

Transportation
Kentucky Transportation Center Research
Report

University of Kentucky

Year 1993

Performance of the Crash Cushion
Attenuating Terminal (CAT) in Traffic
Accidents

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**Research Report
KTC-93-32**

**PERFORMANCE OF THE CRASH CUSHION
ATTENUATING TERMINAL (CAT)
IN TRAFFIC ACCIDENTS**

by

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in cooperation with

**Kentucky Transportation Cabinet
Commonwealth of Kentucky**

and

**Federal Highway Administration
US Department of Transportation**

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December 1993

1. Report No. KTC-93-32		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Performance of the Crash Cushion Attenuating Terminal (CAT) in Traffic Accidents				5. Report Date December 1993	
				6. Performing Organization Code	
7. Author(s) Kenneth R. Agent and Jerry G. Pigman				8. Performing Organization Report No. KTC-93-32	
9. Performing Organization Name and Address Kentucky Transportation Center College of Engineering University of Kentucky Lexington, KY 40506-0043				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No. KYHPR-85-107	
12. Sponsoring Agency Name and Address Kentucky Transportation Cabinet State Office Building Frankfort, KY 40622				13. Type of Report and Period Covered Final	
				14. Sponsoring Agency Code	
15. Supplementary Notes Study Title: Long-Term Monitoring of Experimental Features Prepared in cooperation with US Department of Transportation; Federal Highway Administration					
16. Abstract The objective of this study was to report the results of the continued monitoring of the performance of the Crash Cushion Attenuating Terminal (CAT) in traffic accidents. The documented performance of the CAT system in traffic accidents justifies additional use. A recommended location would be at median piers and bridge abutments in narrow medians. While accidents involving this system should continue to be evaluated, this evaluation results in the conclusion that the CAT system could be classified as operational. The performance of the CAT system indicates a couple of areas which should be addressed. For installations in a raised median, the raised median should be modified so that the back side of the system would be at the proper height. This modification has been designed with changes made at locations on the Western Kentucky Parkway. The amount of translation was not as great as expected. The design of the system should be evaluated to determine if modifications should be made to allow more translation to occur.					
17. Key Words Guardrail Accident End Treatment			18. Distribution Statement Unlimited with Transportation Cabinet Approval		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 23	22. Price

INTRODUCTION

The performance of guardrail end treatments has been a subject of concern to highway engineers for many years. A concentrated effort was begun in the mid 1960's to evaluate guardrail design and recommend warrants for guardrail usage. The first guardrail installations used a blunt end treatment. The blunt end treatment resulted in some severe impacts involving spearing of the vehicle. To eliminate the spearing problem, the end of the guardrail was twisted and anchored to the ground. The problem with this design was that it tended to serve as a ramp such that a number of vehicles rolled over as a result of hitting the turned-down treatment. The first analysis of guardrail accidents in Kentucky, completed in 1976, verified the problems associated with both the blunt and turned-down end treatments (1). Since that study was conducted, many end treatment designs have been used.

A nationwide survey of guardrail end treatment usage was completed by the Kentucky Transportation Research Program in 1983 (2). Generally, the preferred method used to end roadside steel-beam guardrail was to bury the end in a cut slope. However, roadside geometrics prevent this in most instances. When the end could not be buried, either a "breakaway-cable-terminal" (BCT) or turned-down end treatment was generally used with the BCT. The BCT end treatment consists of a rail placed in a 37.5-foot parabola with the end post offset four feet from the back of the rail for the straight section. The first two posts are of a breakaway design.

Guidelines for guardrail end treatment usage were developed and reported in 1983 (2). The recommendation made for guardrail end treatments in Kentucky was that, whenever possible, the approach end of roadside steel-beam guardrail should be buried in a cut slope or anchored into a rock cut. When those end treatments could not be used, either the BCT or a modified turned-down treatment was recommended. The BCT end treatment should be used only when a four-foot flare can be obtained with a 10:1 slope in advance and a sufficient recovery area, not exceeding a 3:1 slope, behind. The first nonbreakaway post should be placed at least 50 feet from the beginning of the point of need.

A modified turned-down design was developed and recommended when conditions for installation of a BCT could not be met (2). This turned-down design consists of a total end-treatment length of 50 feet. The rail is twisted 90 degrees and anchored over the last 25 feet with no posts in that section of rail. The first two posts are breakaway with post spacings of 12.5 feet followed by posts at the regular 6.25-foot spacing. This weakened turned-down end treatment was designed to eliminate the rollover problem. This design was included in Kentucky's Standard Drawings as the Type 7 end treatment.

Four prior studies have reported on the analyses of accidents involving guardrail end treatments in Kentucky (3,4,5,6). The most recent report included an analysis of 67 accidents involving the modified turned-down end treatment (6). The performance of this "weakened turned-down" end treatment showed that continued use was warranted. The rollover problem experienced with the original "stiff" turned-down design was substantially reduced.

