U.S. Department of Transportation
National Highway Traffic Safety Administration

NHTSA

DOT HS 812 639

October 2018

Special Crash Investigations On-Site Guardrail End Treatment Impact Investigation
Vehicle: 2002 Kia Sportage
Location: Missouri
Crash Date: April 2016

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The crash investigation process is an inexact science which requires that physical evidence such as skid marks, vehicular damage measurements, and occupant contact points be coupled with the investigator's expert knowledge and experience of vehicle dynamics and occupant kinematics to determine the pre-crash, crash, and post-crash movements of involved vehicles and occupants. Because each crash is a unique sequence of events, generalized conclusions cannot be made concerning the crashworthiness performance of the involved vehicles or their safety systems.

This report and associated case data are based on information available to the Special Crash Investigation team on the date this report was published.

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Technical Report Documentation Page

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15. *Supplementary Notes* On-site SKT guardrail end treatment investigation involving a 2002 Kia Sportage.			
16. *Abstract* This report documents the on-site investigation of the impact of a 2002 Kia Sportage into a sequential kinking terminal (SKT) guardrail end treatment that is of interest to the Federal Highway Administration (FHWA). This crash occurred on an exit ramp from the northbound lanes of an interstate highway and in an interchange area of three interstate highways. The Kia was a 4-door sport utility vehicle (SUV) equipped with frontal air bags and a driver's knee air bag. The vehicle was not equipped with an event data recorder that was supported by a commercially available tool. An unbelted 20-year-old male driver occupied the vehicle. The Kia was traveling north in the left lane of the exit ramp. The driver fell asleep and the vehicle departed the left side of the exit ramp and entered the gore where the front plane struck the SKT (Event 1). The impact extruded 8.7 m (28.6 ft) of guardrail and displaced eight posts. The impact caused the Kia to rotate counterclockwise and the right corner of the back plane struck the guardrail. The vehicle came to final rest heading southeast. The driver then drove the damaged vehicle to the east shoulder of the exit ramp and waited for emergency responders to arrive. The driver sustained police-reported "B" (non-incapacitating) injuries and was transported by ambulance to a hospital. The Kia was towed from the crash scene due to damage.			
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INDIANA UNIVERSITY

TRANSPORTATION RESEARCH CENTER

ON-SITE GUARDRAIL END TREATMENT INVESTIGATION

CASE NUMBER - IN16011
LOCATION - MISSOURI
VEHICLE - 2002 KIA SPORTAGE
CRASH DATE - APRIL 2016

BACKGROUND

This report documents the on-site investigation of an impact of a sport utility vehicle into a sequential kinking terminal (SKT) guardrail end terminal (**Figure 1**) that is of interest to the Federal Highway Administration (FHWA). This crash was identified by an engineer with the Missouri Department of Transportation who submitted photographs of the damaged guardrail end terminal to the FHWA. The FHWA determined that the guardrail end terminal and crash type were of interest. This crash investigation was then initiated by the National Highway Traffic Safety Administration in April 2016, and assigned to the Special Crash Investigations team at the Indiana University Transportation Research Center. This single-vehicle crash involved a 2002 Kia Sportage (**Figure 2**). The crash occurred in April 2016 at 1830 hours in Missouri and was investigated by a local police agency. The crash scene, SKT, and Kia were inspected in April 2016.

Figure 1: View north to the damaged guardrail

Figure 2: The damaged 2002 Kia Sportage

This crash occurred on an exit ramp from the northbound lanes of an interstate highway and in an interchange area of three interstate highways. The Kia was a 4-door SUV equipped with frontal air bags and a driver's knee air bag. The vehicle was not equipped with an event data recorder (EDR) that was supported by a commercially available tool. An unbelted 20-year-old male driver occupied the vehicle. The Kia was traveling north in the left lane of the exit ramp. The driver fell asleep and the vehicle departed the left side of the exit ramp and entered the gore where the front plane struck the SKT (Event 1). The impact extruded 8.7 m (28.6 ft) of guardrail and displaced seven posts. The impact caused the Kia to rotate counterclockwise (counterclockwise) and the right corner of the back plane struck the guardrail.

The vehicle came to final rest heading southeast. The driver then drove the damaged vehicle to the east shoulder of the exit ramp and waited for emergency responders to arrive. The driver

sustained police-reported "B" (non- incapacitating) injuries and was transported by ambulance to a hospital. The Kia was towed from the crash scene due to damage.

