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EVALUATION OF THE ET2000 GUARDRAIL END TREATMENT

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16. Abstract

The objectives of this study were to monitor and report the performance of the ET2000 guardrail end treatment design in traffic accidents. Data for a total of 34 collisions involving the ET2000 were identified. In most cases, an accident report was obtained and the damaged guardrail was inspected. The involved vehicle was inspected when available. Proper or improper performance of end treatments in the collisions were judged based on whether it performed as designed.

Field performance of the ET2000, as documented in traffic accidents, shows that, considering all the impacts, this end treatment has performed properly. In several instances the end treatment bent, rather than being pushed straight back, during the collision. This could typically be related to the angle at which impact occurred. Results warrant continued use of this end treatment. However, its cost would not justify a widespread use on all types of highways.

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EXECUTIVE SUMMARY

The objectives of this study were to monitor and report the performance of the ET2000 guardrail end treatment design in traffic accidents. 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 34 collisions involving the ET2000 were identified. In most cases, an accident report was obtained and the damaged guardrail was inspected. The involved vehicle was inspected when available. Proper or improper performance of end treatments in the collisions were judged based on whether it performed as designed.

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

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

1.0 INTRODUCTION AND BACKGROUND

Performance of guardrail end treatments has been the subject of investigation for many years. The first guardrail installations used a blunt end treatment. Blunt end treatments resulted in some severe impacts involving spearing of the 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 accidents 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.

Five additional studies have reported on the analysis of accidents involving various types of guardrail end treatments in Kentucky (3, 4, 5, 6, 7). The most recent report included an analysis of 34 accidents involving the Crash Cushion Attenuating Terminal (CAT) (7) which is Kentucky's crash cushion Type IX or IX-A. The accident 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 analysed 67 accidents 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 is 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 accidents 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).

A more recent guardrail end treatment design is the ET2000 (Kentucky Department of Highways End Treatment Type 1) manufactured by Syro Steel. This end treatment is used with standard W-beam guardrail and 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 of the numbers of BCT, Type 7 (modified turned down), CAT, and ET2000 installed in Kentucky for the last several years are given in Table 1. The number installed each year and the average unit price are given. Through 1997, the average cost of 7,864 BCT installations was $498 which was slightly higher than the average cost of $461 for 8,700 installations of Type 7 end treatments. The average cost for 432 modified BCT (MELT) installations was $1,244. The average cost of 746 CAT systems was $5,314 with the average cost of $2,783 for 404 ET2000 installations.

The objective of this study was to report the results of monitoring the performance of the ET2000 in traffic accidents.

2.0 DATA COLLECTION

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

Visual inspection of the guardrail damage resulting from an impact was made when possible. 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 it was available.

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

Information for each accident was summarized. Evaluation of guardrail performance was made unless no relevant information was available. The types of information obtained, when available, for each accident is given in Table 2.

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 a primary criteria for assessing performance. It is possible that the end treatment could perform properly with severe injuries 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. 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 some of those variables. All of the ET2000 systems were installed on the shoulder of the roadway.

3.0 RESULTS

Data for a total of 34 collisions involving the ET2000 were identified. The earliest date was in August 1995 with latest known collision occurring in January 1998.

An accident report was located in 24 of the 34 collisions. Photographs showing damage to the guardrail were either taken during the inspection or located

from other sources in 31 of the collisions. Damage to the vehicle was documented through inspection and photographs in 17 of the accidents. A list of the accidents giving information concerning the location of the accident and the information available is given in Appendix A.

All but three of the accidents occurred on an interstate or parkway. The largest number of collisions (11) were on Interstate 275 in northern Kentucky followed by eight on the Pennyrile Parkway in western Kentucky. All the accidents were in rural areas. Given the location and type of highway, the collisions involved high speed impacts.

A summary of data obtained for accidents involving an ET2000 end treatment is presented in Table 3. The large majority of the collisions involved an impact with the front of a vehicle into 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.

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 23 accidents in which it was known that an automobile hit the end was 11.3 feet with a range of under two feet to almost 36 feet.

Sufficient information was available to rate performance in all but one of the collisions. 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. In some instances where no accident report was filed and the damage to the end treatment was as expected, the performance was judged as proper.

