of curvature, respectively.

Nighttime observations were made and photographs were taken on the sections having recessed markers only and having recessed markers and post delineators. Observations of curves having the same degree of curvature were made on both sections. The recessed markers were placed at a spacing of 80 feet while the post delineators were placed at a 400-foot spacing. The post delineator spacing was so large that, when traveling through the curves having the higher degrees of curvature, not enough delineators were visible to delineate the curve. It was apparent that the primary sources of nighttime delineation were the recessed markers. The post delineators did not add significantly to the delineation provided by the recessed markers.

#### ANALYSIS OF HPMS CURVE DATA FOR INTERSTATES

An analysis of Highway Performance Monitoring System (HPMS) curve data

for interstate routes was made to determine the frequency and length of curved sections. Included in the HPMS data file are 310 sections that represent all of the 746 miles of interstate in Kentucky. The HPMS file has 13 categories of degree of curvature, varying from 0 to 0.4 degrees to 28 degrees or more. The highest degree of curvature in Kentucky falls into the category of 5.5 to 6.9 degrees. Presented in Table 10 is a summary of number of curves and length of curves for all interstates. There are only 7 of the 13 curve categories represented. It may be seen that there are 524 miles of interstate that are either tangent sections or have 0.4 degrees of curvature or less. There are 675 curves on interstates having degree of curvature of 0.5 or more. These 675 curves represent 222 miles of interstate.

It is apparent from Table 10 that a majority of curves on interstates are less than 3.0 degrees. Because of the categories used to summarize degree of curvature in the HPMS file, it was not possible to consider the number of curves having degrees of curvature of 3.0 or more. However, since one of the categories was 2.5 to 3.4 degrees, it may be shown that there are 164 curves representing 45 miles of interstate having curvature of 2.5 degrees or more. If the assumption is made that the distribution of curves in the category of 2.5 to 3.4 degrees is even, then the curves of 3.0 degrees or more would total approximately 113 and the total length would be approximately 31 miles.

#### RECOMMENDATIONS

The MUTCD states that post delineators are guidance devices having the advantage that they remain visible when the roadway is wet or snow-covered. However, when raised pavement markers or snowplowable markers are used, the need for post delineators for wet-nighttime delineation is eliminated. Also, in border states such as Kentucky, interstate-type highways are snow-covered for only a very short time each year. The difficulty of making a recommendation concerning use of post delineators on interstates is complicated by the wording of the addition to Section 3D-4 of the MUTCD. The addition makes roadside delineation optional on tangent sections of expressways and freeways when raised pavement markers are used. An inquiry was made into the meaning of tangents as used in the MUTCD addition. The opinion obtained from FHWA was that optional use of post delineators was intended only for tangent sections and exceptions were not made for curves.

It appears that the additional delineation provided by post delineators on interstates is minimal when used in conjunction with raised pavement markers and consideration should be given to eliminating them on most sections of interstates. However, visual observations made on I 71 of varying degrees of curvature with and without post delineators indicate that curves greater than 3.0 degrees may warrant use of post delineators in addition to raised pavement markers. The AASHTO Policy on Geometric Design of Highways and Streets states that, for a 70-mph design speed and 0.08 maximum superelevation, the maximum degree of curvature is three degrees. However, given the opinion from FHWA that post delineators would only be optional for tangents, it would be prudent to use post delinators on curves having less than a degree of curvature of three degrees. From Table 10, the number of curves having curvature of 1.5 degrees or more totals approximately 339 and the length of interstate would be approximately 106 miles. It is recommended that post delineators should only be used where the degree of curvature is 1.5

degrees or more, and the spacing should be based on the formula listed in Table III-1 of the MUTCD. For example, for a two-degree curve, the spacing would be about 160 feet and, for a four-degree curve, the spacing would be 110 feet. If this was implemented on the total interstate system, the number of post delineators on the mainline would be reduced from almost 20,000 to approximately 8,000. This recommendation is contingent upon requesting and receiving a broader interpretation of the meaning of tangents as it now appears in the addition to Section 3D-4 of the MUTCD.

No evaluation of the effect of removing post delineators from the mainline of interstate-type highways was available in the literature. After recessed markers are added and post delineators are removed for a substantial number of miles, a detailed analysis should be conducted to determine if removal of the post delineators on the tangents and curves less than 1.5 degrees and the closer spacing of posts on curves 1.5 degrees or more had any effect on accidents. Such an experimental research study could be used as justification for the recommended changes in the application of post delineators on the interstate system.