CRASH SUMMARY

Crash Site: This crash occurred during daytime hours on an exit ramp of the northbound lanes of an interstate highway that was in the interchange area of three interstate highways. The weather conditions were clear with 16.1 kilometers (10 miles) visibility, east-southeast winds at 26 km/h (16 mph), a temperature of 9.4 °C (49 °F), and a dew point of -7.2 ° C (19 °F), according to local weather reports.

The Kia was traveling north in the left exit ramp lane on the northbound side of an 11-lane divided interstate highway. The interstate had three concrete northbound through lanes and two concrete exit ramp lanes. The northbound lanes were separated from the six southbound lanes by a concrete median barrier. The northbound through lanes and exit ramp lanes were each 3.7 m (12.1 ft) wide. The exit ramp was bordered by a 1.8 m (5.9 ft) wide left shoulder and a 3.1 m (10.2 ft) wide right shoulder. A blocked-out W- beam guardrail equipped with an SKT end terminal was located on the west side of the exit ramp in the gore. The speed limit was 105 km/h (65 mph). The crash diagram is included at the end of this report.

Pre-Crash: The Kia was traveling north in the left exit ramp lane (**Figure 3**). The driver fell asleep and the vehicle departed the left (west) side of the exit ramp (**Figure 4**) and entered the gore heading straight at the SKT.

Figure 3: View south from the end of the damaged guardrail to the approach of the Kia

Figure 4: View northwest to the area of impact with the SKT

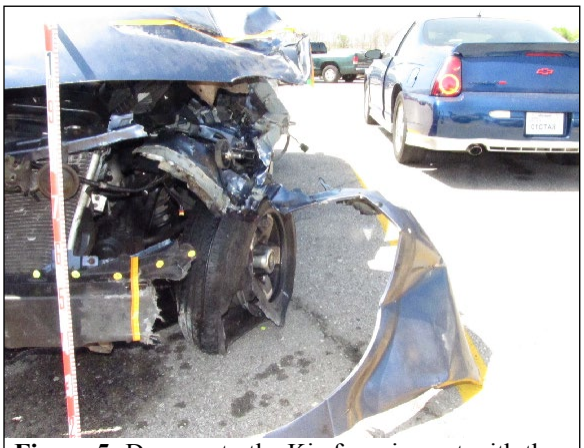


Figure 5: Damage to the Kia from impact with the SKT

Crash: The left corner of the Kia's front plane (**Figure 5**) struck the SKT (**Figure 6**). The right half of the front plane also sustained damage from contact with the traffic side of the guardrail as it was deformed and displaced as the vehicle rotated counterclockwise. The force direction on the Kia was in the 12 o'clock sector and the impact resulted in deployment of both frontal air bags and the driver's knee air bag.

WinSMASH could not be used to calculate delta-V since impacts with a yielding object are out of scope for the program; however, the barrier algorithm of WinSMASH was used to calculate a barrier equivalent speed (BES) of 26 km/h (16 mph) based on the crush to the front plane. The impact extruded 8.7 m (28.6 ft) of guardrail from the SKT and displaced eight posts as the vehicle rotated counterclockwise. The right corner of the vehicle's back plane struck the guardrail as the vehicle rotated (event 2), and the vehicle came to final rest heading southeast with the front portion of the vehicle on the roadway and the back portion on the west shoulder. The driver then drove the vehicle to the east shoulder of the exit ramp and waited for emergency responders to arrive according to the driver's statement to police. The police schematic also showed the final rest position of the vehicle on the east shoulder heading southwest.

Figure 6: The damaged SKT

Figure 7: Extruded guardrail from the SKT and posts 6 to 12, view south

Post-Crash: The police were notified of the crash at 1830 hours according to the police crash report and arrived on scene at 1839 hours. The driver sustained police-reported "B" (incapacitating) injuries and was transported by ambulance to a hospital. His level of treatment is not known.