Another report dealt with analyses of 232 accidents involving a BCT and 66 accidents involving Kentucky's version of a median BCT (MBCT) (5). The performance of the BCT was satisfactory and the recommendation was made that the BCT should be used where geometrics permit. Where those geometrics are not present, the Type 7 turned-down end treatment was recommended. Results suggested that use of the MBCT design should be eliminated due to its stiffness and problems associated with impacts at shallow angles. This end treatment has been removed as a standard device to shield a vehicle from a median pier.

Kentucky was one of the first states to install BCT's, beginning in 1974. Summaries of the numbers of various end treatments that have been installed are given in Table 1. These are the end treatments which have been included in past accident analyses. Unit prices are also given. Through 1992, the total number of BCT installations included in the Kentucky Department of Highway's summaries of unit bid prices was 6,685. The weighted average cost for each BCT installation was \$495.

Kentucky's version of the median BCT (MBCT) has not been installed in Kentucky as extensively as the BCT. There have been 866 installations at a unit cost of \$624. Kentucky's design for its MBCT utilizes two BCT's joined together at the end section. There appears to be little uniformity nationwide in the types of designs used for MBCT types of end treatments.

Since the first installations in 1985, there have been 5,708 installations of the modified turned-down (Type 7) end treatment at a unit cost of \$443. It should be noted that there have been substantially more installations of the Type 7 end treatment than the BCT in recent years. The Type 7 end treatment has typically been installed on maintenance and other minor reconstruction projects.

Alternatives to the use of the MBCT have been developed with two types installed in Kentucky. These include the Crash Cushion Attenuating Terminal (CAT) manufactured by Syro Steel Company and the Breakmaster System manufactured by Energy Absorption Systems. The CAT end treatment has two versions. One version was originally designated as the Type 8 end treatment and was later changed to a Crash Cushion Type IX-A and is used at the ends of steel beam double-faced guardrails. The second version has been designated as the Crash Cushion Type IX and is used at the ends of a rigid barrier such as a concrete barrier median wall. Both versions are based on the principle of absorbing the energy of the crash vehicle by shredding the metal between slots in the rail element as they telescope. The first

six posts are breakaway. There have been 184 CAT systems installed. The average unit price has been \$4,656 for the Crash Cushion Type IX-A and \$5,932 for the Crash Cushion Type IX.

The Breakmaster System has a design which consists of a framework of W-beam steel guardrail panels which move rearward during head-on impacts and redirects vehicles in side angle impacts. There have been 20 installations of the Breakmaster System at a unit price of \$14,000. It appears that this price for the Breakmaster should be substantially less when used on a larger scale.

The objective of this study was to report the results of the continued monitoring of the performance of the Crash Cushion Attenuating Terminal (CAT) in traffic accidents. This report includes an increased sample of accidents involving a CAT system compared to the 12 accidents reported in a previous report (5).

DATA COLLECTION

Data collection consisted of obtaining information concerning the performance of the CAT in traffic accidents. The data used in a previous report were used as a base (5). The previous data included 12 accidents occurring between August 1989 and March 1991. Additional data were obtained for accidents involving the CAT system through the end of 1993. The data were obtained primarily through contact with highway department personnel. Also, observations were made while traveling throughout the state.

Visual inspection of the guardrail damage resulting from an impact was made when possible. In some instances, the inspection was made after the guardrail was repaired. When the damage could not be inspected, photographs showing the damage were obtained from highway department personnel or from police photographs.

An effort was made to obtain an accident report for each location where an impact had occurred. In some instances, no accident report could be located which could definitely be associated with the end treatment impact. Factors causing problems in identification of these accidents included the lack of an accident diagram or description of the accident and the location of the accidents. If no diagram or detailed description was given on the accident report, it was impossible to determine if the accident involved a collision with a guardrail end treatment. The method of locating the accident was not accurate enough in some cases to determine if the accident was at the location of the end treatment. Evidence also indicated that an accident report was probably not filed in a few of the accidents.

Where possible, photographs were taken to document damage to the end treatment. Repair forms were also obtained when available. The information for each accident was summarized with an evaluation of the performance of the guardrail given if sufficient information was available. The types of information obtained, where available, for each accident is given in Table 2.

End-treatment performance, when it could be determined, was defined as either proper or improper. Impact severity (which involves guardrail damage, vehicle damage, and injury severity) was not used as the criteria for assessing performances. It is possible that the end-treatment could perform properly with severe injuries occurring as a result of other factors such as vehicle size and lack of safety belt usage. Vehicle and guardrail damage may be more related to type and size of vehicle than end-treatment performance. Proper or improper performance was judged based on whether the end treatment performed as designed. An accident report was not essential to judge performance if other sufficient information was available. This information could include an inspection of the damaged end treatment or discussions with the personnel who repaired the end treatment. In addition to end-treatment performance, information concerning vehicle size, impact severity, impact angle, guardrail placement, vehicle action after impact, and end-treatment damage were analyzed. Subjective judgment was used to determine many of those variables. All of the CAT systems were installed in the median.

RESULTS

Data for a total of 34 accidents involving the CAT were identified. The earliest accident date was in August 1989 with data collected through the end of 1993.

