Research Report
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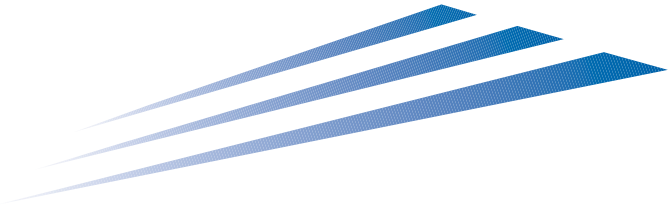
EVALUATION OF THE ET2000 GUARDRAIL END TREATMENT



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EVALUATION OF THE ET2000 GUARDRAIL END TREATMENT

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in cooperation with
Kentucky Transportation Cabinet
Commonwealth of Kentucky

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TABLE OF CONTENTS

LIST OF TABLES

EXECUTIVE SUMMARY

The objective of this study was to report the results of the monitoring of the performance of the ET2000 guardrail end treatment in traffic crashes. This end treatment has an energy absorbing design in which a vehicle will push a guardrail extruder back as posts designed to break away are broken. The W-beam guardrail is flattened as it goes through the extruder and exits a slot away from traffic.

Data for a total of 135 collisions involving the ET2000 were identified. A crash report was obtained in the majority of crashes and the damaged guardrail was inspected in almost all cases. The involved vehicle was inspected when available. Proper or improper performance of end treatments in the collisions were judged, when a police report was available, based on whether it performed as designed.

Field performance of the ET2000, as documented in traffic crashes, shows that, considering all the impacts, this end treatment has performed properly. In some instances the end treatment bent, rather than being pushed straight back, during the collision. This could typically be related to the angle at which the impact occurred.

Results warrant continued use of this type of end treatment. However, its cost compared to other end treatments would not justify a widespread use on all types of highways.

1.0 INTRODUCTION AND BACKGROUND

The performance of guardrail end treatments has been the subject of investigation for many years. The performance of end treatments can be evaluated either with crash tests and by monitoring the results of crashes involving the installed end treatments.

The first guardrail installations used a blunt end treatment. Blunt end treatments resulted in some severe impacts involving spearing of the impacting vehicle. To eliminate the spearing problem, a design was developed in which the end of the guardrail was twisted and anchored to the ground. A problem with this design was that, in some instances, vehicles ramped up the end and rolled over when they collided with the turned-down treatment. The first analysis of guardrail crashes in Kentucky, completed in 1976, verified 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 at that time 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.

The 1983 report included guidelines to consider for the type of end treatment to use for roadside steel beam guardrail (2). The recommendation made, at that time, for guardrail end treatments in Kentucky was that, whenever possible, the approach end of the 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 modified turned-down design (Kentucky's Standard Drawing Type 7 end treatment) was developed and recommended when conditions for installation of a BCT could not be met. This weakened turned-down end treatment was designed to eliminate the rollover problem.

Six additional studies have reported on the analysis of crashes involving various types of guardrail end treatments in Kentucky (3, 4, 5, 6, 7, 8). The most recent report included an analysis of 34 collisions involving the ET2000 end treatment with the end treatment found to perform properly. One previous analysis was of 34 crashes involving the Crash Cushion Attenuating Terminal (CAT) (7) which is Kentucky's crash cushion Type IX or IX-A. The crash experience involving the CAT showed it performed properly in most collisions with continued use recommended at locations such as median piers and bridge abutments in narrow medians.

One of the prior reports analyzed 67 crashes involving the modified turned-down end treatment (6). The rollover problem associated with the original "stiff" turned-down design was substantially reduced with this "weakened turned-down" design. The performance indicated continued use was warranted. Use of this end treatment has continued but limited to certain road types. For example, it is not used on the interstate system.

The most recent report involving the BCT end treatment included an analysis of 232 crashes involving the BCT and 66 involving Kentucky's version of the 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. A modified version of the BCT is currently used. The analysis of impacts with the MBCT resulted in its removal as a standard device (due to its stiffness and problems associated with impacts at shallow angles).

The objective of this study was to report the results of the continued monitoring of the performance of the ET2000 in traffic crashes since the previous report (8). The ET2000 guardrail end treatment (Kentucky Department of Highways End Treatment Type 1) is used with standard W-beam guardrail. Its intended use has been at fills where an adequate vehicle recovery zone exists behind the guardrail. It has an energy absorbing design in which a vehicle will push a guardrail extruder back as posts designed to break away are broken. The W-beam guardrail is flattened as it goes through the extruder and exits from a slot which is on the side away from the flow of traffic. In Kentucky's design, eight breakaway posts are included at a 1:66 taper resulting in a total end treatment length of 50 feet.