END TERMINAL AND GUARDRAIL DAMAGE

A placard on the SKT identified the model as an "SKT 350 Guardrail Terminal" manufactured by Road Systems, Inc. The front plane impact of the Kia to the SKT resulted in the extrusion of 8.7 m (28.6 ft) of guardrail toward the field side (**Figure 7**). The guardrail was displaced from posts 0 to 6[1] The anchor cable was displaced from the guardrail and was not present at the scene. Posts 0 and 1 were bolted, hinged steel posts. Post 0 was not present at the SCI inspection; however, the post hinge bolt was present and remained attached to the post base. No strut plate was present between posts 0 and 1. Post 1 was displaced to the ground in the downstream direction and remained attached to the post hinge bolt. Post 2 was displaced downstream 50 degrees off vertical. The offset block was displaced from the post and was not present at the scene. Post 3 was displaced downstream approximately 60 degrees off vertical and was twisted approximately 80 degrees toward the field side. The offset block was displaced off the post and was not present at the scene. Post 4 was displaced downstream approximately 45 degrees off vertical and was twisted approximately 80 degrees toward the field side. The offset block remained attached to the post. Post 5 was displaced downstream 60 degrees off

[1] Due to the SCI team's misunderstanding of a post numbering protocol change that occurred just prior to this investigation, post 1 was mistakenly numbered as post 0. The post number references in this report and the "In Service End Treatment Evaluation Data Collection Form" retains the post 1 reference as post 0 since otherwise it would not correspond to the photographic documentation.

vertical and twisted approximately 80 degrees to the field side. The offset block remained attached to the post. Post 6 was displaced downstream approximately 15 degrees off vertical and was twisted approximately 30 degrees toward the field side. The guardrail remained attached at post 7, which was displaced downstream approximately 20 degrees off vertical. A kink was formed in the guardrail at post 7 as the guardrail was displaced to the field side. Posts 8 to 12 were undamaged. There were small deformations in the guardrail near posts 8 and 10 that appeared related to the displacement of the guardrail during the crash. These were not considered kinks. Two kinks were located in the guardrail, one at post 7 and one near the bolt holes for post 6. The total length of damaged guardrail was 17.0 m (55.8 ft). MoDOT markings identifying sections of guardrail to be replaced ended just prior to post 12. The "In-Service End Treatment Evaluation Data Collection Form" is attached to the end of this report as **Appendix A**.

2002 KIA SPORTAGE

DESCRIPTION

The Kia was a front-wheel drive, five-occupant, 4-door SUV with VIN KNDJA723525xxxxxx that was equipped with a 2.4-liter, I-4 engine, automatic transmission, and electronic brake force distribution. The vehicle was not equipped with an EDR. The vehicle was also equipped with second generation frontal air bags, a driver's knee air bag, and a tilt steering column. The tilt adjustment could not be determined since the steering column was displaced vertically and locked from driver contact. The specified wheelbase was 265 cm (104.3 in).

The vehicle manufacturer's recommended tire size was P205/75R15. The vehicle was equipped with Hankook Optimo H724 tires of the recommended size. The manufacturer's recommended cold tire pressure for the front and rear tires was 179 kPa (26 psi). The tires were in good condition prior to the crash. The left front tire was torn during impact with the SKT.

The front row was equipped with driver and front right occupant cloth-covered bucket seats with integral head restraints. The second row was equipped with a cloth-covered bench seat with folding backs and integral head restraints in the outboard seating positions. The driver's seat track was adjusted between the forward and middle positions and the seat back was upright. The front right occupant's seat track was adjusted to the rear-most position and the seat back was slightly reclined.

EXTERIOR DAMAGE

Exterior Damage Event 1: The front plane sustained direct damage to 15 cm (5.9 in) of the left corner of the front bumper bar, left headlamp/turn signal assembly, fender, and hood from the initial impact with the SKT. Direct damage also occurred to the remaining 137 cm (53.9 in) portion of the front plane as the vehicle rotated counterclockwise and the guardrail deformed (**Figure 2**). This damage occurred above the bumper. The sheet metal of the hood was torn and the radiator and radiator frame were crushed. The totality of the damage involved the full width of the front plane, 152 cm (59.8 in). A set of crush measurements was taken on the bumper bar and a second set on the upper radiator frame. The maximum crush at the bumper level was 10 cm (3.9 in) occurring at C_1. The maximum crush at the upper radiator frame was 49 cm (19.3 in), also occurring at C_1. The two levels of crush measurements were averaged in accordance

with the crush measurement protocol and the crush values were: C_1 = 30 cm (11.8 in), C_2 = 26 cm (10.2 in), C_3 = 2 cm (0.8 in), C_4 = 1 cm (0.4 in), C_5 = 0 cm, C_6 = 7 cm (2.8 in).

Damage Classification Event 1: The Collision Deformation Classification (CDC) was 12FDEW3. The severity of the damage was moderate.