As previously noted, sources of information included accident reports, photographs, and repair forms. An accident report was obtained for 23 of the 34 accidents. A repair form was obtained for 11 accidents. Photographs showing damage to the guardrail were either taken during the inspection or located from other sources in all of the accidents. Either the vehicle was inspected or photographs of damage to the vehicle was reviewed in seven accidents. Lists of the accidents giving information concerning the location of the accident and the information available are included in Appendix A.

A summary of data obtained for accidents involving a CAT end treatment is presented in Table 3. Data are included for the Type 8 end treatment, which was later reclassified as a Type IX-A crash cushion, and the Type IX crash cushion versions of the CAT. Of the 33 accidents, 27 involved the Type 8 end treatment or Type IX-A crash cushion used at the end of steel beam double-faced guardrail. They were all placed in the median. The remaining seven involved a Type IX crash cushion used in advance of a median pier.

Twenty-nine of the accidents occurred on the Western Kentucky Parkway. This roadway is a four lane, divided highway having a raised median. The road is a rural parkway having a speed limit of 65 mph. Six of the accidents occurred at the same location.

There were three general types of accidents. One was a head-on impact with the CAT system. This was the most common accident with 16 of this type. A second type would be a sideswipe accident with impact occurring to the side of the system.

There were five accidents of this type. The third type was an impact to the back side of the system. There were 13 accidents of this type. This accident occurred when a driver lost control on a bridge deck and hit the back side of the system provided for traffic in the opposite direction.

Performance was determined for all of the accidents. Proper performance was related to an interpretation of whether the posts broke away as designed with the rail elements telescoping without causing the vehicle to overturn or causing any spearing of the vehicle. Proper redirection of the vehicle was also considered.

Performance was judged to be proper in 28 of the 34 accidents (82 percent). In the six impacts in which performance was judged as improper, three involved a head-on impact in which a vehicle overturned, one involved a head-on impact with substantial penetration of the side of a car, and two involved an impact to the back of the system where the vehicle flipped over the rail.

In seven of the 16 accidents involving a head-on collision, there was no rail translation. In another five accidents there were a few inches of translation. In four accidents there were several feet of translation. In three of these four accidents the vehicle overturned with performance rated as improper. The raised median could have been a factor in two of the accidents where the vehicle overturned.

The extent of the damage to the posts in the 16 accidents involving an impact with the end of the system was analysed. In six of the 16 impacts, only the first wooden post was broken and there was no translation. In another five accidents, the second wooden post was also broken with less than one foot of translation of the 12 gage guardrail at the fourth post occurring in four of these accidents. In the other accident, the vehicle went onto the top of the system. The remaining impacts of this type were the most severe and resulted in breaking three or four of the posts with several feet of translation.

The two accidents in which a vehicle hit the back of a system and flipped over the rail were related to the height of the rail. The raised median resulted in a low guardrail height when the rail was hit from the rear.

Several of the accidents involved a vehicle sliding sideways into the end of the CAT. Typically, the first and sometimes the second wooden post would be broken.

Discussions with the maintenance personnel who repaired the CAT system did not reveal any problems with the repair. Even the most severe impact required only a few hours to repair.

RECOMMENDATIONS

The documented performance of the CAT system in traffic accidents justifies additional use. A recommended location would be at median piers and bridge abutments in narrow medians. While accidents involving this system should continue to be evaluated, this evaluation results in the conclusion that the CAT system could be classified as operational.

The performance of the CAT system indicates a couple of areas which should be addressed. For installations in a raised median, the raised median should be modified so that the back side of the system would be at the proper height. This modification has been designed with changes made at locations on the Western Kentucky Parkway. The amount of translation was not as great as expected. The design of the system should be evaluated to determine if modifications should be made to allow more translation to occur.

TABLE 2. DESCRIPTION OF INFORMATION OBTAINED

VARIABLE	CATEGORY	DESCRIPTION
Vehicle Size	A-L	Full or mid-sized passenger car; full-sized pickup truck; van
	A-S	Compact or sub-compact car; small pickup truck
	A-U	Automobile, size unknown
	SUT	Single-unit truck
	Comb	Combination tractor and semi-trailer
	Unk	Type of vehicle unknown
Impact Severity	S	Impact sufficient to cause heavy or extensive damage to the guardrail, severe damage to the vehicle, and/or injury severity of fatal or incapacitating injury
	N-S	Slight or moderate damage to the guardrail, minor or moderate damage to the vehicle, and/or slight or no injury
Impact Angle	Shal	0 - 15 degrees
	Mod	16 - 45 degrees
	Shp	Over 45 degrees
Guardrail Placement	RHS	Right shoulder (mainline)
	RHS/R	Right shoulder (ramp)
	LHS	Left shoulder (mainline)
	LHS/R	Left shoulder (ramp)
	Gore	Area between roadway split
Median	Area between divided, multilane highway	
Injury Severity (Most Severe Injury)	1	Fatal
	2	Incapacitating injury
	3	Non-incapacitating injury
	4	Possible injury
	5	No injury
Vehicle Action after Impact	STOP	Stopped immediately upon contact
	SP-CW-D	Spun clockwise D number of degrees
	SP-CCW-D	Spun counterclockwise D number of degrees
	OVER	Overturned
	RAMP	Ramped over top or over end of turned down
	BT	Broke through
	SS	Sideswiped guardrail
	RB-L	Rebounded left
	RB-R	Rebounded right
	RB-B	Rebounded back
	SPEAR	Guardrail end speared vehicle
TOP	Went on top of rail past breakaway portion	