Summaries were made of the numbers and cost of ET2000 (guardrail end treatment Type 1) installations from the first installation in 1995 through 2002. Following is a list of the number installed each year along with the average unit price.

Year	Number	Unit Cost ($)
1995	48	3,492
1996	96	2,892
1997	260	2,263
1998	58	2,950
1999	199	2,274
2000	98	2,723
2001	55	2,770
2002	72	2,400

The data show there were 886 installed in these eight years with an average cost of $2,644. This cost was compared to the average unit cost of some of the other common end treatments for the period of 1996 through 2002. The average unit cost was $1,394 for 1,057 installations of the modified breakaway cable terminal (end treatment type 4A), $583 for 1,036 installations of the modified turn down (end treatment type 7), and $507 for end treatment type 3 where the end flairs back to the slope. The average unit cost of the original breakaway cable terminal was about $500 (8).

2.0 DATA COLLECTION

Data collection consisted of obtaining information concerning performance of the ET2000 in traffic crashes. Much of the information concerning crashes involving a collision with an ET2000 was obtained through contact with highway department personnel. Also, observations were made while traveling throughout the state. Information were obtained for collisions from August 1995 through December 2003.

Visual inspection of the guardrail damage resulting from an impact was made in most cases. In a few instances, the inspection was made after the guardrail was repaired. When damage could not be inspected, photographs showing the damage were obtained. The vehicle which hit the guardrail was inspected when possible.

An effort was made to obtain a crash report for each instance where an impact had occurred. In many instances, no crash report could be located which could definitely be associated with the end treatment impact. Factors causing problems in the ability to identify the related crash reports included both the lack of a diagram or description of the crash on the report and the lack of adequate location information. Evidence also indicated that a crash report was probably not filed for several of the minor impacts.

Available information for each crash was summarized. Evaluation of guardrail performance was made when the crash report was available. The types of information obtained, when available, for each crash is given in Table 1.

End-treatment performance was defined as either proper or improper. Impact severity (which involves guardrail damage, vehicle damage, and injury severity) was not used as the primary criteria for assessing performance. It is possible that the end treatment could perform properly with severe injuries still occurring as a result of other factors such as lack of safety belt usage and vehicle size. Vehicle and guardrail damage may be more related to the type and size of the impacting vehicle than end-treatment performance. Proper or improper performance was judged based on whether the end treatment performed as designed. A crash report would not be 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. However, since a large number of crash reports were available, proper performance was only evaluated in this study when a crash report was located.

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 some of those variables. All of the ET2000 systems were installed on the shoulder of the roadway.

3.0 RESULTS

A total of 135 collisions involving the ET2000 were identified with varying amounts of data available. The earliest date of a collision was in August 1995 with latest collision occurring in December 2003.

A crash report was located in 80 of the 134 collisions. Photographs showing damage to the guardrail were either taken during the inspection or located from other sources in 128 of the collisions. Damage to the vehicle was documented through inspection or photographs in 21 of the crashes. A list of the crashes giving information concerning the location of the crash and the information available is given in Appendix A.

All but seven of the crashes occurred on an interstate or parkway. The largest numbers of collisions were 27 on the Western Kentucky Parkway, 23 on the Pennyrile Parkway, 20 on Interstate 75, and 16 on Interstate 275. All the crashes were in rural areas. Given the location and type of highway, the collisions typically involved high speed impacts.

A summary of data obtained for crashes involving an ET2000 end treatment where a crash report was located is presented in Table 2. The large majority of the collisions involved an impact between the front of a vehicle and the end of the guardrail. The exception was when the vehicle rotated prior to impact resulting in an impact with the side of the vehicle. Most of the collisions involved a passenger car colliding with the end treatment at a shallow angle. In almost all cases, the guardrail was located on the right-hand shoulder.

There was no reported injury in about one-half of the 80 crashes where a police report was located. An incapacitating injury was noted in 12 crashes. There was one crash in which a fatality occurred but the fatal injury was not related to the guardrail impact.

The most common actions of the vehicle after impacting the end treatment were to rebound, break through, or stop at the end of the extruded rail.