Data obtained concerning the performance of flexible posts do not support widespread use at this time. Various types of flexible posts have been used with varying degrees of success. Typically they are used only in areas where there is a high chance of being hit. A testing program should be developed with the objective of obtaining a list of approved flexible posts. After an evaluation period, expanded use of flexible posts might be recommended.

The steel posts used as delineator posts should be lightweight. Most states have changed to a 1.1 pounds-per-foot post, which is recommended.

TABLE 1. USE OF POST DELINEATORS ON MAINLINE INTERSTATE

STATE	COMMENT
Alabama	Use on mainline with 30-minute curve or greater at 528-foot spacing.
Arkansas	Raised pavement markers are used on the interstate system, so the use of post delineators on the mainline is being eliminated.
Florida	Use on interstates only in gores and on ramps.
Georgia	Since all interstates have raised pavement markers, post delineators between interchanges are not replaced.
Illinois	Use delineator posts on mainline at 400-foot spacing (528-foot spacing on new installations). No plan to use raised pavement markers but, even with raised markers, would not delete post delineators.
Indiana	Use on mainline at 400-foot spacing.
Kansas	Use on mainline except in lighted areas.
Louisiana	Stopped using post delineators on mainline about seven to eight years ago.
Mississippi	Currently using post delineators on mainline at 528-foot spacing but, considering the change to the MUTCD, will be removing post delineators in areas with raised pavement markers since there is no problem with snow in the state.
Missouri	Never have used post delineators on mainline.
North Carolina	Use post delineators on mainline at maximum spacing of 264 feet (20 per mile).
Ohio	Use post delineators on mainline at 400-foot spacing.
Oklahoma	Use on mainline at 528-foot spacing, with closer spacing on curves.
South Carolina	Use on mainline at 400-foot spacing, except near the coast where the roads are straight and level where a 528-foot spacing is used. Considering not using post delineators near the coast.
Tennessee	Starting in 1985, post delineators were not placed on the mainline; may remove mainline posts.
Texas	Use on mainline with 1-degree or greater curve at spacing based on formula in MUTCD. In northern part of state where it snows, raised pavement markers are not used as lane lines, so post delineators are still used on mainline.
Virginia	Use on mainline at 528-foot spacing.
West Virginia	Use on mainline at 300-foot spacing.

TABLE 2. USE OF FLEXIBLE POSTS

STATE	COMMENT
Alabama	Only used flexible posts in limited areas by maintenance.
Arkansas	Limited use of flexible posts with mixed results.
Florida	Flexible posts used extensively. Considering policy to only use steel posts where they would be outside the clear recovery area.
Georgia	Flexible posts have been used with good results, typically on ramps and other areas where the post is likely to be hit. Encourage the use of steel posts where practical and use lot more steel than flexible.
Illinois	Limited use of flexible posts in high-hit areas but none of the flexible posts have worked very well.
Indiana	Use flexible posts only in some limited high-hit areas.
Kansas	Policy is to use flexible posts in urban areas on ramps and mainline and steel posts in rural areas on ramps and mainline.
Louisiana	Currently, approximately 20 percent of post delineators are using flexible posts but considering expanded use of flexible posts for reasons of maintenance.
Mississippi	Using flexible posts only in high-hit areas, not on mainline.
Missouri	Limited use of flexible post in high-hit areas.
North Carolina	Using limited amount of flexible posts.
Ohio	Changed completely from steel to flexible posts about four years ago and change is now complete.
Oklahoma	Using flexible posts on secondary roads and in high-hit areas and especially in snowbelt part of state. Not considering use of flexible posts on interstates.
South Carolina	Limited use of flexible posts of the interstate system by the maintenance division.
Tennessee	Using flexible posts on ramps with success.
Texas	Successful experience with flexible posts and considering policy change in which a switch would be made entirely from steel to flexible.
Virginia	Use mostly steel posts with some flexible posts.
West Virginia	Very limited experience with flexible posts. Considering experimental project on interstate using flexible posts. Turnpike Authority has installed flexible posts on West Virginia Turnpike.