TABLE 2. DESCRIPTION OF INFORMATION OBTAINED (continued)

VARIABLE	CATEGORY	DESCRIPTION
End-Treatment Performance	P	End treatment performed as designed
	Imp	Performance other than as designed
End-Treatment Damage	S	Slight deflection of rail; no posts broken
	M	First breakaway post broken
	H	Two breakaway posts broken
	E	Damage past two breakaway posts
Vehicle Damage	1	No damage
	2	Minor damage
	3	Moderate damage
	4	Severe damage
Vehicle Initial Contact Area	1	Front
	2	Right front
	3	Right side
	4	Left front
	5	Left side
	6	Rear

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5. Agent, K. R. and Pigman, J. G.; "Performance of Guardrail End Treatments in Traffic Accidents," Kentucky Transportation Research Program, Report UKTRP-91-1, March 1991.
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TABLE 1. SUMMARY OF INSTALLATIONS BY YEAR (NUMBERS AND UNIT PRICES
TABULATED FROM CONTRACTS AWARDED)

TYPE OF END TREATMENT												
NUMBER							AVERAGE UNIT PRICE (DOLLARS)					
YEAR	BCT	MBCT	TYPE 7	CAT *	**	BM	BCT	MBCT	TYPE 7	CAT *	**	BM
1974	285	2					668	700				
1975	443	98					617	742				
1976	421	63					446	590				
1977	541						423					
1978	229	73					444	545				
1979	350	101					482	574				
1980	244	10					516	680				
1981	160	14					519	657				
1982	498	90					572	636				
1983	462	122					487	631				
1984	180	49					490	622				
1985	197	35	118				484	585	477			
1986	298	71	392				464	549	450			
1987	438	35	742				459	558	450			
1988	369	34	878	21	31		483	595	457	4,600	5,686	
1989	250	19	830	18	52		468	586	438	5,096	6,053	
1990	341	32	821	21	10	20	474	581	446	4,250	6,000	14,000
1991	633	13	1,453	2	16		460	601	430	5,570	5,754	
1992	346	5	474		11		475	570	435		6,255	
ALL	6,685	866	5,708	62	120	20	495	624	443	4,656	5,932	14,000

* CAT Guardrail End Treatment Type 8 or Crash Cushion Type IX-A

** CAT Crash Cushion Type IX

TABLE 2. DESCRIPTION OF INFORMATION OBTAINED

VARIABLE	CATEGORY	DESCRIPTION
Vehicle Size	A-L	Full or mid-sized passenger car; full-sized pickup truck; van
	A-S	Compact or sub-compact car; small pickup truck
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	LHS/R	Left shoulder (ramp)
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	Median	Area between divided, multilane highway
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	3	Non-incapacitating injury
	4	Possible injury
	5	No injury
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	SP-CCW-D	Spun counterclockwise D number of degrees
	OVER	Overtuned
	RAMP	Ramped over top or over end of turned down
	BT	Broke through
	SS	Sideswiped guardrail
	RB-L	Rebounded left
	RB-R	Rebounded right
	RB-B	Rebounded back
	SPEAR	Guardrail end speared vehicle
TOP	Went on top of rail past breakaway portion	

TABLE 2. DESCRIPTION OF INFORMATION OBTAINED (continued)

VARIABLE	CATEGORY	DESCRIPTION
End-Treatment Performance	P	End treatment performed as designed
	Imp	Performance other than as designed
End-Treatment Damage	S	Slight deflection of rail; no posts broken
	M	First breakaway post broken
	H	Two breakaway posts broken
	E	Damage past two breakaway posts
Vehicle Damage	1	No damage
	2	Minor damage
	3	Moderate damage
	4	Severe damage
Vehicle Initial Contact Area	1	Front
	2	Right front
	3	Right side
	4	Left front
	5	Left side
	6	Rear