The length of guardrail extruded was measured. This length varied from none to almost 90 feet in a collision involving a combination truck. The average length of extrusion in the 73 crashes in which it was known that an automobile or pickup hit the end treatment was 11 feet with a range of none to 35 feet. About three-fourths of the crashes resulted in breaking at least three posts.

Sufficient information was available to rate performance in the collisions where a police report was located. Proper performance was related to an interpretation of whether the guardrail extruded and the posts broke away as designed without causing the vehicle to overturn or causing any spearing of the vehicle. Proper redirection was also considered.

Performance was judged to be proper in 70 of 80 of the collisions (88 percent) where a police report was located. This percentage is very close to that found in the previous ET2000 evaluation (8). Seven of the ten impacts in which performance was judged as improper involved a vehicle overturning after hitting the end treatment. One crash involved a vehicle rotating and the rail bending such that there was intrusion into the occupant compartment. In one crash the vehicle rebounded back into the interstate with a secondary collision occurring. The other crash with improper performance involved no extrusion although several posts were broken. In several other instances which were rated as proper, the guardrail was bent around a post at the end of its extrusion rather than being pushed completely straight back as it was extruded. This was typically the result of the angle of the impact. However, this did not prevent the performance from being rated as proper if no adverse results occurred.

Descriptions of several of the crashes where a police report was found are given in Appendix B. These examples show that the ET2000 has been effective in crashes involving various types of vehicles.

4.0 CONCLUSIONS

The field performance of the ET2000 as documented in traffic crashes shows that, considering all the impacts, this end treatment has performed as designed. In some instances, the guardrail bent along a post at the end of its extrusion, rather than being pushed completely straight back, during the collision. This could typically be related to the angle at which the impact occurred and has not caused a significant problem with performance.

The results document the proper performance of this end treatment in traffic crashes and warrant continued use of the ET2000. However, its cost compared to other end treatments would not justify a widespread use on all types of roadways.

5.0 REFERENCES

1. Agent, K. R. “Guardrail Performance: An Analysis of Accident Records,” Kentucky Department of Transportation, Division of Research, Report 442, March 1976.

2. Pigman, J. G. and Agent, K. R., “Survey of Guardrail End Treatment Usage,” Kentucky Transportation Research Program, Report UKTRP-83-23, October 1983.

3. Pigman, J. G.; Agent, K. R.; and Creasey, T.; “Analysis of Accidents Involving Breakaway-Cable-Terminal End Treatments,” Kentucky Transportation Research Program, Report UKTRP-84-16, June 1984.

4. Pigman, J. G. and Agent, K. R.; “ Performance Evaluation of Breakaway-Cable-Terminal End Treatments,” Kentucky Transportation Research Program, Report UKTRP-87-14, June 1987.

5. Agent, K. R. and Pigman, J. G.; “Performance of Guardrail End Treatments in Traffic Accidents,” Kentucky Transportation Center, Report KTC-91-1, March 1991.

6. Agent, K. R. and Pigman, J. G.; “Performance of a Modified Turned-Down Guardrail End Treatment in Traffic Accidents,” Kentucky Transportation Center, Report KTC-92-11, August 1992.

7. Agent, K. R. and Pigman, J. G.; “Performance of the Crash Cushion Attenuating Terminal (CAT) in Traffic Accidents,” Kentucky Transportation Center, Report KTC-93-32, December 1993.

8. Agent, K.R.; Pigman, J.G.; McAlister, D; and Gatewood, T.; “Evaluation of the ET2000 Guardrail End Treatment,” Kentucky Transportation Center, Report KTC-97-25, December 1997.

TABLE 1. 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 truck
	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 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
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 by guardrail
	SP-CW-D	Spun Clockwise D number of degrees past guardrail
	SP-CCW-D	Spun Counterclockwise D number of degrees past guardrail
	BT	Broke through
	OVER	Overturned
	RB-L	Rebounded left
	RB-R	Rebounded right
End Treatment Performance	P	End treatment performed as designed
	Imp	Performance other than as designed
End-Treatment Damage	S	No posts broken
	M	One or two breakaway posts broken
	H	Three to four breakaway posts broken or damaged
	E	Damage past four breakaway posts
Vehicle Damage	1	Minor damage
	2	Moderate damage
	3	Severe damage
Vehicle Initial Contact Area	1	Front
	2/3	Right side/Left Side
	4	Rear