Performance was judged to be proper in 30 of 33 collisions (91 percent). In the three impacts in which performance was judged as improper, two involved a vehicle overturning and the other involved a vehicle rotating and the rail bending such that there was intrusion into the occupant compartment. 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 being rated as proper if no adverse results occurred.

4.0 CONCLUSIONS

The field performance of the ET2000 as documented in traffic accidents shows that, considering all the impacts, this end treatment has performed as designed. In several 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.

The results warrant continued use of this end treatment. However, its cost would not justify a widespread use on all types of roadways.

5.0 REFERENCES

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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.

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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	TYPE 7	CAT	ET 2000	BCT	TYPE 7	CAT	ET 2000
1974	285				668			
1975	443				617			
1976	421				446			
1977	541				423			
1978	229				444			
1979	350				482			
1980	244				516			
1981	160				519			
1982	498				572			
1983	462				487			
1984	180				490			
1985	197	118			484	477		
1986	298	392			464	450		
1987	438	742			459	450		
1988	369	878	52		483	457	5,247	
1989	250	830	70		468	438	5,807	
1990	341	821	31		474	446	4,815	
1991	633	1,453	18		460	430	5,734	
1992	346	474	11		475	435	6,255	
1993	304	598	25		476	424	5,524	
1994	326	736	7		489	490	6,229	
1995	335	978	57	48	561	490	5,846	3,429
1996	145	235	275	96	548	539	5,267	2,892
1997	69	445	200	260	583	583	5,000	2,623

* The BCT is the breakaway cable terminal. A modified version (MELT) has been installed with 205 installations in 1996 and 227 in 1997 with an average cost of $1,244. The Type 7 is a modified turned down. The CAT is the Crash Cushion Attenuating Terminal. Another type is the buried end treatment with an average cost of $455 for the 265 installed in 1995 and 1996.

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 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

TABLE 3. ET2000 END TREATMENT PERFORMANCE

ACC. NO.	VEH. SIZE	SEV.	IMP. ANG.	LN. EXTR.	INJ.	VEH ACT.	END TREAT. PERF.	GR DAM.	VEH. DAM.	INIT. CONT.
1	A-S	S	Shal	15.0'	4	BT; SP-CCW- 180	P	E	3	1
2	Comb	N-S	Shal	1.0'	5	RB-L	P	M	1	2
3	A-S	S	Shal	3.0'	5	RB-L	P	H	3	1
4	A-L	S	Shal	8.5'	4	STOP	P	M	2	1
5	A-L	S	Shal	13.0'	4	STOP	P	M	2	1
6	Comb	N-S	Shal	3.0'	5	RB-L	P	M	1	Unk
7	A-S	S	Shal	13.5'	5	RB-L	P	H	2	1
8	A-L	S	Mod	3.5'	4	BT	P	M	2	1
9	A-S	S	Mod	6.0'	2	BT; SP-CW	Imp	E	2	1
10	A-S	S	Shal	35.5'	3	BT	P	E	2	1
11	Unk	Unk	Unk	1.7'	Unk	Unk	Unk	H	Unk	Unk
12	A-S	S	Shal	7.1'	5	SP-CW; RB-L	P	M	3	2
13	A-S	S	Shal	20.0'	3	STOP	P	H	2	1
14	Comb	S	Shal	89.6'	5	STOP	P	E	3	1
15	A-S	S	Mod	30.0'	3	RB-L	P	E	2	1
16	A-L	S	Shal	2.0'	3	SP-CW-45	P	H	3	2
17	Unk	N-S	Unk	6.0'	Unk	Unk	P	M	Unk	Unk
18	Unk	N-S	Unk	8.5'	Unk	Unk	P	M	Unk	Unk
19	Unk	S	Unk	15.0'	Unk	BT	P	H	Unk	Unk
20	A-L	N-S	Shal	2.0'	5	STOP	P	M	3	1
21	Unk	N-S	Unk	2.0'	Unk	Unk	P	M	Unk	Unk
22	A-L	S	Shp	7.5'	5	BT	P	M	3	1
23	A-L	S	Unk	7.0'	Unk	Unk	P	H	Unk	Unk
24	A-L	S	Unk	1.6'	5	RB-L; OVER	Imp	H	3	2
25	A-L	S	Shal	26.0'	4	BT; OVER	Imp	E	3	1
26	A-S	S	Shp	10.0'	2	BT	P	H	3	3
27	A-L	S	Mod	14.0'	2	STOP; SP-CCW-45	P	H	3	1
28	A-L	S	Shal	4.5'	5	BT	P	H	3	1
29	A-L	S	Shal	17.0'	2	BT	P	E	3	1
30	A-S	S	Shal	4.0'	4	RB-L	P	M	3	2
31	Unk	S	Unk	5.5'	Unk	BT	P	H	Unk	Unk
32	Unk	S	Shal	4.0'	Unk	Unk	P	M	Unk	Unk
33	Unk	N-S	Unk	0.0'	Unk	RB-R	P	S	Unk	Unk
34	A-S	S	Shal	10.0'	5	RB-L	P	H	2	1