Exterior Damage Event 2: The Kia sustained direct damage to the right corner of the back plane (**Figure 8**) during the secondary impact with the guardrail as the vehicle rotated counterclockwise. The direct damage began at the right corner of the back bumper and extended 40 cm (15.7 in) to the left. The maximum residual crash was 3 cm (1.2 in) occurring at C_1. The crush values were: C_1 = 0 cm, C_2 = 0 cm, C_3 = 0 cm, C_4 = 0 cm, C_5 =0 cm, C_6 = 3 cm (1.2 in).

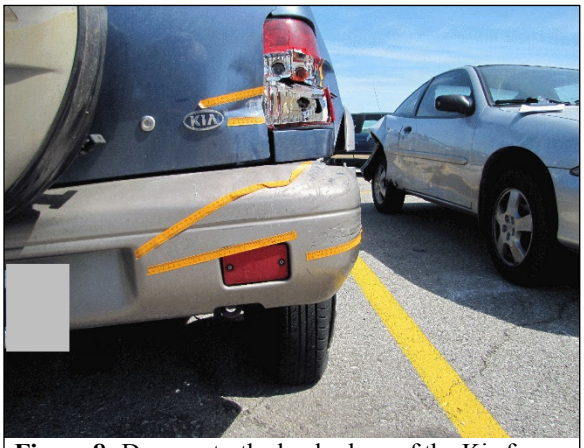


Figure 8: Damage to the back plane of the Kia from secondary impact with the guardrail

Damage Classification Event 2: The CDC was 05BREE1. The severity of the damage was minor.

INTERIOR DAMAGE

The interior of the Kia sustained no intrusions. The lower left instrument panel was fractured from contact by the driver's left knee. The center lower instrument panel was scuffed from contact by the driver's right knee. The steering column was displaced upward from contact by the driver's chest as it loaded through the deployed frontal air bag. The steering wheel was not deformed. All the doors and the back hatch remained closed and operational. There was no damage to any of the glazing.

MANUAL RESTRAINT SYSTEMS

The front and second row seating positions were equipped with three-point lap and shoulder seat belts with sliding latch plates. The front row seat belts had adjustable upper anchors and pretensioners. Both upper anchors were adjusted to the full-down position. Both retractors functioned normally and actuation of the pretensioners could not be determined.

The driver was not restrained by the lap and shoulder seat belt. Inspection of the seat belt assembly revealed no evidence of loading to the latch plate belt guide, D-ring, or belt webbing.

SUPPLEMENTAL RESTRAINT SYSTEMS

The Kia was equipped with second-generation frontal air bags and a driver's knee air bag. Both frontal air bags and the driver's knee air bag deployed during the impact with the SKT. There was no damage to any of the air bags.

2002 KIA SPORTAGE OCCUPANT

DRIVER DEMOGRAPHICS

Age/Sex:	20 years/male
Height:	Unknown
Weight:	Unknown
Eyewear:	Unknown
Seat Type:	Bucket
Seat Track Position:	Between forward-most and middle
Manual Restraint Usage:	None
Usage Source:	Vehicle inspection
Air Bags	Frontal and knee bags, deployed
Alcohol/Drug Involvement:	None
Egress From Vehicle:	Unknown
Transport From Scene:	Ambulance
Medical Treatment:	Unknown