APPENDIX A

Location of Crashes and Available Information

APPENDIX B

Appendix B. Description of Selected Crashes

Crashes Involving the ET 2000

Number	Description
1	The crash occurred on August 8, 1995 in Christian County on the Pennyrile Parkway southbound at milepoint 16.4. The guardrail was on the right-hand shoulder. This was a single vehicle crash involving a 1995 Mitsubishi Galant. The front of the vehicle struck the extruder head approximately one foot from the driver's side at a shallow angle. The police report noted that the driver fell asleep and his vehicle drifted out of his lane of travel hitting the guardrail at an estimated speed of 60 to 70 mph. There was no intrusion into the occupant compartment. The driver, who was the only occupant, was using a safety belt with a "possible injury" code listed. Approximately 15 feet of guardrail was extruded before the remaining guardrail buckled and twisted. Five wooden posts were broken. After impact, the vehicle broke through the guardrail with its final rest position in the ditch line behind the guardrail about 120 feet past the first post. After impact, the vehicle rotated counterclockwise but did not roll.
4	The single vehicle crash occurred on October 30, 1995 in Kenton County on Interstate 275 eastbound at exit 79 (near milepoint 80) . The guardrail was on the right-hand shoulder. The vehicle was a 1985 full size Chevrolet pickup. The vehicle struck the guardrail on the extreme right front of the pickup at a shallow angle. The report noted that the driver was intoxicated and evidently passed out. The vehicle collided with the guardrail at an estimated speed of 55 to 60 mph. The driver was using his seat belt and complained of neck and shoulder pain. About 8.5 feet of the guardrail was extruded. The first two posts were broken off with the third post cracked. The extruder head was pushed straight back with no kinking of the guardrail.
5	The single vehicle crash occurred on October 26, 1995 in Fayette County on Interstate 75 southbound at milepoint 109.6. The guardrail was on the right-hand shoulder. The vehicle was a Buick Century. The driver advised he started to take an exit ramp but realized he should continue on the interstate and hit the guardrail while attempting to merge back onto the interstate. The driver's estimated impact speed was 45 to 55 mph. The driver was not injured with a non-incapacitating injury listed for the front seat passenger. The extruder head was pushed straight back to the third post with the first two posts broken. About 13 feet of rail was extruded.

Number	Description
7	The single vehicle crash occurred on December 13, 1995 in Kenton County on Interstate 275 at milepoint 79. The guardrail was on the right-hand shoulder. The vehicle was a 1993 Ford Tempo. The vehicle hit the guardrail at an estimated speed of 45 to 50 mph and rebounded back into the road. Four posts were broken off with about 13.5 feet of rail extruded. There was no reported injury.
9	The single vehicle crash occurred on February 12, 1996 in Christian County on the Pennyrile Parkway southbound at milepoint 16.4. The guardrail was on the right-hand shoulder. The vehicle was a 1992 Chevrolet S10 pickup truck. The driver was traveling at an estimated speed of 50 to 70 mph when he swerved to avoid a deer and hit the guardrail end with the right front of the vehicle. The pickup broke through the end while rotating clockwise to a final rest position behind the guardrail. Seven posts were broken with about seven feet of extruded rail. The rail bent as it was pushed back and a portion of the buckled rail intruded into the driver's door. The driver sustained "incapacitating" injuries.
10	The single vehicle crash occurred on April 6, 1996 in Kenton County on Interstate 275 eastbound at milepoint 78. The guardrail was on the right-hand shoulder. The driver was traveling at an estimated speed of 45 to 50 mph when he swerved to miss another vehicle and hit the guardrail. The vehicle was a 1988 Mazda Cosmo. The right front of the car hit the end of the guardrail and the vehicle then broke through the rail coming to a final rest behind the rail. Seven posts were broken with about 35 feet of rail extruded. The driver, who was the only occupant, was reported to have sustained "non-incapacitating" injuries.
12	The single vehicle crash occurred on June 15, 1996 in Kenton County on Interstate 275 westbound near milepoint 78. The guardrail was on the exit ramp to KY 16. The vehicle was a Toyota Tercel. The driver indicated he lost control due to a tire failure. The car rotated with the initial contact near the right rear tire. The car then rotated clockwise with the right front contacting the guardrail. The first two posts were broken with about seven feet of guardrail extruded. There was additional damage to other posts resulting from the vehicle rotation. The driver, who was the only occupant, was not injured.