APPENDIX A

Location of Accidents and Available Information

ACC NO.	COUNTY	ROUTE	MP	DATE OF ACCIDENT	DATE OF INSPECTION	ACCIDENT REPORT	PHOTOGRAPHS ET2000	PHOTOGRAPHS VEH.
1	Christian	Pennyrile Parkway	16.4	8/8/95	8/10/95	Yes	Yes	Yes
2	Kenton	I 275	78.7	9/21/95	9/24/95	No	Yes	No
3	Kenton	I 275	78.7	10/14/95	10/16/95	Yes	Yes	Yes
4	Kenton	I 275	80.0	10/30/95	11/3/95	Yes	Yes	Yes
5	Fayette	I 75	109.6	10/26/95	11/95	Yes	Yes	Yes
6	Christian	Pennyrile Parkway	10.7	11/95	11/24/95	No	No	No
7	Kenton	I 275	79.0	12/13/95	12/15/95	Yes	Yes	Yes
8	Henderson	Pennyrile Parkway	69.1	12/16/95	12/26/95	Yes	Yes	No
9	Christian	Pennyrile Parkway	16.4	2/12/96	2/21/96	Yes	Yes	Yes
10	Kenton	I 275	78.0	4/6/96	4/12/96	Yes	Yes	Yes
11	Kenton	I 275	78.7	4/96	5/2/96	No	Yes	No
12	Kenton	I 275	78.0	6/15/96	6/18/96	Yes	Yes	Yes
13	Kenton	I 275	82.3	6/23/96	7/96	Yes	No	No
14	Kenton	I 275	79.0	8/12/96	8/14/96	Yes	Yes	Yes
15	Henderson	Pennyrile Parkway	66.4	10/20/96	10/23/96	Yes	Yes	Yes
16	Logan	US 68	16.2	9/12/96	9/96	Yes	Yes	No
17	Barren	I 65	48.3	1996	1996	No	Yes	No
18	Kenton	I 275	79.4	2/97	2/17/97	No	Yes	No
19	Grayson	West Ky. Parkway	96.0	1996	DNA	No	No	No

ACC NO.	COUNTY	ROUTE	MP	DATE OF ACCIDENT	DATE OF INSPECTION	ACCIDENT REPORT	PHOTOGRAPHS ET2000	PHOTOGRAPHS VEH.
20	Hopkins	Pennyrile Parkway	44.3	2/16/97	2/21/97	Yes	Yes	Yes
21	Kenton	I 275	77.9	3/97	3/27/97	No	Yes	No
22	Pulaski	US 27	5.2	4/5/97	4/16/97	Yes	Yes	Yes
23	Laurel	I 75	42.3	5/17/97	5/30/97	Yes	Yes	No
24	Jefferson	I 64	21.6	5/20/97	6/19/97	Yes	Yes	Yes
25	Shelby	I 64	24.1	6/15/97	6/19/97	Yes	Yes	Yes
26	Hamilton (Ohio)	I 71	Unk.	11/14/96	3/6/97	Yes	Yes	Yes
27	Laurel	I 75	33.3	6/30/97	8/7/97	Yes	Yes	No
28	Henderson	US41	18.6	8/14/97	8/14/97	Yes	Yes	Yes
29	Christian	Pennyrile Parkway	14.5	10/12/97	10/19/97	Yes	Yes	Yes
30	Barren	I 65	48.1	9/9/97	10/20/97	Yes	Yes	No
31	Barren	I 65	48.2	9/97	10/20/97	No	Yes	No
32	Edmonson	I 65	44.0	10/97	11/10/97	No	Yes	No
33	Warren	I 65	24.4	10/97	11/10/97	No	Yes	No
34	Christian	Pennyrile	27.1	1/5/98	1/14/98	Yes	Yes	No