TABLE 3. CAT END TREATMENT PERFORMANCE

ACC. NUM.	VEH. SIZE	SEV.	IMP. ANG.	GR. LOC	INJ.	VEH. ACT.	END TREAT. PERF.	GR. DAM.	VEH. DAM.	INIT. CONT.
300	Unk	N-S	Shal	Med	Unk	Unk	P	M	Unk	Unk
301	A-S	S	Shal	Med	2	SP-CW-150	Imp	M	4	3
302	A-L	S	Shal	Med	5	RB-R	P	H	4	6
303	A-S	S	Shal	Med	2	RB-R	P	H	4	5
304	A-L	S	Mod	Med	4	RB-R	P	M	4	5
305	Unk	S	Mod	Med	Unk	BT	P	H	Unk	Unk
306	A-L	S	Mod	Med	5	RB-R	P	H	4	1
307	A-L	S	Mod	Med	3	STOP	P	M	4	4
308	A-L	S	Shal	Med	3	OVER	Imp	E	4	1
309	A-L	S	Mod	Med	5	STOP	P	H	3	5
310	A-S	S	Mod	Med	3	OVER	Imp	M	4	4
311	A-S	S	Mod	Med	5	RB-R	P	S	4	4
312	Unk	Unk	Mod	Med	Unk	RB-R	P	H	Unk	Unk
313	A-S	N-S	Shal	Med	3	RB-R	P	M	3	5
314	A-S	S	Shal	Med	3	SP-CW-135	P	E	4	1
315	A-S	S	Shal	Med	3	OVER	Imp	E	4	1
316	Unk	N-S	Mod	Med	Unk	RB-R	P	S	Unk	Unk
317	A-L	N-S	Mod	Med	5	RB-R	P	S	4	1
318	A-L	S	Shal	Med	5	TOP	P	E	3	1
319	A-S	S	Shp	Med	5	SP-CCW-135	P	E	4	1
320	A-L	S	Mod	Med	5	SP-CW-100	P	H	3	2
321	A-L	S	Shal	Med	5	RB-R	P	H	4	4
322	Unk	S	Mod	Med	Unk	RB-R	P	H	Unk	Unk
323	Unk	Unk	Mod	Med	Unk	RB-R	P	M	Unk	Unk
324	Unk	Unk	Mod	Med	Unk	RB-R	P	S	Unk	Unk
325	A-L	S	Mod	Med	2	OVER	Imp	E	4	3
326	A-L	S	Mod	Med	5	TOP	P	H	4	1
327	Unk	S	Mod	Med	Unk	OVER	Imp	E	Unk	Unk
328	Unk	N-S	Mod	Med	Unk	RB-R	P	M	Unk	4
329	A-L	S	Shal	Med	4	TOP	P	E	3	1
330	A-L	S	Mod	Med	4	RB-R	P	E	2	1
331	A-L	S	Mod	Med	4	RB-R	P	E	4	2
332	Unk	N-S	Shal	Med	Unk	STOP	P	M	Unk	Unk
333	Unk	N-S	Mod	Med	Unk	RB-R	P	M	Unk	Unk

APPENDIX A
Location of Accidents and
Available Information

APPENDIX A

**Location of Accidents and
Available Information**

TABLE 3. CAT END TREATMENT PERFORMANCE

ACC. NUM.	VEH. SIZE	SEV.	IMP. ANG.	GR. LOC	INJ.	VEH. ACT.	END		INIT. CONT.	
							TREAT. PERF.	GR. DAM.		
300	Unk	N-S	Shal	Med	Unk	Unk	P	M	Unk	Unk
301	A-S	S	Shal	Med	2	SP-CW-150	Imp	M	4	3
302	A-L	S	Shal	Med	5	RB-R	P	H	4	6
303	A-S	S	Shal	Med	2	RB-R	P	H	4	5
304	A-L	S	Mod	Med	4	RB-R	P	M	4	5
305	Unk	S	Mod	Med	Unk	BT	P	H	Unk	Unk
306	A-L	S	Mod	Med	5	RB-R	P	H	4	1
307	A-L	S	Mod	Med	3	STOP	P	M	4	4
308	A-L	S	Shal	Med	3	OVER	Imp	E	4	1
309	A-L	S	Mod	Med	5	STOP	P	H	3	5
310	A-S	S	Mod	Med	3	OVER	Imp	M	4	4
311	A-S	S	Mod	Med	5	RB-R	P	S	4	4
312	Unk	Unk	Mod	Med	Unk	RB_R	P	H	Unk	Unk
313	A-S	N-S	Shal	Med	3	RB-R	P	M	3	5
314	A-S	S	Shal	Med	3	SP-CW-135	P	E	4	1
315	A-S	S	Shal	Med	3	OVER	Imp	E	4	1
316	Unk	N-S	Mod	Med	Unk	RB-R	P	S	Unk	Unk
317	A-L	N-S	Mod	Med	5	RB-R	P	S	4	1
318	A-L	S	Shal	Med	5	TOP	P	E	3	1
319	A-S	S	Shp	Med	5	SP-CCW-135	P	E	4	1
320	A-L	S	Mod	Med	5	SP-CW-100	P	H	3	2
321	A-L	S	Shal	Med	5	RB-R	P	H	4	4
322	Unk	S	Mod	Med	Unk	RB-R	P	H	Unk	Unk
323	Unk	Unk	Mod	Med	Unk	RB-R	P	M	Unk	Unk
324	Unk	Unk	Mod	Med	Unk	RB-R	P	S	Unk	Unk
325	A-L	S	Mod	Med	2	OVER	Imp	E	4	3
326	A-L	S	Mod	Med	5	TOP	P	H	4	1
327	Unk	S	Mod	Med	Unk	OVER	Imp	E	Unk	Unk
328	Unk	N-S	Mod	Med	Unk	RB-R	P	M	Unk	4
329	A-L	S	Shal	Med	4	TOP	P	E	3	1
330	A-L	S	Mod	Med	4	RB-R	P	E	2	1
331	A-L	S	Mod	Med	4	RB-R	P	E	4	2
332	Unk	N-S	Shal	Med	Unk	STOP	P	M	Unk	Unk
333	Unk	N-S	Mod	Med	Unk	RB-R	P	M	Unk	Unk