Number	Description
13	The single vehicle crash occurred on June 23, 1996 in Kenton County at the exit ramp from westbound Interstate 275 to US 25. The guardrail was on the right-hand shoulder. The vehicle was a 1995 Toyota Corolla. The driver states she was distracted and over steered to her right. Her estimated speed was 45 to 50 mph. The impact was to the right front of the car. The driver had minor cuts but refused medical attention. Three posts were broken with an estimate that about 20 feet of rail was extruded. The end was pushed straight back with no bending of the rail.
14	The single vehicle crash occurred on August 12, 1996 in Kenton County on Interstate 275 eastbound at Exit 79. The guardrail was on the right-hand shoulder. The vehicle was a combination, five-axle tractor trailer. The driver stated the truck pulled to his right and he lost control with the front of the truck hitting the guardrail. About 200 feet of guardrail was damaged with about 90 feet of rail extruded. There were no reported injuries.
15	The single vehicle crash occurred on October 20, 1996 in Henderson County on the Pennyrile Parkway at milepoint 67.4. The guardrail was on the right-hand shoulder. The vehicle was a 1990 Ford Ranger pickup. The driver stated he fell asleep allowing his vehicle to drift into the guardrail. His estimated speed was 65 to 70 mph. A witness stated the pickup passed him and then continued to the right across the shoulder after completing the passing maneuver. The vehicle then rebounded to the left with its final rest position in the median. Impact was to the right front of the pickup. Six posts were broken with the extruded head pushed straight back and about 30 feet of rail extruded. The driver was thrown into the windshield and sustained a “non-incapacitating” injury.
23	The single vehicle crash occurred in April 1997 in Laurel County on Interstate 75 northbound at milepoint 42.3. The guardrail was on the right-hand shoulder. The vehicle was a 1991 Oldsmobile Cutlass. The driver lost control when he attempted to avoid an object in the road. His estimated speed was 60 to 65 mph with deceleration evident prior to impact. The vehicle rotated prior to hitting the guardrail end with the passenger side of the car. The extruder head was pushed straight back with the first three posts broken and about seven feet of rail extruded. The car rebounded from the impact to its final rest position off the shoulder. No injury was reported.

Number	Description
25	The single vehicle crash occurred on June 15, 1997 in Shelby County on westbound Interstate 64 at milepoint 24.1. The vehicle was a 1985 GMC van. The vehicle ran off the right side of the road, broke through the guardrail and then overturned. About 26 feet of rail was extruded. There were two “possible” injuries listed.
27	The single vehicle crash occurred on June 30, 1997 in Laurel County on Interstate 75 southbound at milepoint 33.3. The guardrail was on the left-hand shoulder. The vehicle was a 1992 Dodge Daytona passenger car. The driver lost control on wet pavement at an estimated speed of 35 to 45 mph. Impact was to the left front of the car with the car rotating slightly counterclockwise to its final rest position adjacent to the guardrail on the shoulder. The first three posts were broken with about 14 feet of rail extruded. The belted driver was not injured while the unbelted front seat passenger sustained injuries.
28	The crash occurred on August 14, 1997 in Henderson County on US41. The vehicle was a 1987 Mercury Cougar. The vehicle ran off the right side of the road at a shallow angle with impact to the left front of the car. The vehicle then continued down an embankment into a parking lot. The estimated speed was 55 to 60 mph. Approximately four to five feet of rail was extruded. There were no reported injuries.
29	The crash occurred on October 12, 1997 in Christian County on the Pennyrile Parkway at milepoint 14.5. The guardrail was on the right-hand shoulder. The vehicle was a 1990 Ford Econoline 150 van. The driver stated he looked away from the road before hitting the guardrail at an estimated speed of 50 to 60 mph. Impact was to the middle of the front of the van. The eight wooden posts were broken with major damage to the rail for about 44 feet. Contact extended to the start of the metal posts (50 feet from the end) with about 17 feet of rail extruded. The van ran over the rail with its final rest behind the rail over 200 feet from the impact area. An unbelted passenger in the van sustained a reported incapacitating injury.
30	The crash occurred in September 1997 in Barren County on northbound I 65 at milepoint 48.1. The vehicle was a 1992 Honda Accord. The driver lost control on wet pavement with the passenger side rear rotating off the right side of the road hitting the end of the guardrail. The first two posts were broken with the guardrail bent around the third post. About four feet of rail was extruded. The vehicle rotated and the right front of the vehicle contacted the outside of the guardrail at the fifth and sixth posts. The vehicle came to rest in the northbound lanes.