APPENDIX B

Description of Accidents Involving the ET 2000

Accidents Involving the ET 2000

Number	Description
1	The accident 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 accident 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. The extruder head extruded approximately 15 feet of guardrail before the remaining guardrail buckled and twisted. Five wooded posts were broken. After impact, the vehicle broke through the guardrail with its final rest position of the vehicle was in the ditch line behind the guardrail about 120 feet south of the first post. The vehicle rotated counterclockwise but did not roll.
2	The accident occurred on September 21, 1995 in Kenton County on Interstate 275 eastbound at exit 79 (milepoint 78.7). The guardrail was on the right-hand shoulder. No police report was located. The information is that a truck hauling a wide load hit the guardrail and continued without stopping. The impact was minor. The extruder head was bent with about one foot of rail extruded through the head before the rail collapsed. The first two posts were broken with the third post defected backward but not broken. The rail bent between the second and third posts.
3	The accident occurred on October 14, 1995 in Kenton County on Interstate 275 eastbound at exit 79 (milepoint 78.7). The guardrail was on the right-hand shoulder. The single vehicle accident involved a 1995 Toyota Corolla. Impact was to the right front of the car with no intrusion into the occupant compartment. The driver was utilizing the shoulder to pass another car when the impact occurred. After hitting the guardrail, the car rebounded into the right lane sideswiping another vehicle. The estimated speed was 75 to 80 mph. The extruder head was bent with about three feet of rail extruded through the head before the rail collapsed. The first three posts were broken completely with the rail bend between the third and fourth posts.

Number	Description
4	The single vehicle accident occurred on October 30, 1995 in Kenton County on Interstate 275 eastbound at exit 79. 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 driver was intoxicated and evidently passed out while driving and 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 accident 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.
6	The single vehicle accident was a "hit-and-run" impact involving a truck. It occurred in November 1995 in Christian County on the Pennyrile Parkway at milepoint 10.7. The first two posts were broken with about three feet of rail extruded. The guardrail was on the right-hand shoulder.
7	The single vehicle accident 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 driver ran off the road and 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.

Number	Description
8	The single vehicle accident occurred on December 16, 1995 in Henderson County on the Pennyrile Parkway southbound at milepoint 69.1. The guardrail was on the right-hand shoulder. The vehicle was a 1979 Pontiac Bonnyville. The driver ran into the median and then over corrected, crossed the road, and hit the guardrail. The driver's estimated speed was 60 to 65 mph. The vehicle broke through the rail and stopped behind the guardrail. The first post was broken with the head pushed straight back and about 3.5 feet of rail extruded. A possible injury was coded for the driver who was the only occupant.
9	The single vehicle accident 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. The right front of the vehicle hit the guardrail end. 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 accident 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 35.5 feet of rail extruded. The driver, who was the only occupant, was reported to have sustained "nonincapacitating" injuries.
11	This accident occurred in Kenton County on Interstate 275 at milepoint 78.7. No accident report has been located. About 20 inches of rail was extruded with several posts broken. The guardrail was on the right-hand shoulder.

Number	Description
12	The single vehicle accident 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 7.1 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.
13	The single vehicle accident 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 accident 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 89.6 feet of rail extruded. There were no reported injuries.
15	The single vehicle accident 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.