APPENDIX B

Description of Accidents Involving the CAT

Accidents Involving the CAT

Number	Description
300	The accident occurred on the Western Kentucky Parkway at milepoint 43.4. No accident report was located. An unknown vehicle was westbound and hit the end of the CAT. The first wood post was broken and pushed back about three feet from its original position. The nose section was bent. There was no damage to the second wooden post with no translation occurring. The inspection was on March 13, 1990.
301	The accident occurred on May 28, 1990 on the Western Kentucky Parkway at milepoint 43.4. A 1981 Volkswagon Jetta was westbound and slid into the end of the CAT with contact occurring at the passenger's door. The impact pushed the bottom of the door about two feet inward. The vehicle rotated clockwise after impact to its final rest position in the median. The first wood post was broken and the nose section bent. There was no damage to the second post and no translation. The driver was not injured while the passenger sustained an "incapacitating" injury.
302	The accident occurred on July 22, 1990 on the Western Kentucky Parkway at milepoint 43.4. A 1974 Mercury Monarch was westbound and the driver lost control on a wet pavement. The vehicle rotated and slid into the end of the CAT with the contact to the rear of the vehicle. The vehicle then rotated counterclockwise to its final rest position in the westbound lanes. The first wood post was broken and pushed back about four feet. The second wood post was partially broken. At the fourth post, there was translation of less than one foot. There was no injury.
303	The accident occurred on September 21, 1990 on the Western Kentucky Parkway at milepoint 43.4. A 1990 Nissan 300 was westbound and slid into the end of the CAT with contact to the driver's side slightly behind the driver's door. The vehicle then rotated counterclockwise back into the westbound lanes and had a sideswipe impact with another vehicle. This impact resulted in the Nissan hitting the CAT system at about the fourth post and being redirected to its final rest position in the westbound lanes. The first two wood posts were broken with the first wood post pushed back about five feet. There was no damage to the third post. There was some translation on the "road" side at the fourth post (about one foot) but none on the median side. The driver sustained an "incapacitating" injury.
304	The accident occurred on August 18, 1989 on the Western Kentucky Parkway at milepoint 77.7. A 1983 Plymouth Reliant was westbound and slid into the end of the CAT with initial contact to the driver's side behind the driver's door. The vehicle then rotated counterclockwise and hit the CAT a second

time at the fifth post before stopping in the median. The driver sustained what was termed as a possible injury. The first wood post was broken with no damage to the second post. The first post was pushed back almost five feet. No translation was noted.

- 305 The accident occurred on the Western Kentucky Parkway at milepoint 129. No accident report was located. The accident scene was inspected on February 21, 1990. An unknown vehicle travelled into the median and hit the CAT system from the rear. The impact occurred between the first and second post. The first post was broken with the second post twisted at the base. The vehicle continued across the median and the opposing lanes.
- 306 The accident occurred on October 9, 1990 on the Western Kentucky Parkway at milepoint 65.7. A 1985 Chevrolet Celebrity slid into the median and hit the side of the CAT between the first and second posts with the front of the vehicle. The first three posts were broken with the rail pushed sideways into the median. The vehicle rotated counterclockwise and hit the CAT again at about the sixth post before coming to a final rest position in the emergency lane. There was no rail translation. The driver was not injured.
- 307 The accident occurred on December 21, 1990 on the Western Kentucky Parkway at milepoint 43.4. A 1983 Chevrolet Camero was westbound and slid into the end of the CAT. The vehicle rotated clockwise into the CAT with impact into the driver's side of the car. The vehicle stopped at the end of the guardrail. Two "non-incapacitating" injuries occurred in the accident. The first wood post was broken with the nose pushed back to the second post. The second post was not damaged and no translation was noted.
- 308 The accident occurred on December 30, 1990 on the Western Kentucky Parkway at milepoint 43.4. A 1987 Chevrolet Cavalier was westbound and slid into the front of the CAT. Impact was to the front of the vehicle. The CAT had not been repaired from a previous accident (Number 307) such that the first post was broken when the impact occurred. This impact broke the second and third posts with about 42 inches of rail translation at the fourth post. There was no damage to the fourth or fifth posts but the sixth post was broken. There were two "possible" injuries noted. A conversation with the passenger revealed that they hit the rail head-on and then the car flipped and landed in the median on its wheels.
- 309 The accident occurred on December 24, 1990 on the Western Kentucky Parkway at milepoint 85.8. A 1988 Volvo 740 was westbound and slid into the median. The vehicle rotated counterclockwise into the median with impact to the passenger's side of the car at the rear wheel. The vehicle stopped at the end of the rail. No injuries were reported. The first two wood posts were broken. There were a few inches of rail translation at the fourth post.