Number	Description
34	The crash occurred on January 5, 1998 in Christian County on the Pennyrile Parkway northbound at milepoint 27.1. The guardrail was on the right-hand shoulder. The vehicle was a 1992 Pontiac Sunbird. The estimated impact speed was 55 to 60 mph. The impact was to the right front of the vehicle with the car coming to rest in the median. The first post was broken with the blockout twisted on the second and third posts. The guardrail was pulled away from the fourth and fifth posts. About 10 feet of rail was extruded. There were no reported injuries.
35	The single vehicle crash occurred on February 5, 1998 in Henderson County southbound on the Pennyrile Parkway at milepoint 75.2. The vehicle was a 1997 Dodge Neon. The driver stated he was traveling at a speed of 45 to 55 mph when he lost control on snow and slid into the guardrail. There was moderate damage to the front of the car. About 8.5 feet of rail was extruded. The driver reported a possible injury.
36	The single vehicle crash occurred on January 20, 1998 in Shelby County on westbound Interstate 64 at milepoint 31. The vehicle was a single unit, two axle truck. The driver stated he was traveling at a speed of 60 to 65 mph when he fell asleep and drifted off the right side of the road. There was moderate damage to the right front of the truck, and it was driven from the scene. Approximately 17.5 feet of rail was extruded. There were no reported injuries.
39	The single vehicle crash occurred on May 13, 1998 in Christian County on the Pennyrile Parkway southbound at milepoint 15. The vehicle was a 1994 Ford Ranger pickup. The driver fell asleep, drifted off the road, and hit the end treatment with the right front of the pickup. The pickup rolled with its final rest position partially on the road and partially on the shoulder. Approximately 10 posts were damaged with major extrusion (over 10 feet) of rail occurring.
42	The single vehicle crash occurred on November 3, 1998 in Hopkins County on the Western Kentucky Parkway westbound at milepoint 30.8. A 1993 Chevrolet 1500 pickup ran head on into the end treatment. The driver was interviewed and estimated the impact speed as about 50 mph. There was about 15 inches of crush to the front of the pickup. There were four posts broken, three posts pulled out of the ground, and one post bent with six feet of rail extruded. The vehicle broke through the rail and went behind the guardrail.

Number	Description
43	The single vehicle crash occurred on October 8, 1998 in Christian County on the Pennyrile Parkway southbound at milepoint 24. The front of a 1993 Ford Escort hit the end of the guardrail in a head on impact at an unknown speed. The car came to rest in the middle of the adjacent lanes. There were no reported injuries. Four posts were broken with 15 to 20 feet of rail extruded.
47	The single vehicle crash occurred on May 4, 1999 in Christian County on the Pennyrile Parkway southbound at milepoint 16.1. The driver of a 1997 Ford F150 pickup fell asleep with the front of the pickup hitting the end of the guardrail at an estimated speed of 65 to 70 mph. The vehicle rotated clockwise 180 degrees with its final rest position at the end of the guardrail. The rail was damaged to a point 57 feet from the front of the rail with about 33 feet of rail extruded. There were two reported injuries.
50	The single vehicle crash occurred on May 8, 1999 in Grayson County on the Western Kentucky Parkway westbound near milepoint 94. The driver of a 1995 Toyota Tacoma pickup fell asleep with the front of the pickup hitting the end of the guardrail head on. The impact broke seven posts and pushed the end straight back about 34 feet. The impact speed was estimated at about 65 mph. There was no reported injury.
55	The single vehicle crash occurred on November 24, 1999 in Anderson County on the Bluegrass Parkway. The driver of a Chrysler passenger car lost control while avoiding an animal. The end of the rail was pushed straight back while breaking three posts and extruding 14 feet of rail. There were no reported injuries.
61	The single vehicle crash occurred on April 2, 2000 in Christian County on the Pennyrile Parkway southbound near milepoint 27. The driver of a 1998 Chevrolet Blazer lost control at an estimated speed of 60 to 70 mph. There was a head on impact with the end of the guardrail with the final rest position at the end of the rail. Several posts were broken with 29 feet of rail extruded. There was one reported injury.
69	The single vehicle crash occurred on March 6, 2001 in Fayette County on westbound Interstate 64 at milepoint 83.7. The driver of a loaded tractor trailer was traveling at an estimated speed of 70 to 75 mph when the right side of the truck left the road. The driver overcorrected as he attempted to return to the road. The truck overturned with the driver, who was ejected, sustaining a fatal injury. The truck slid into the guardrail as it overturned. Numerous posts were broken with about 32 feet of rail extruded. The fatal injury was not related to the guardrail impact.