Number	Description
16	The single vehicle accident occurred on September 12, 1996 in Logan County on US 68 near milepoint 16.2. The guardrail was on the right-hand shoulder. The vehicle was a 1985 Ford Thunderbird. The driver lost control while avoiding a deer and slid into the guardrail with the passenger side of his car. His estimated speed was 65 to 70 mph. The car then rotated clockwise to its final rest position while contacting the guardrail again. Three posts were broken with about two feet of rail extruded. The driver sustained a "non-incapacitating" injury.
17	The accident occurred in 1996 in Barren County on northbound Interstate 65 near milepoint 48.3. No accident report was located so specific details are unknown. The guardrail was on the right-hand shoulder. Two posts were broken with about six feet of rail extruded. The rail was bent between the second and third posts.
18	The accident occurred in February 1997 in Kenton County on eastbound I 275 at milepoint 79.4. No accident report was located so specific details are unknown. The first post was broken with the second and third posts split. About 8.5 feet of rail was extruded. There was a slight bend in the guardrail at the third post. The guardrail was on the right-hand shoulder.
19	The accident occurred in 1996 in Grayson County on the Western Kentucky Parkway at milepoint 96.0. No accident report was located so specific details are unknown. The available information is that the vehicle broke through the guardrail with about 15 feet of rail extruded. The guardrail was on the right-hand shoulder.
20	The single vehicle accident occurred on February 16, 1997 on the Pennyrile Parkway northbound at milepoint 44.3. The guardrail was on the right-hand shoulder at the end on an entrance ramp. The vehicle was a 1993 Pontiac GrandAm. The driver stated she was distracted and ran head on into the end of the guardrail. The first post was pushed back with about two feet of rail extruded. The final rest position of the car was at the end of the guardrail. There were no injuries.

Number	Description
21	The accident occurred in March 1997 in Kenton County on eastbound Interstate 275 at milepoint 77.9. No accident report was located so specific information is unknown. One post was broken with about two feet of rail extruded. The extruder head was pushed straight back with no bending of the rail. The guardrail was on the right-hand shoulder.
22	The single vehicle accident occurred on April 5, 1997 in Pulaski County on US 27 near milepoint 5.2. The guardrail was on the left-hand shoulder in the direction of travel of the vehicle. The vehicle was a 1979 Dodge Ram van. The vehicle hit a guardrail on one side of the road and then rebounded across the road hitting the end of the rail. The first two posts were broken with about 7.5 feet of rail extruded. The vehicle came to rest behind the guardrail. There were no injuries.
23	The single vehicle accident 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 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.
24	The single vehicle accident occurred on May 20, 1997 in Jefferson County on westbound Interstate 64 near milepoint 21.6. The vehicle was a 1985 Lincoln passenger car. The driver fell asleep and the passenger side of the vehicle, at the rear tire, slid into the guardrail. The vehicle rebounded into the roadway and rolled coming to rest on its top. Three posts were broken with about 1.6 feet of rail extruded. The guardrail was on the right-hand shoulder. There were no reported injuries.
25	The single vehicle accident 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.

Number	Description
26	The accident occurred on November 14, 1996 in Cincinnati, Ohio on Interstate 71. There was a multiple vehicle accident with a 1987 Nissan Pickup hitting the end of the rail. This vehicle was sideswiped and it then rotated off the right side of the road into the rail at a sharp angle. The driver side of the vehicle impacted the end of the guardrail. The vehicle broke through the rail. About 9.5 feet of rail was extruded.
27	The single vehicle accident 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 accident 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 accident 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 accident 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 contacting the outside of the guardrail at the fifth and sixth posts. The vehicle came to rest in the northbound lanes.

31 The accident occurred in September 1997 in Barren County on northbound I 65 at milepoint 48.2. No accident report was located so specific details are unknown. The first three posts were broken with the guardrail bent at the fourth post. About 5.5 feet of rail was extruded. There was evidence showing the vehicle traveled behind the guardrail. The guardrail was on the right-hand shoulder.

32 The accident occurred in October or November 1997 in Edmonson County on southbound I 65 at milepoint 44.0. No accident report was located so specific details are unknown. The first post was broken with the second post cracked. The rail was pushed straight back with no bending with about four feet of rail extruded. The guardrail was on the right-hand shoulder.

33 The accident occurred in October or November 1997 in Warren County on southbound I 65 at milepoint 24.4. No accident report was located so specific details are unknown. The outside edge of the extruder was hit with the first post broken and pushed to the side. The guardrail was pulled from the second post with a tire mark on the rail at this point. The evidence is the vehicle contacted the edge of the end the rail with a glancing blow with the vehicle redirected back onto the roadway. The guardrail was on the left-hand shoulder.

34 The accident 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 post. The guardrail was pulled away from the fourth and fifth posts. About 10 feet of rail was extruded. There were no reported injuries.