- 310 The accident occurred on March 15, 1991 on the Western Kentucky Parkway at milepoint 132.6. A 1985 Toyota SR5 pickup was eastbound and lost control on an ice covered bridge. The vehicle slid across a raised median and hit the CAT system from the back at the sixth post. The fifth and sixth posts were broken. The pickup then flipped over the guardrail and landed on its top in the westbound lanes. The height of the top of the guardrail on the raised median side was 17 to 19 inches which was a factor in the vaulting of the vehicle. The height of the guardrail next to the westbound lanes was about 26 inches. Two "non-incapacitating" injuries were reported.
- 311 The accident occurred on March 30, 1991 on the Western Kentucky Parkway at milepoint 36.9. A 1990 Ford Ranger pickup was westbound and lost control on an ice covered bridge. The vehicle slid across a raised median and hit the CAT system from the back. The initial impact was behind the CAT system. The vehicle then slid down the rail coming to rest in the median. No posts were broken. One section of rail in the CAT system was bent and replaced. The height of the rail on the median side was 16 to 17 inches but the vehicle was redirected properly.
- 312 The accident occurred on the Western Kentucky Parkway at milepoint 22.1. No accident report has been located. Repairs were made on April 17, 1991. The guardrail was hit from the rear by a vehicle exiting a bridge. Impact was between the third and fourth wooden posts. The second and third wooden posts were broken with damage to the blockout on the first post. From inspection of the damage to the guardrail and the pre-impact and post-impact tiretracks, it appears the vehicle was redirected.
- 313 The accident occurred on October 20, 1991 on KY 4 at milepoint 16.1 in Fayette County. The driver of a 1985 Chevrolet Cavalier fell asleep with impact to the driver's side of the vehicle. An angle impact occurred at the first post. The first post was broken and pushed to the left. The second post was undamaged. Evidence at the scene showed that the vehicle continued forward about 20 feet past impact. There was no rail translation. The driver sustained a "non-incapacitating" injury.
- 314 The accident occurred on February 12, 1992 on the Western Kentucky Parkway at milepoint 76.8. The driver of a 1988 Hyunda Excel GL fell asleep and ran into the end of the rail at an estimated speed of 55 to 65 mph. After the frontal impact, the car then rotated clockwise with a second impact occurring to the driver's door. The maximum crush to the front of the car was about 11 inches. Impact to the front of the car was not to the center of the car. This offset, which was toward the driver's side, resulted in the rotation. There was a maximum crush of about 6 inches to the driver's door. The driver was wearing a seat belt and sustained minor ("non-incapacitating") injuries. Four wooden posts were replaced. There was about 8 feet of translation with an equal amount on both sides of the system.

- 315 The accident occurred on March 4, 1992 on the Western Kentucky Parkway at milepoint 21.9. The driver of a 1990 Chevrolet Geo Prism fell asleep and ran into the end of the rail at an estimated speed of 60 to 65 mph. The car rotated counterclockwise into the roadway and overturned. Four posts were broken with two additional posts shattered. The police report noted damage to 40 feet of guardrail with several feet of rail translation occurring. There was more translation on the roadway side of the rail with translation into the 10-gage rail on the roadway side. The rail on the roadway side buckled while the rail on the median side remained straight. The driver was wearing a safety belt and sustained a "non-incapacitating" injury.
- 316 The accident occurred on the Western Kentucky Parkway at milepoint 36.9. A vehicle crossed into the median and hit the back of the rail between the last two posts. This was a minor impact with one section of rail replaced. No accident report was located. The inspection was conducted on April 5, 1992.
- 317 The accident occurred on March 14, 1992 on the Western Kentucky Parkway at milepoint 85.6. The driver lost control of his vehicle (a 1986 Ford Arrowstar) on a bridge, crossed the median, and hit the rail from the rear. The guardrail redirected the vehicle down the median with no injuries occurring.
- 318 The accident occurred on April 1, 1992 on the Western Kentucky Parkway at milepoint 132.6. A 1980 Chevrolet Impala station wagon had a head on impact with the end of the CAT system at an estimated speed of from 60 to 70 mph. The first post was broken with rail pushed back to the second post which was shattered. The vehicle then vaulted and contacted the rail at the fourth post with final rest at the fifth post. There was no rail translation. There were no injuries. While there was no rail translation, the system did successfully stop the vehicle with no injuries occurring.
- 319 The accident occurred on May 3, 1992 on the Western Kentucky Parkway at milepoint 69.8. A 1985 Nissan pickup swerved to avoid another vehicle and hit the CAT system at an angle between the first and second post at an estimated speed of 55 to 65 mph. The first post was broken and the second post cracked. The vehicle then rotated counterclockwise and came to rest about 15 feet from the initial impact point in the median lane. There was about two inches of rail translation. The unbelted driver was not injured.
- 320 The accident occurred on June 30, 1992 on the Western Kentucky Parkway at milepoint 21.9. The vehicle involved was a 1989 Ford Thunderbird. The driver lost control on and hit the end of the system at an angle. The first post was broken and pushed back about 18 inches and sideways toward the median about one foot. The second post was broken but not pushed back. The third post was undamaged. There was very minor rail translation (one

to two inches) at the fourth post on the median side. Impact was to the right front of the car with the right front tire assembly broken and the tire pointed to the outside of the car. Damage was limited to the right front area of the car. No injury was reported.