Number	Description
75	The single vehicle crash occurred on April 20, 2001 in Powell County on the Mountain Parkway westbound at milepoint 13.2. The driver of a 1991 Chevrolet Lumina fell asleep and traveled off the right side of the road. Eight posts were broken with about 23 feet of rail extruded. The vehicle continued past the guardrail with its final rest position about 250 feet past the original impact point at the guardrail end. There were no reported injuries.
81	The single vehicle crash occurred on June 30, 2001 in Fayette County on Interstate 75 southbound at milepoint 109.4. The crash was on an exit ramp from I 75 to US 60. A vehicle forced a 1999 Chevrolet Cavalier into the end of the guardrail. The first post was broken with the second post pushed back slightly. The guardrail was bent between the second and third posts. About six feet of rail was extruded. Tire marks indicate the vehicle stopped at the end of the guardrail.
85	The single vehicle crash occurred on October 23, 2001 in Whitley County on Interstate 75 southbound at milepoint 18.3. The driver of a 1998 Volvo combination five-axle truck stated he was in the left lane when another truck changed lanes and he swerved to the median to avoid an impact. The truck hit the end of the rail and pushed the extruder head straight back about 20 feet. The first four posts were broken. The final rest position of the truck was behind the guardrail. There was no reported injury.
87	The single vehicle crash occurred on December 29, 2001 in Grayson County on the Western Kentucky Parkway eastbound at milepoint 96. The driver of a 1993 Jeep Cherokee lost control on wet pavement. The vehicle hit the end of the rail with four posts broken and the guardrail separated from the next three posts. About 7.5 feet of rail was extruded. The final rest position of the vehicle was behind the rail. There was a major bend in the rail at the fifth post. The driver reported a possible injury.
88	The single vehicle crash occurred on May 28, 2001 in Hopkins County on the Pennyrile Parkway northbound at milepoint 33.9. A 1989 Chevrolet S10 pickup was involved with the impact to the left front of the pickup. The extruder was pushed straight back with 20 to 25 feet of rail extruded and five posts broken. There were three occupants in the pickup with all reporting possible injuries.

Number	Description
89	The single vehicle crash occurred on December 2, 2001 in Shelby County on Interstate 64 eastbound at milepoint 30.7. The driver of a 1995 Saturn SL passenger car stated he fell asleep with a speed estimate of 50 to 55 mph. The front of the vehicle hit the end of the rail with four posts broken and the extruder pushed straight back to the fifth post and 25 feet of rail extruded. There was no reported injury.
91	The single vehicle crash occurred on July 28, 2001 in Powell County on the Mountain Parkway westbound at milepoint 13.4. The driver of a 1999 Chevrolet 1500 pickup lost control on wet pavement with the right front of the pickup hitting the rail as it proceeded off the right shoulder. All eight wooden posts were broken with the first metal post bent. There was about 22 feet of rail extruded. The restrained driver was not injured while the restrained passenger reported a possible injury.
95	The single vehicle crash occurred on January 10, 2002 in Fayette County on Interstate 75 northbound at milepoint 102.9. The driver of a 2001 Chevrolet S10 pickup lost control on wet pavement when he swerved to avoid a vehicle which changed lanes into his path. The pickup rotated clockwise with the driver's side of the pickup hitting the end of the guardrail. The extruder head was pushed straight back to the fourth post with about 20 feet of rail extruded. The estimated speed was 70 to 76 mph. The driver, who was the only occupant, sustained a non-incapacitating injury.
98	The single vehicle crash occurred on February 2, 2002 in Christian County on the Pennyrile Parkway northbound at milepoint 23. The driver of a 1998 Chevrolet Monte Carlo fell asleep with the front of the car hitting the extruder head at a shallow angle. The vehicle rotated counterclockwise behind the guardrail and rolled to a final rest position about 110 feet past the initial impact area. Five wooden posts were broken with the extruder head pushed straight back with about 20 feet of rail extruded. Non-incapacitating injuries were reported for the three occupants.
101	The single vehicle crash occurred on April 21, 2002 in Boone County on Interstate 275 westbound at milepoint 1.5. The driver of a 1996 Pontiac Sunfire ran off the left shoulder and then overcorrected and crossed all lanes hitting the guardrail on the right shoulder. The estimated speed was 55 to 65 mph. Three posts were broken with the guardrail bent at the location of the third post. The rail was pushed toward the ditch indicating that the vehicle traveled behind the rail. Only about 1.5 feet of rail was extruded. There were no reported injuries.