TABLE 3. TYPES OF FLEXIBLE POSTS USED

STATE	COMMENT
Alabama	Approved list includes Carson (used primarily), Carsonite, and Proven Products PVC.
Arkansas	Carsonite has been used.
Florida	Carsonite Roadmarker only type used. Carson tested but did not pass.
Georgia	Carsonite is only flexible post used. Other posts tested but not approved include Potters, Guardian, and Proven Products.
Illinois	Carsonite and tubular types of posts have been used.
Indiana	The Carsonite Roadmarker, PVC Flex-O-Post, and Unistrut Safe Hit are approved. The Carsonite Curv-Flex and FlexTron Curved were rejected because could not drive.
Kansas	Only approved post is Safe Hit by Unistrut Corporation. Carsonite post rejected because it weakened over time due to ultraviolet rays and would weaken if bent.
Louisiana	Only flexible post used is Carsonite Curv-Flex.
Mississippi	Approved list includes Carsonite Curv-Flex, Carson, and Safe Hit.
Missouri	Used Carsonite among others.
North Carolina	Approved list includes Carsonite, Carson, and Flex-o-post.
Ohio	Use Carsonite primarily (both Roadmarker and Curv-Flex) but also have used Safe Hit and posts made by Parker Industry and Potters.
Oklahoma	Have used only Carsonite Curv-Flex.
South Carolina	Have used fiberglass-type flexible posts.
Tennessee	Using both Carson and Carsonite.
Texas	Using two types of flexible posts - Carsonite Roadmarker and a tubular type.
Virginia	Using a square cross-section plastic post. Problem with fiberglass posts because posts break and leave dangerous jagged edges.
West Virginia	Carsonite posts used on West Virginia Turnpike.

TABLE 4. COST COMPARISON OF FLEXIBLE AND STEEL POSTS

STATE	COMMENTS
Alabama	Flexible post slightly more expensive.
Arkansas	Flexible post at least twice the cost of steel posts.
Illinois	Flexible posts not cost effective except in high-hit area.
Indiana	Flexible post cost about three times cost of steel post.
Kansas	Cost of flexible post about twice cost of steel post.
Louisiana	Flexible posts costs considerable more.
Mississippi	Cost of flexible post slightly less than steel post used when consider cost of the delineator which is made of high-intensity sheeting and an aluminum plate.
North Carolina	Flexible posts costs about one to two dollars more per post than steel posts.
Texas	Flexible post cost-effective if can withstand five hits.

TABLE 5. PROBLEMS ASSOCIATED WITH FLEXIBLE POSTS

COMMENT
1. Fiberglass post weakened over time by ultraviolet rays and will weaken if bent.
2. Tend to lean giving poor appearance.
3. Problem to drive certain types.
4. Damaged by mowers.
5. When fiberglass posts break, a dangerous jagged edge is left.
6. Problem with installing straight.
7. Heavy truck stopping next to post will make it lean and then can not straighten post.
8. In strong wind, post tend to walk out.
9. Problem with keeping reflective sheeting on some posts.
10. Post will not drive in rocky fill.
11. Damaged by snowplows.

TABLE 6. COMMENTS ON MUTCD CHANGE RELATED TO POST DELINEATORS  
(FHWA DOCKET 83-26, REQUEST III-2)

STATE OR ORGANIZATION	COMMENT
Texas	We concur with the FHWA in the proposed change.
Ohio	We doubt that this would be practical in Ohio, or other snowbelt states. We are presently researching the optimum combination of delineation for highways, but we have not received the results. Therefore, we are inclined to disagree with the proposal until research is completed.
Connecticut	Opposed. Delineators serve a useful purpose during winter conditions; raised pavement markers and painted pavement marking are obliterated during snow conditions. Post-mounted delineators provide the motorist with an unaffected guidance system.
Ohio Section - ITE	We generally concur with the change. But, believe the snowbelt areas should still be required to erect the post delineators.
South Carolina	Concur in general, but we believe clarification should be made to include both recessed markers and markers set on the surface.
Pennsylvania	Disagree. We concur with the recommendation of the National Committee on Uniform Traffic Control Devices that this request be deferred until further research is completed.
National Committee on Uniform Traffic Control Devices	The first opportunity for the Markings Technical Committee to review this request was at its January 12, 1984, meeting. The National Committee requests that FHWA defer action on this item until the National Committee has had the opportunity to formulate a recommendation for submittal to FHWA. (Note: After further review, the National Committee expressed support for the change.)
Arizona	Suggest revising the next to last sentence as follows: "On tangent sections of expressway and freeways not subject to accumulations of snow, raised retroreflective pavement markers may be used to supplement the lane lines in lieu of post delineators to indicate roadway alignment."
California	Support.
North Carolina	We concur with FHWA to amend Section 3D-4 to allow the use of raised pavement markers as a substitute for delineators on tangent sections not subject to snow accumulation.
Minnesota Urban Traffic Engineering Council	MUTEC agrees with the FHWA decision on this request.
Jack Anderson Associates	Support FHWA view.
Washington	Concur. We further suggest that on curves the delineators need only be placed on the side of the road which is on the outside of the curve. Curves, with radii greater than 2,000 feet, should be treated as tangents. Provisions also should be made to allow for using snowplowable markings as a substitute for delineators.
North Dakota	Concurs.
Idaho	Delay until National Committee reviews.
Vermont	We are neutral on this proposed change as it would not be applicable in Vermont.
Oregon	Agree.
Maine	Concur with FHWA conclusions.