DRIVER INJURIES

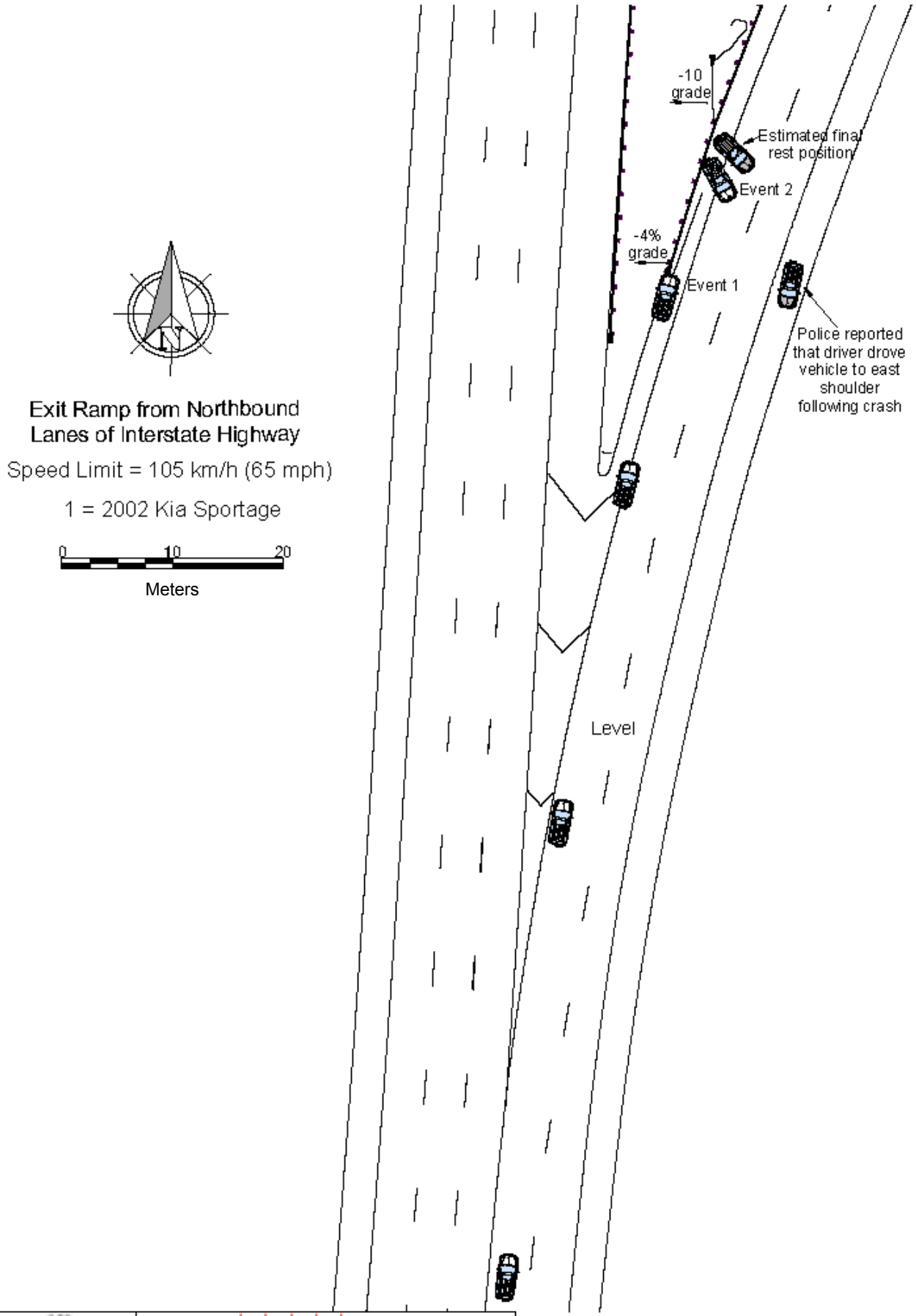
Injury No.	Injury	AIS 2015	Involved Physical Components (IPC)	IPC Confidence Level
1 2	Contusions (bruising) and lacerations, small, on face, not further specified	210402.1 210602.1	Air bag, driver's frontal	Certain
3	Hemorrhage (epistaxis) nose, not further specified	251004.1	Air bag, driver's frontal	Certain
4	Contusion (bruising) on his chest, not further specified	410402.1	Steering wheel hub and/or spokes and rim	Certain
5	Contusion (bruising) on his back, not further specified	410402.1	Seat back, driver's	Probable
6	Lacerations, small, on his right leg, not further specified	810602.1	Center lower instrument panel	Certain
7	Lacerations, small, on his left leg, not further specified	810602.1	Left lower instrument panel, left of steering column	Certain

Source: Police Crash Report.

DRIVER KINEMATICS

The driver was not restrained by the lap and shoulder seat belt. The seat track was adjusted between the forward-most and middle positions and the seat back was upright. The frontal impact with the SKT resulted in deployment of the driver's frontal air bag and knee air bag. The driver was displaced forward and his face and chest loaded the deployed frontal air bag. He sustained contusions and small lacerations on his face and a bloody nose from contact with the frontal air bag. His chest loaded through the frontal air bag and contacted the steering wheel resulting in

contusions to his chest. He also sustained small lacerations to both legs from contact with the lower instrument panel. The driver rebounded into his seat and sustained a contusion to his back from contact with the seat back. The driver was transported by ambulance to a hospital. His level of treatment is not known since the hospital that he was reportedly transported to had no record of his treatment. The injuries to the driver reported in the police crash report narrative were all of minor severity.