- 321 The accident occurred on July 30, 1992 on the Western Kentucky Parkway at milepoint 130.9. The vehicle involved was a 1981 Oldsmobile Cutlass. The left-front tire was flat and the car lost control and ran into the median. The left front of the vehicle hit the side of the CAT system between the first and second posts. The first two wooden posts were broken. The vehicle then rotated back into the roadway. The system was offset toward the median up to the third post. No rail translation was noted. There was no injury.
- 322 The accident occurred on the Western Kentucky Parkway at milepoint 74.5. The impact was at an angle between the first and second wooden posts. The first two posts were broken with the CAT system offset a few inches toward the median. There was no rail translation. No accident report has been located. The inspection was conducted on August 14, 1992.
- 323 The accident occurred on KY 4 (New Circle Road) in Lexington. The impact was to the rear of the CAT system. The vehicle entered the median and hit the system between the first and second posts. The first post was broken and pushed over about one foot opposite the direction of impact. The second post was undamaged. There were tiremarks leading to impact but no debris or evidence of the travel path after impact. No accident report has been located. The inspection was conducted on October 12, 1992.
- 324 The accident was on the Western Kentucky Parkway at milepoint 37. A vehicle crossed the median and hit the CAT system from the rear. The impact was at the third post. There was minor bending of the rail and the post was cracked. The evidence is that the vehicle was redirected. The inspection was conducted on December 28, 1992.
- 325 The accident occurred on January 17, 1993 on the Western Kentucky Parkway at milepoint 132.4. A 1987 Pontiac Sunbird was eastbound. The driver lost control with the vehicle rotating counterclockwise with the driver's side door hitting the end of the CAT system. The first four posts were broken with complete translation of the first slotted rail. The impact was at a slight angle toward the left of the system. The system was offset to the left. The first three posts were broken and pushed to the left and behind the fourth post. There was no translation in the second slotted rail. The vehicle overturned and came to rest in the opposing westbound lanes. The driver received an incapacitating injury.
- 326 The accident occurred on December 1, 1992 on KY 4 at milepoint 17.7 in Fayette County. A 1981 Chevrolet pickup truck lost control on ice on a bridge

and hit the back of the CAT system. The speed of the pickup was estimated as 50 to 60 mph. The first contact was with the 17th post back from the front of the system. The vehicle traveled along the top of the guardrail and came to a stop on top of the guardrail just behind the second post. The 6th, 5th and 3rd breakaway posts were broken. The driver was not injured.

- 327 The accident occurred on the Western Kentucky Parkway at milepoint 11.2 in Caldwell County. The accident site was inspected on February 22, 1993. An unknown vehicle lost control after crossing a bridge and hit the back of the CAT system. The first contact was with the 19th post back from the start of the system. There was contact to the 14th post with no contact again until slight contact at the 9th post. There was major contact at the top of the 6th post with the 5th and 6th posts broken. The first post was also broken. There were gouge marks in the pavement in front of the CAT system. The vehicle hit the back of the system and then ramped onto and over the rail.
- 328 The accident occurred in March 1993 on the Western Kentucky Parkway at milepoint 76.4 in Ohio County. An unknown vehicle hit the back of a CAT system protecting a median pier. Contact started at about the fifth post from the front of the system and extended to about the second post. The posts were not damaged. The evidence indicates the vehicle was redirected and continued.
- 329 The accident occurred on April 5, 1993 on the Western Kentucky Parkway at milepoint 36.8 in Hopkins County. A 1981 Oldsmobile Delta 88 hit the front of the CAT system. The first three posts were broken with damage to the top of the fourth post where the vehicle went on top of the rail. The head on impact resulted in 2 to 2.5 inches of rail translation at the fourth post. The impact speed was estimated on the police report as 50 to 60 mph. The driver was not injured while the front seat passenger sustained a "possible injury".
- 330 The accident occurred on October 9, 1993 on the Western Kentucky Parkway at milepoint 76.5 in Ohio County. A Dodge pickup truck hit the rear of the CAT system with contact between the third and fourth posts. The first three posts were broken with no damage farther back from the end of the system. Damage to the vehicle was listed as minor with two "possible injuries" reported.
- 331 The accident occurred on October 30, 1993 on the Western Kentucky Parkway at milepoint 82.1 in Ohio County. A 1975 Chevrolet Malibu hit the side of the CAT system protecting a median pier. Contact was around the second wooden post. All six wooden posts were broken with the end of the system pushed from the median into the opposing lane. There was no rail translation. Damage extended to the first metal post. The vehicle stopped in the median adjacent to the CAT system. The speed of the car was estimated at 60 to 70 mph with a "possible injury" listed.

332 The accident site was inspected on November 30, 1993 on the Mountain Parkway at milepoint 18.5 in Powell County. An unknown vehicle hit the end of the system. The first post was broken with no damage for the second post. The evidence is that the vehicle stopped at the end of the system after breaking the first post. The first post was pushed back about four feet and about 1.5 feet to its left. There was no rail translation.