TABLE 7. SURVEY OF CONDITION OF POST DELINEATORS\*

DESCRIPTION	NUMBER	PERCENT
Post and Delineator in Good Condition	198	69
Post Straight but No Delineator	23	8
Post Leaning with Delineator	26	9
Post Leaning and No Delineator	10	4
Missing**	29	10

\* Survey of 11 miles in each direction on the Mountain Parkway for a section of the parkway where the post delineators had not been checked for several months.

\*\* The number missing was determined by assuming that, at a spacing of 400 feet, there should be 13 post delineators per mile.

TABLE 8. ACCIDENTS AT INTERSTATE LOCATIONS WITH AND WITHOUT POST DELINEATORS

LOCATION	TIME PERIOD	ACCIDENTS				
		TOTAL	NIGHTTIME	WET-NIGHTTIME	ON CURVE	CURVE-NIGHTTIME
171; MP 47.3-56.6*	07-01-80 to 03-31-82	47	27	2	1	1
	07-01-83 to 03-31-85	71	26	4	3	2
171; MP 56.6-65.9**	07-01-80 to 03-31-82	64	26	5	11	3
	07-01-83 to 03-31-85	49	27	2	13	5

\* Post delineators were present during both time periods.

\*\* Post delineators were present between July 1, 1980 and March 31, 1982 but were removed before July 1, 1983.

TABLE 9. ACCIDENTS BEFORE AND AFTER INSTALLATION OF RECESSED MARKERS AT INTERSTATE LOCATIONS\*

TIME PERIOD	TOTAL ACCIDENTS	NIGHTTIME ACCIDENTS		WET-NIGHTTIME ACCIDENTS	
		NUMBER	PERCENT	NUMBER	PERCENT
Before Installation					
December 1981-November 1982	308	109	35	16	5.2
December 1982-November 1983	306	123	40	17	5.6
After Installation					
December 1984-November 1985	416	133	32	17	4.1

\* Recessed markers were installed on 122 miles of interstate highways (on I 24, I 64, I 65)

TABLE 10. DISTRIBUTION OF CURVES ON THE INTERSTATE SYSTEM

DEGREE OF CURVATURE	NUMBER OF CURVES	LENGTH (MILES)
0.0 - 0.4	444*	523.6
0.5 - 1.4	336	115.8
1.5 - 2.4	175	61.5
2.5 - 3.4	102	28.4
3.5 - 4.4	38	12.4
4.5 - 5.4	5	2.1
5.5 - 6.9	19	2.1

\* There are 444 entries in the first category of curvature that represent either tangent sections or curves of 0.4 degrees or less.



Figure 1. One-Degree Curve.



Figure 2. Two-Degree Curve.



Figure 3. Three-Degree Curve.



Figure 4. Four-Degree Curve.

**APPENDIX**

**ANNOTATED BIBLIOGRAPHY**

Bali, S. G.; McGee, H. W.; and Taylor, J. I.; "State-of-the-Art on Roadway Delineation Systems," Science Applications, FHWA-RD-76-73, May 1976.