	NHTSA www.nhtsa.gov
Case Number:	IN16011

Appendix A
In-Service End Treatment Evaluation
Data Collection Form

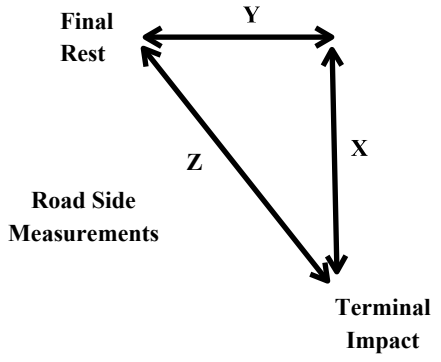
Case No.: IN16011

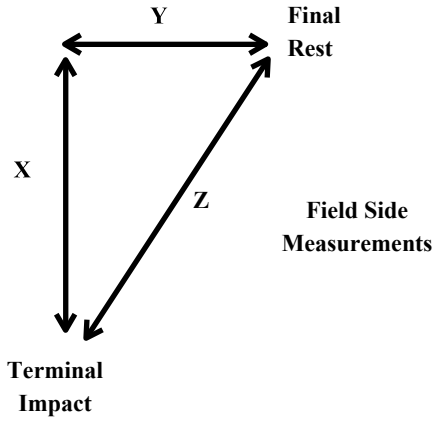
PREPOPULATED DATA (BY OTHERS)			
Date of Crash	April 2016	**TIME OF CRASH (MILITARY)**	Unknown
Case Number	IN16011	**State**	Missouri
Traffic Route	Interstate	**Direction (Southbound = SB)**	NB
Ambient Conditions (at time of crash)			
Temperature (°F)	Unknown	**Lighting**	Unknown
Atmospheric	Unknown		

SCENE INFORMATION	
Type of area where crash occurred	❒Urban ❒Rural ☒Suburban
Terminal on a horizontal curve?	❒No ❒Curve/LT ☒Curve/RT
Estimated or Reconstructed Speed at Impact (MPH)	Unknown
Est. distance (straight line) from terminal impact to COM final rest position (ft.)	Z = 47 ft
Est. distance (longitudinal) along guardrail from terminal impact to COM final resting location (ft.)	X = 47 ft
Est. distance (normal) from either 1. the white paint line; or 2. roadway/shoulder/pavement edge to COM rest position (ft.)	Y = 2 ft into left exit ramp lane and 8 ft from traffic side of guardrail
Super elevation	❒+2% ❒-2% ☒ NONE or FLAT
Curve Radius (ft.)	1,359

KEY:

- COM - Center of Mass of Vehicle
- Distance Measurements





Case No.: IN16011

ON-SCENE INFORMATION		
End Treatment Type	❒Extruder	❒ET2000 ❒ET-PLUS 4in ❒ET-PLUS 5in ☒SKT ❒FLEAT ❒SOFT STOP
	❒Telescope	❒X-LITE ❒X-TENSION
Curb?	☒No ❒Yes	❒AASHTO Type A ❒AASHTO Type B ❒AASHTO Type C ❒AASHTO Type D ❒AASHTO Type E ❒AASHTO Type F ❒AASHTO Type G ❒AASHTO Type H
Curb Height:		

GUARDRAIL INSTALLATION

Post No.	Post		Offset Block		PRE-Existing Damage		Offset to post or post hole (ft.)		Spacing to next post (ft. -in.)
	Type	Dim.	Type	Dim.	Yes No Unknown	Describe	Travel way	Curb	
	Steel Wood Other	D x W (in.) or Dia. (in.)	Steel Wood Composite	D x W (in.)					
0	Steel	6 x 4	None		Unk		6.9		7ft 6 in
1	Steel	6 x 4	None		Unk		7.1		Unk
2	Steel	6 x 4	Unk	Unk	Unk		7.2		Unk

Case No.: IN16011

Post No.	Post		Offset Block		PRE-Existing Damage		Offset to post or post hole (ft.)		Spacing to next post (ft. -in.)
	Type	Dim.	Type	Dim.	Yes No Unknown	Describe	Travel way	Curb	
	Steel Wood Other	D x W (in.) or Dia. (in.)	Steel Wood Composite	D x W (in.)					
3	Steel	6 x 4	Unk	Unk	Unk		7.2		Unk
4	Steel	6 x 4	Composite	8x 4	Unk		7.2		Unk
5	Steel	6 x 4	Composite	8 x 4	Unk		7.2		Unk
6	Steel	6 x 4	Composite	8 x 4	Unk		7.2		6 ft 1 in
7	Steel	6 x 4	Composite	8 x 4	Unk		7.2		5 ft 7 in
8	Steel	6 x 4	Composite	8 x 4	No		7.4		6 ft 2 in