Number	Description
103	The single vehicle crash occurred on June 4, 2002 in Lyon County on the Western Kentucky Parkway westbound at milepoint 3.6. The driver of a 1990 Honda Prelude fell asleep with the front of the car hitting the end of the guardrail at a shallow angle. An impact speed of 75 to 80 mph was estimated. The driver, who was restrained, sustained a non-incapacitating injury. About eight posts were broken with about five feet of rail extruded. The car rotated and stopped at the end of the damaged section of guardrail.
104	The single vehicle crash occurred on July 18, 2002 in Madison County on Interstate 75 northbound at milepoint 88.2. The driver of a 1994 Geo Metro stated he was going straight ahead when his car suddenly veered off to the right hitting the guardrail with the front of the vehicle. Four posts were broken with the end pushed straight back. About 18 inches of rail were extruded. The evidence showed the final rest position of the car was in the gravel area behind the final position of the end of the guardrail. The driver reported incapacitating injuries.
109	The single vehicle crash occurred on January 22, 2003 in Madison County on Interstate 75 northbound at milepoint 89.1. The driver of a 1995 Lexus lost control of his vehicle on snow with the car rotating onto the shoulder with the rear hitting the end of the rail. The car then rotated clockwise with the front contacting the rail. The car came to rest in the road. The first four posts were broken with about three feet of rail extruded. There were no reported injuries.
110	The single vehicle crash occurred on January 27, 2003 in Hopkins County on the Western Kentucky Parkway westbound at milepoint 24.4. A 1997 Ford Taurus veered from the right lane off the roadway onto the right shoulder. It then traveled off the pavement along the adjacent grass area and struck a reflective white marker before striking the guardrail head on. The vehicle broke 10 posts and came to final rest in the ditch behind the guardrail about 80 feet past the start of the guardrail. There was about 21 feet of rail extruded. There were reported injuries to the two front seat occupants.
111	The single vehicle crash occurred on February 7, 2003 in Caldwell County on the Western Kentucky Parkway eastbound at milepoint 18.6. A 1994 Dodge Ram slid on ice off the right shoulder striking a guardrail and coming to rest behind the rail. The reported speed was 45 to 55 mph. The first three posts were broken with the rail pulled from the next two posts. The evidence shows the pickup broke through the rail and came to rest about 56 feet from the start of the guardrail. About 10 feet of rail was extruded. The driver, who was not wearing a safety belt, was injured.

Number	Description
117	The single vehicle crash occurred on February 18, 2003 in Madison County on Interstate 75 southbound at milepoint 81. A 1997 Chevrolet Tahoe passed another vehicle and then proceeded onto the left shoulder and hit the guardrail head-on. After impact with the guardrail, the vehicle veered left over a steep embankment for about 45 feet into a rock ditch line. About 28 feet of rail was extruded with numerous posts broken. There was no reported injury.
119	The single vehicle crash occurred on March 22, 2003 in Whitley County on Interstate 75 northbound at milepoint 18. A 1998 Toyota Camry was in the left lane when the driver stated her vehicle veered off the left side of the road. The rear of the vehicle rotated clockwise when the driver attempted to steer back onto the road. The impact was to the driver's side of the car. About 23.5 feet of rail was extruded. The driver and two passengers were wearing their safety belt with the only injury a possible injury for the driver.
124	The single vehicle crash occurred on June 5, 2003 in Hopkins County on the Pennyrile Parkway southbound at milepoint 44.5. The right front tire on a single unit truck went flat causing the driver to hit the end of a guardrail on the right side of an exit ramp. The estimated speed was 40 to 45 mph. The first three posts were broken with additional posts damaged. About 30 feet of rail was extruded. The evidence shows that the truck pushed the rail straight back with the right front of the truck stopping at the seventh post. There was no reported injury.
125	The single vehicle crash occurred on August 15, 2003 in Madison County on Interstate 75 northbound at milepoint 90. The right front of a 1998 Ford Contour hit the end of the guardrail and spun clockwise to a final rest position on the shoulder. About two feet of rail was extruded. No injury was reported.