Post delineators were one of the delineation treatments included in this report. A conclusion was that increased emphasis should be placed on the use of post delineators on rural two-lane roads. On tangent sections on two-lane rural roads, the post delineators should be placed along the right side at a spacing of 400 feet. The spacing would be closer on winding, hilly roads so that three delineators would be visible at all times. To maintain consistent application, post delineators should be used at all curves over five degrees of curvature having a central angle exceeding 20 degrees. Post delineators were not recommended for use on sections with fixed roadway illumination, and they were not effective in areas with moderate to high ambient light levels.

Bali, S.; Potts, R.; Fee, J. A.; Taylor, J. I.; and Glennon, J.; "Cost-Effectiveness and Safety of Alternative Roadway Delineation Treatments for Rural Two-Lane Highways," Science Applications, FHWA-RD-78-50, April 1978.

This study involved assessing the effect of various delineation treatments on accident rates by analyzing accident data from more than 500 roadway sites in ten states for tangent, winding, and isolated horizontal curve sections on two-lane rural highways. On these two-lane highways, it was found that highways with post delineators had lower accident rates than those without post delineators (in the presence or absence of edge lines).

Creasey, T. and Agent, K. R.; "Development of Accident Reduction Factors," University of Kentucky, Transportation Research Program, Report UKTRP-85-6, March 1985.

A literature review and survey of states was conducted to identify reduction factors used for various types of safety improvements. One category was delineation with delineators as a subcategory. The recommended reduction factors for post delineators was a 20 percent reduction in total accidents. Of the many reduction factors observed for delineators, only one dealt specifically with tangent sections. The state of Montana used a 23 percent reduction in accidents for the addition of delineators to tangent sections.

Hoffman, A.; Shideh, S.; and Firth, B.; "Flexible Delineator Post Test Procedures," Federal Highway Administration, Report FHWA-TS-84-225, December 1984.

Simplified test procedures were developed to provide reliable comparative data for evaluation of flexible delineator posts. Current commercial designs were tested. Tests included shear, flexure, tension, and impact at ambient and low temperatures and before and after ultraviolet exposure. It was concluded that the simplified tests can be used in conjunction with field performance data to evaluate performance of new designs/materials.

Niessner, C. W.; "Post Mounted Delineators," Federal Highway Administration, Report FHWA-TS-83-208, July 1983.

Across the nation many road jurisdictions use a variety of reflectorized post mounted delineators. In an effort to evaluate the various types of post delineators, projects were initiated with eight state highway agencies. This report summarized the results of those studies.

The report described the various types of post delineators that were evaluated and includes a discussion on the installation, maintenance, and reflectivity. Accident and cost data also were included in the report.

In general, it was found that the flexible posts are twice as expensive as the standard (U-channel) type delineator post. However, in those areas where the posts are subject to numerous impacts, flexible posts were cost effective to use if they could survive two or more hits.

It was not possible to state that the installation of post delineators, under all conditions, would result in a reduction in the number of run-off-the-road type accidents. The data that were collected indicated a trend toward reducing this type of accident with the installation of post delineators. The test site locations were primarily on two-lane rural roads, although some interchange ramps also were studied.

Stimpson, W. A.; McGee, H. W.; Kiltelson, W. K.; and Ruddy, R. H.; "Field Evaluation of Selected Delineation Treatments on Two-Lane Rural Highways," Voorhees and Associates, Inc., FHWA-RD-77-118, October 1977.

The relationship between traffic performance and accident probability on two-lane rural highways and the effectiveness of various delineation treatments were investigated. Post delineators were one of the treatments included. The roadways were divided according to horizontal alignment and a tangent section was defined as a predominately straight roadway with horizontal curves of three degrees or less. It was determined that post delineators along a basically tangent highway had a negligible effect on mean lateral placement. At isolated horizontal curves, raised pavement markers were preferred over post delineators.

Taylor, J. I. and McGee, H. W.; "Roadway Delineation Systems," National Cooperative Highway Research Program, Report 130, 1972.

A state-of-the-art summary was provided from a review of current practices and the literature. Reported applications of delineation treatments at various geometrical situations were synthesized and evaluated. In the discussion of post delineators, comments included that post delineators provided little delineation during the day, they became ineffective under a constant pole-mounted light source and were not recommended for use on continuous lighted sections of the highway, the reflector effectiveness was reduced when there is a coating of road film or water, and that replacement of damaged delineator and/or posts was a major maintenance item, particularly in heavy snow areas.