Case No.: IN16011

Post No.	Post		Offset Block		PRE-Existing Damage		Offset to post or post hole (ft.)		Spacing to next post (ft. -in.)
	Type	Dim.	Type	Dim.	Yes No Unknown	Describe	Travel way	Curb	
	Steel Wood Other	D x W (in.) or Dia. (in.)	Steel Wood Composite	D x W (in.)					
9	Steel	6 x 4	Composite	8 x 4	No		7.2		6 ft 6 in
10	Steel	6 x 4	Composite	8 x 4	No		7.2		6 ft 0 in
11	Steel	6 x4	Composite	8 x 4	No		7.2		6 ft 5 in
12	Steel	6 x 4	Composite	8 x 4	No		7.2		6 ft 5 in

Additional Comments

Due to SCI Team's misunderstanding of a post numbering protocol change that occurred just prior to this investigation, post 1 was mistakenly identified as post 0. This data form retains the identification of the first post as post 0 so that this form is consistent with the post numbering in the photographic documentation.

Case No.: IN16011

EXTRUDER			
Feeder Channel Width at impact head	❒4inches ❒5 inches ☒Other 4.5 in		
Guide Chute Exit Height (in.)	13.5 in		
Connection of feeder channels to head damaged?	☒No ❒Yes	Are Welds Broken?	☒No ❒Yes
Anchor Cable Present?	☒No ❒Yes	Connected?	❒No ❒Yes
Rail Extrusion?	❒No ☒Yes	Length (ft. in.)	28 ft 7 in
Rail Extrusion Direction	❒Traffic Side ☒Field Side		
Total Length of Rail Damaged (ft.) [total length would include extruded rail plus damaged rail downstream from head.]	55.8		

TELESCOPE				
Rail Displacement	❒No	❒Yes; Length:	No of Panels Displaced	❒1 ❒2 ❒3 ❒4 ❒5 ❒6

ALL-SYSTEM PERFORMANCE			
Railkinks Downstream of Head?	❒No	☒Yes ;	No. of Kinks in Rail: 2
Was there intrusion into the Occupant Compartment by foreign object (guardrail)?	☒No ❒Yes		
Did vehicle impact other objects after impact with terminal?	☒No ❒Yes		
Object Contacted			

ALL-SYSTEM PERFORMANCE ENVIRONMENT			
SIDESLOPE	**50 ft in advance of Post 0**	**At Post 0**	**50 ft Past Post 0**
Percent - %	Unk	-4%	-10%
Adjacent Lane Width (ft)	12.1 ft		
Lane Type (NAS EDS Variable: Sur. Type)	Concrete		
Shoulder Type	Concrete		

Shoulder Width (ft)	5.9
Guardrail Height (in)	25.5

VEHICLE INFORMATION		
Vehicle Type (NHTSA Input)	Sport Utility Vehicle	
Vehicle Identification Number (VIN)	KNDJA723525xxxxxx	
Vehicle Mass (NASS var.: veh.wgt)	3360 lbs	
Vehicle orientation upon impact	☒Case Type 1 ❒ Case Type 2 ❒ Case Type 3 ❒ Case Type 4 ❒ Case Type 5 ❒ Case Type 6 ❒ Case Type 7 ❒ Case Type 8 ❒ Other	
If 'Other', describe		
Collision Deformation Classification	12FDEW3	
Delta-V	Unknown (WinSMASH BES = 16 mph)	
Occupant Compartment Penetration of rail	☒No	❒Yes; Describe:
Quarter Turns (NASS EDS variable: Rollover)	❑1 ❒2 ❒3 ❒4 ❒5 ❒6 ❒7 ❒8 ❒9 ❒10 ❒11 ❒12 ❒13 ❒14 ❒15 ❒16 ❒17+	
Object Precipitating Rollover, (NASS EDS variable: Rollobj)	N/A	
Rollover Type, Terhune Scale, (NASS EDS variable: rolintyp)	N/A	

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October 2018

U.S. Department
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Traffic Safety
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